failures of the electronic TCU to be read. The communication between the control unit and the service tester is mainly car manufacturer-specific and must be defined by the car manufacturer before going into series production. The communication runs on a bidirectional, separate communication link.

The failure storage takes place in a nonvolatile memory device; e.g., in a permanent supplied RAM or in an EEPROM. It is also possible to store sporadic failures to detect such problems during the next service. The failure codes, number of stored failures, the handling of the failure storage, as well as the reaction of the TCU in case of a particular failure, is manufacturer-specific and is part of the unit specification. The real safety functions are part of the basic functions of an electronic TCU. The diagnostic functions concerning service tester and communication protocols are, over a wide range, manufacturer-specific. These range from a simple blink code up to a real self-test of the electronic unit, including all peripheral components.

13.3.2 Improvement of Shift Control

In a second development stage, the basic functions can be revised by a modification of the software functions and by adding new parts to the basic functions. This action results in a significant enhancement of the driving and shifting comfort. By a revision of the basic safety and diagnostic functions with so-called substitute functions, it is possible to increase the availability of the vehicle with AT as well as the driveability in case of a malfunction.

Shift Point Control. The basic function can be improved significantly by adding a software function, the so-called adaptive shift point control.[8] This function requires only signals which are available in an electronic TCU with basic functions. The adaptive shift point control is able to prevent an often-criticized attribute, the tendency for shift hunting especially when hill climbing and under heavy load conditions.

The adaptive function calculates the vehicle acceleration from the transmission output speed over time. The value of the actual acceleration in relation to a set value of the acceleration is the input for the shift point correction. The set value is given by the traction resistance characteristic. For a certain difference between set and actual value, the adaptation of the shift point occurs. The dimension of the shift point correction can be determined by calibration data and depends in general also on the actual vehicle speed and the engine load.

The shift point correction leads to higher hysteresis between upshift and downshift characteristics. With a high difference between set and actual values, it is also possible to forbid certain gears. The return to the basic shift point control is organized by software and can be fixed by calibration data. Usually, in the case of power-on, the adaptive shift point control is reset (Figs. 13.9 and 13.10).

In addition to these functions, different shift maps can be implemented into the data field of the TCU. For example, it is possible to have one shift map for low fuel consumption, which has shift points in the range of the best efficiency of the engine, and additionally to have another map for power operation, where the shift points are placed at points of highest engine output power. The character and number of different shift maps can be selected over a wide range. The choice of the different shift maps can be done by a selector push button or switch commanded by the driver. In further applications, the changing of the different shift programs is possible by self-learning strategies. It is also possible to implement a manual program in which fixed gears are specific to predetermined positions of the selector lever.

Lockup Control. There are some additional functions which can improve considerably the shift comfort of the lockup. In a first step, it is possible to replace the on/off control of the lockup actuator by a pulse control during opening and closing. This can be achieved using conventional hardware only by a software modification. In a further step, the on/off solenoid is replaced by a pressure regulator or a PWM solenoid.

By coordinating intelligent control strategies and corresponding output stages within the electronic TCU, a considerable improvement of the shift behavior of the lockup results. Here

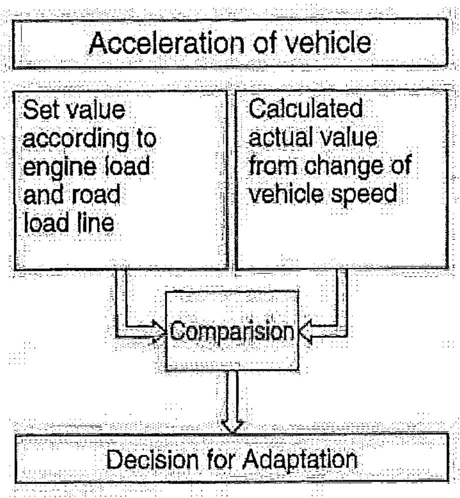

FIGURE 13.9 Basic principle of adaptive shift point control.

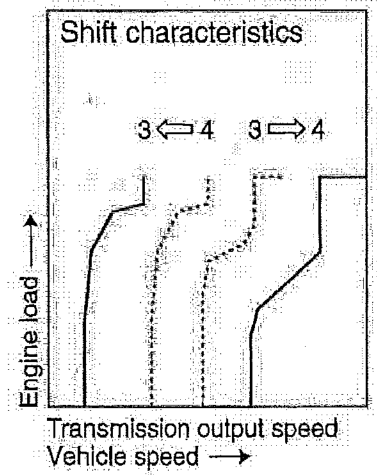

FIGURE 13.10 Shift characteristics before (- - -) and after (—) adaptation.

it is possible to close the lockup at low engine speed and low engine load with good shift comfort, resulting in decreased fuel consumption.

Engine Torque Reduction During Gear Shifting. By an improved interface design to the engine management system, it is possible to extend the engine torque reduction function. It is necessary to use a PWM signal with related fixed values or a bus interface. The engine torque reduction is controlled directly by the TCU. The advantage of such an interface is an independent calibration of the TCU data over a wide range without changing the engine management data. A further advantage is the improved possibility for the coordination of the engine torque reduction and the pressure control within the TCU. The improvement of this interface can be extended up to a real torque interface, especially when using a bus communication link.

Pressure Control.[8] The pressure control can be improved in a similar way as the shift point control with an adaptive software strategy. The required inputs for the adaptive pressure control are calculated from available signals in the transmission control. The main reasons for the implementation of the adaptive pressure control are the variations of the attributes of the transmission components like clutch surfaces and oil quality as well as the changing engine output torque over the lifetime of the car.

The principle of adaptive pressure control is a comparison of a set value for the shift time with an actual value, measured by the transmission input speed course. At a specific difference of the set value to the actual value, the pressure value is corrected by a certain increment in the positive or negative direction. The original adaptation time and the pressure value increment were fixed during the calibration phase. For safety reasons, the total deviation of the pressure value from a given value is limited, depending on the particular application. Usually the correction values are stored in the nonvolatile memory to have the correct values available after power-on of the electronic TCU.

Safety and Diagnostic Functions. The safety functions extend over better monitoring of the selector lever and functions concerning misuse by the driver. With a corresponding transmission hardware design, the implementation of a reverse gear inhibit function is possible; i.e, above a certain vehicle speed, the position R is blocked hydraulically by a single solenoid or by a particular solenoid combination commanded by the electronic TCU. This function prevents the destruction of the transmission in the event of an unintentional shift to the reverse gear. Downshift prevention is part of the safety function, especially during manual shifting by the driver. Here the synchronous speed of the new gear is calculated and compared with the admissable maximum engine speed. In the case of a calculated synchronous speed above the maximum engine speed, the downshift is prohibited by the TCU. This function can be supported by an overrun safeguard which releases the limp home mode in case of exceeding the admissable maximum engine speed.

All of those functions can be extended and have to be defined during the development stage by the automobile transmission and electronic TCU manufacturers. To increase availability of the AT system, even with the failure of certain signals, it is possible to provide a substitute operation with better drivability than in the limp home mode. This can be done by substitute functions. The electronic TCU falls back on substitute values or signals in the case of a breakdown of certain interfaces. There is, for example, the possibility to run with a programmable fixed throttle value with a breakdown of the throttle position signal. This results in a reduction of the shift characteristics to shift points. Shifting into all gears is possible, however, with reduced shift comfort. A further method is to use secondary signals in case the original signals break down. For example, the calculation of vehicle speed can be from wheel speed during breakdown of the transmission output speed signal. This technique usually requires a connection between ABS and transmission control. The third variant is the canceling of certain functions if the necessary input signals are missed. For example, in the case of a kickdown switch failure, the kickdown function is canceled. This results in no downshift after operation of the kickdown. Downshifts are nevertheless still possible via the full-throttle opening point according to the full-load shift characteristic.

The availability and driveability of automobiles equipped with electronic TCU in case of system failures can be improved significantly with the implementation of substitute functions. This results in a considerable increase in acceptance by the drivers of automobiles with electronic transmission control.

13.3.3 Adaptation to Driver's Behavior and Traffic Situations

In certain driving conditions, some disadvantages of the conventional AT can be prevented by using self-learning strategies.[9] This is especially valid when improving the compromise in the shift characteristics regarding gear selection under particular driving conditions and under difficult environmental conditions. The intention of the self-learning functions is to provide the appropriate shift characteristic suitable to the driver under all driving conditions. Additionally, the behavior of the car under special conditions can be improved by suitable functions. Available input signals of the car, provided by the related electronic TCUs from interfaces and communication links, are processed by the TCU with specific algorithms. The self-learning functions can be divided into a long respectively medium term adaptation for driver's style detection and into a short-term adaptation which reacts to the present driving situation, such as hills or curves.

The core of the adaptive strategies is the driver's style detection. The driver's style can be detected by monitoring of the accelerator pedal movements. The inputs are operation speed, operation frequency, and the rating position of the accelerator pedal. These inputs are processed depending on priorities with special algorithms related to the desired driving behavior of the car. The calculated driver style is related to certain shift maps. There is a large choice of shift maps available. With the currently known applications, there are mostly four different shift maps ranging from fuel economic to extremely sporty vehicle behavior. The calculated driver's style can also depend on the actual vehicle speed and the share of constant driving conditions during a certain driving cycle. These self-learning functions can be calibrated by the car manufacturer, depending on his philosophy and target market. In this way, the number of shift maps and the speed of the adaptation have the main influence. A further possibility to match the driver's style is by rating the accelerator pedal operation during vehicle start, for example, after a red light stop. In this way the operation speed and frequency of the accelerator pedal below a certain vehicle speed can be interpreted and calculated as part of the driver's style rating. In the event of kickdown, the shift maps of the driver's style rating are shut down by a priority command. The driver has the usual behavior of the car during kick-down, generally a downshift, providing no other safety function is in operation.

To prevent shift hunting, the self-learning functions are carried out over a long respectively medium term adaptation with the adaptation timer ranging from several seconds up to one minute. The second part of the self-learning functions is the driving condition detection. There is a correlation between the input signals of the transmission control and the driving condition.

One of the main disadvantages of a conventional electronic transmission control is the upshifting at constant vehicle speed by crossing the upshift characteristic with a reduction of the accelerator pedal angle. This results in an unintended gear shift, especially when cornering and when approaching a crossing or an obstacle. To prevent these gear shifts it is possible to use so-called upshift prevention. Cornering can be detected by the acceleration of the car along the driving direction related to the vehicle speed. The vehicle speed is calculated from the transmission output speed. The acceleration can be detected by an acceleration sensor or by the difference between the nondriven wheel speeds. In this way it is possible to prevent the upshift when cornering, resulting in a considerable improvement in vehicle stability.

The detection of a crossing or obstacle approach is possible by the detection of a fast off condition of the accelerator pedal. At a certain gradient of the pedal position, the upshift is prevented. This is a considerable advantage especially when overtaking low-speed vehicles. With this strategy the correct gear is available without a shift delay.

Another part of the driving situation detection is the recognition of uphill driving and full-load conditions. This is possible by adding special functions to the adaptive gear shift control. When driving downhill, it makes sense to support the engine braking effect for a better deceleration of the car. Downhill driving can be detected by a comparison of throttle position and vehicle speed gradient. An upshift is prevented and, in some special cases, a downshift is activated by the electronic TCU.

A further section of the self-learning functions is the environmental monitoring with related shift strategies. A special application can be a self-learning winter program. The wheel slip of the driven wheels is compared with a set value of a combination of given wheel torque and vehicle speed. When exceeding a set limit of wheel slip, a special shift strategy is chosen. For example, the vehicle starts off in second gear or an upshift takes place at lower engine speeds.

The development of adaptive shift strategies started a few years ago and is currently one of the main areas in electronic transmission development. The efficiency of the self-learning functions has led to a wide acceptance of AT-equipped vehicles. The future development concerning new adaptive functions and an improvement of the already known functions is an important area in control development. This can be supported by an increasing share of electronic units and interfaces for the communication between units. With multiple use of sensors providing the necessary input signals, the total system gains increased functionality, especially with bus systems.

At present, an increasing share of manual programs with an AT can be registrated. The driver instructs the AT to shift via a switch or a push button. In this manner, the driver can operate the AT like a manual gearbox independently of other shift maps, with only the safety functions in operation. This has led to a broad acceptance, especially in the sports car market. These functions can all be calibrated and applied by the car manufacturer with data relating to his philosophy and to the target market. The result is the prevention of the known disadvantages of the conventional AT control without canceling the advantages in driving comfort and safety.

13.4 COMMUNICATIONS WITH OTHER ELECTRONIC CONTROL UNITS

With the existence of electronic control units for various applications in vehicles, many opportunities exist to link these ECUs and to establish communications between them. The main partner of the TCU is the engine management system. Due to the coupling of engine and transmission within the vehicle powertrain, it is necessary to have an interface between these ECUs for a functional coupling and an interchange of signals. It is essential for the pressure control inside the transmission control to sensor the engine load, the engine speed, and the throttle position. The engine torque reduction during shifting is also important to establish a good shift comfort and a satisfactory lifetime for the clutches. By handing over certain signals like position lever state, lockup condition, or shift commands to the engine management, the driving comfort of the vehicle can be improved significantly. An interface to ABS and traction control is useful for some self-learning functions in the transmission control when using the wheel speeds.

It is possible to implement certain shift strategies in the transmission control as an active support for ABS and traction control. A link to the electronic throttle control or cruise control makes it possible to optimize certain functions for the total vehicle. By interfaces between the ECUs, a reduction of the sensor expense results by a multiple use via communications. Suitable links include, especially, PWM or bus configurations for trouble-free communication. Bus systems in particular have the advantage of the link-up of additional ECUs without changing their existing hardware. Additional coupling requires only a software change. The interchange of required supplementary signals for new functions is possible without any problems. An example of powertrain management by coupling the powertrain ECUs to achieve lower fuel consumption, simultaneously improving the driveability, is described as follows.

13.5 OPTIMIZATION OF THE DRIVETRAIN

The newest generation of transmission controllers has overcome the former disadvantage regarding fuel efficiency. Adaptive functions in cooperation with carefully designed torque converter clutch control,[8] which allows the clutch to be closed even at low gears, have improved fuel consumption significantly. Based on the driver's behavior, together with an adaptive shift strategy as previously described, part of the TCU's adaptive program software may select an economy or even super-economy shift strategy whenever possible. There is, however, still more potential for fuel economy by optimization of the drivetrain.

The concept called Mastershift[10] is shown in Fig. 13.11. The basic idea is to interpret the accelerator pedal position as an acceleration request. That acceleration request, or a request for wheel torque, has to be converted by operating the engine at high torque, i.e., open throttle and low rpm values. In order to realize this, it is necessary to use an electronic throttle control system. The communication between the electronic throttle, the engine, and transmission is shown in Fig. 13.12.

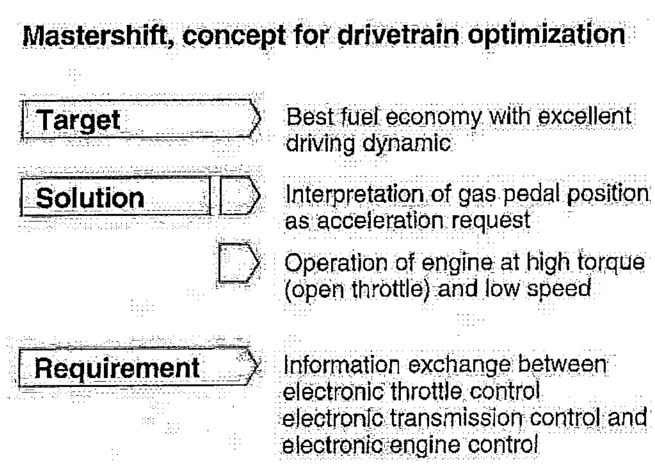

FIGURE 13.11 Drivetrain operation.

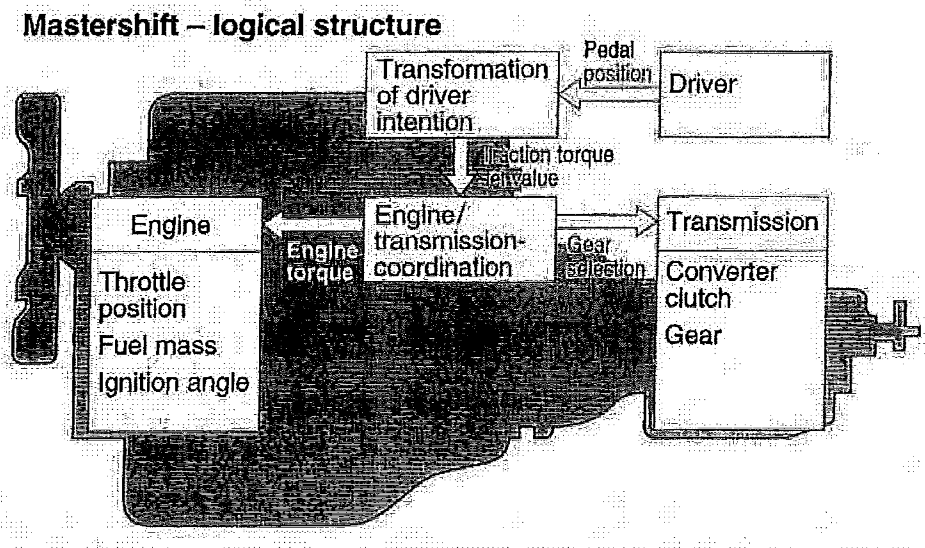

FIGURE 13.12 Mastershift: logical structure and communication between different control systems.[1]

In such a system, a well-defined coordination between the engine torque, mainly given by throttle position (air mass), fuel mass, and ignition angle on one side and selection of the appropriate gear including torque converter clutch on the other side, is imperative. Depending on the type of engine, fuel consumption can be reduced further by 5 to 10 percent with this optimized Mastershift concept. Because the average engine operation is at higher torque levels compared to standard systems, a greater number of gear shifts may occur. This is important to guarantee optimal shift comfort. Figure 13.13 shows how that can be accomplished by using the additional degree of freedom given by the electronic throttle control. It is possible to operate the throttle angle during the gear shift in such a way as to achieve constant wheel torque before and after downshifts.

13.6 FUTURE DEVELOPMENTS

In future years, development work will be concentrated on redesign of hardware components for cost reduction, improvement of yield to reduce fuel consumption, and improvement of driveability. A good approach to meet cost targets on the electronic hardware side would be to integrate two or more individual control modules into a common housing. Regarding the electronic components, one could continue using two separate microcontrollers. This would have the advantage that the software development and application could be done individually for two different systems, for example engine and transmission controllers. Another approach could be to mount the TCU on the transmission housing itself. This could lead to a significant reduction in the expense for the wiring harness. Here, however, the problem of hostile ambient temperatures on electronic components has to be solved. Today's stand-alone actuators could be integrated into a common housing similar to the solution shown by Chrysler Corp. in its A 604 transmission.

The improvement of the yield is a main topic for designers of ATs. Oil pumps and torque converters are a major source of energy losses. A significant improvement of yield will be possible as soon as torque converter clutches are available with the capability for continuous slip operation. The torque converter clutch can then be operated in low gears and at low engine speeds without facing problems from drivetrain oscillations and/or noise emission.

The driveability is the most important feature for the drivers' acceptance of ATs. In addition to the self-adaptive functions described, the implementation of shift strategies benefiting from control algorithms using fuzzy theory may further improve driveability.

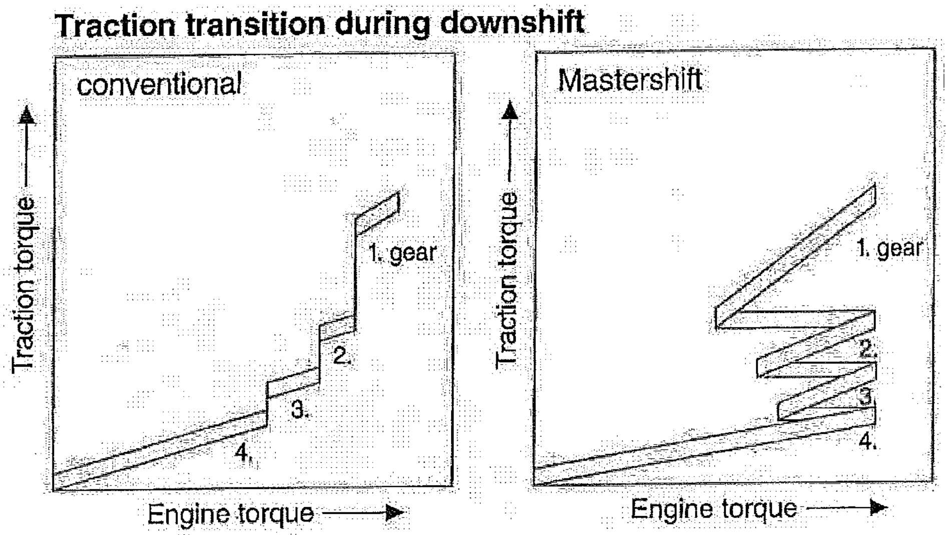

FIGURE 13.13 Constant traction torque by operation of throttle opening during gear shift.

GLOSSARY

ASIC Application-specific integrated circuit.

AT Automatic transmission.

ATF Automatic transmission fluid.

CAN Controller area network.

CVT Continuously variable transmission.

EEPROM Electrically erasable and programmable read-only memory.

EMC Electromagnetic compatibility.

EPROM Erasable programmable read-only memory.

PWM Pulse-width modulation.

RAM Random access memory.

RFI Radio frequency interference.

TCC Torque converter clutch.

TCU Transmission control unit.

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CHAPTER 14
CRUISE CONTROL

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14.1 CRUISE CONTROL SYSTEM

A vehicle speed control system can range from a simple throttle latching device to a sophisticated digital controller that constantly maintains a set speed under varying driving conditions. The next generation of electronic speed control systems will probably still use a separate module (black box), the same as present-day systems, but will share data from the engine, ABS, and transmission control systems. Futuristic cruise control systems that include radar sensors to measure the rate of closure to other vehicles and adjust the speed to maintain a constant distance are possible but need significant cost reductions for widespread private vehicle usage.

The objective of an automatic vehicle cruise control is to sustain a steady speed under varying road conditions, thus allowing the vehicle operator to relax from constant foot throttle manipulation. In some cases, the cruise control system may actually improve the vehicle's fuel efficiency value by limiting throttle excursions to small steps. By using the power and speed of a microcontroller device and fuzzy logic software design, an excellent cruise control system can be designed.

14.1.1 Functional Elements

The cruise control system is a closed-loop speed control as shown in Fig. 14.1. The key input signals are the driver's speed setpoint and the vehicle's actual speed. Other important inputs are the faster-accel/slower-coast driver adjustments, resume, on/off, brake switch, and engine control messages. The key output signals are the throttle control servo actuator values. Additional output signals include cruise ON and service indicators, plus messages to the engine and/or transmission control system and possibly data for diagnostics.

14.1.2 Performance Expectations

The ideal cruise system features would include the following specifications:

- *Speed performance:* ±0.5 m/h control at less than 5 percent grade, and ±1 m/h control or vehicle limit over 5 percent grade.
- *Reliability:* Circuit designed to withstand overvoltage transients, reverse voltages, and power dissipation of components kept to minimum.

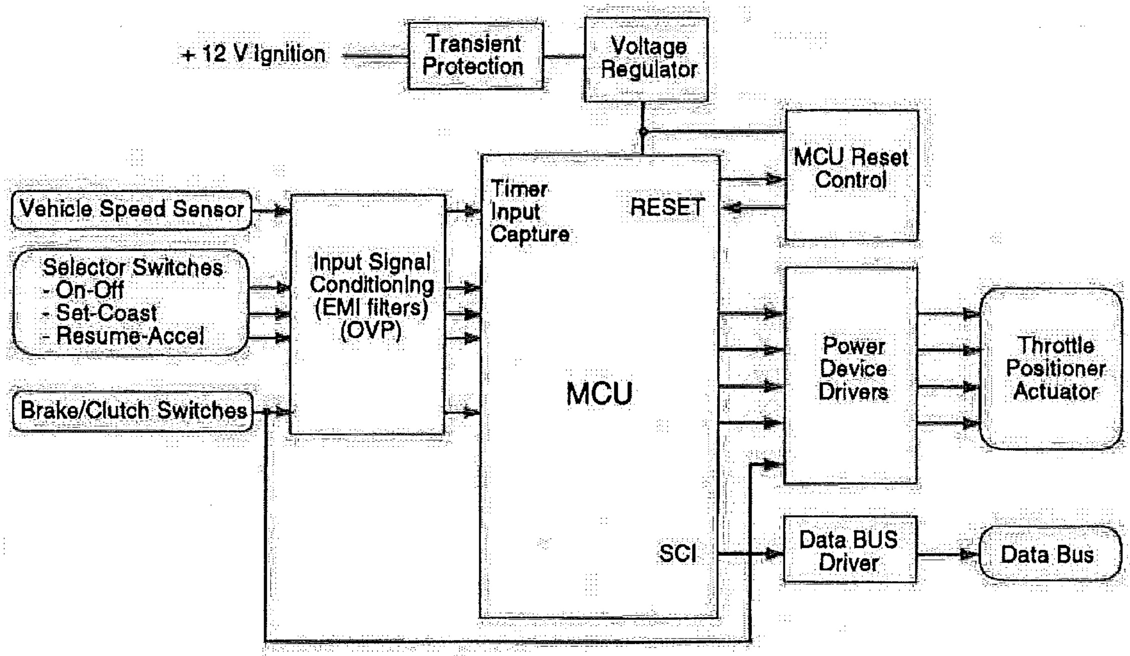

FIGURE 14.1 Cruise control system.

- *Application options:* By changing EEPROM via a simple serial data interface or over the MUX network, the cruise software can be upgraded and optimized for specific vehicle types. These provisions allow for various sensors, servos, and speed ranges.
- *Driver adaptability:* The response time of the cruise control can be adjusted to match the driver's preferences within the constraints of the vehicle's performance.
- *Favorable price-to-performance ratio:* The use of integrated actuator drivers and a high-functionality MCU reduce component counts, increase reliability, and decrease the cruise control module's footprint.

14.1.3 Safety Considerations (Failsafe)

Several safety factors need to be considered for a vehicle speed control design. The most basic is a method designed into the throttle control circuit to insure a failsafe mode of operation in the event that the microcontroller or actuator drivers should fail. This electronic failsafe circuit shuts off the control servos so that the throttle linkage will be released when the brake switch or cruise off switch is activated, no matter the condition of the MCU or servo actuator control transistors. (This assumes the actuators are mechanically in good shape and will release.)

Other safety-related items include program code to detect abnormal operating conditions and preserving into memory the data points associated with the abnormal condition for later diagnostics. Abnormal conditions, for example, could be an intermittent vehicle speed sensor, or erratic driver switch signals. A test could also be made during the initial ignition "key on time" plus any time the cruise is activated to verify the integrity of the cruise system, with any faults resulting in a warning indicator to the driver. Obviously, the most serious fault to avoid is runaway acceleration. Continuous monitoring of the MCU and key control elements will help minimize the potential for this type of fault.

14.2 MICROCONTROLLER REQUIREMENTS FOR CRUISE CONTROL

The MCU for cruise control applications requires high functionality. The MCU would include the following:

- a precise internal timebase for the speed measurement calculations
- A/D inputs
- PWM outputs
- timer input capture
- timer output compares
- serial data port (MUX port)
- internal watchdog
- EEPROM
- low-power CMOS technology

14.2.1 Input Signals

The speed sensor is one of the most critical parts in the system, because the microcontroller calculates the vehicle speed from the speed sensor's signal to within ½ m/h. Any speedometer cable whip or oscillation can cause errors to be introduced into the speed calculation. An averaging routine in the speed calculations can minimize this effect. The speedometer sensor drives the microcontroller's timer input capture line or the external interrupt line. The MCU then calculates the vehicle's speed from the frequency of the sensor signals and the MCU internal timebase. The vehicle's speed value is continually updated and stored into RAM for use by the basic speed control program. Speed sensors traditionally have been a simple ac generator located in the transmission or speedometer cable. The ac generator produces an ac voltage waveform with its frequency proportional to the sensor's rpm and vehicle speed. Optical sensors in the speedometer head can also be incorporated. Usually the speed sensor produces a number of pulses or cycles per km or mile. With the increasing ABS system usage, a backup speed sensor value could be obtained from the ABS wheel speed sensors. The ABS speed data could be obtained by way of a MUX network.

The user command switch signals could either be single MCU input lines to each switch contact or a more complex analog resistor divider type to an A/D input line. Other input signals of interest to the cruise system program would be throttle position, transmission or clutch status, A/C status, actuator diagnostics, engine status, etc., which could be obtained over the MUX data network.

14.2.2 Program Flow

The microcontroller is programmed to measure the rate of vehicle speed and note how much, and in which direction, the vehicle speed is drifting. The standard PI (proportional-integral) method produces one output signal *p* that is proportional to the difference between the set-speed and actual vehicle speed (the error value) by a proportional gain block *Kp*. Another signal *i* is generated that ramps up or down at a rate set by the error signal magnitude. The gains of both *Ki* and *Kp* are chosen to provide a quick response, but with little instability. In effect, the PI system adds up the error rate over time, and, therefore, if an underspeed condition occurs as in a long uphill grade, the error signal will begin to greatly increase to try to compensate. Under level driving conditions, the integral control block *Ki* will tend toward zero

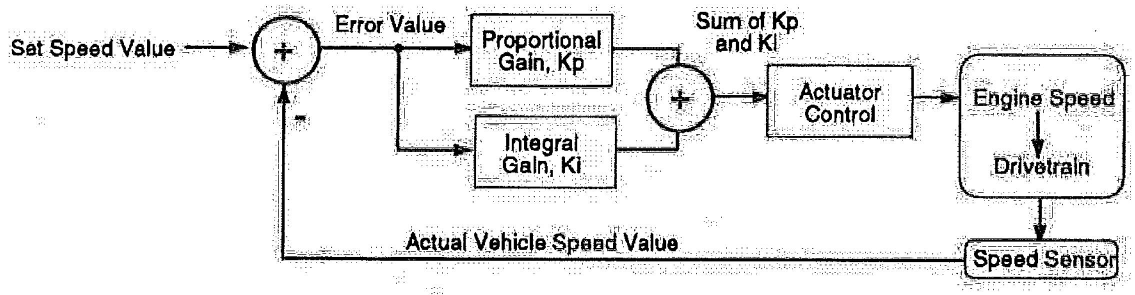

FIGURE 14.2 PI speed error control.

because there is less error over time. The vehicle's weight, engine performance, and rolling resistance all factor in to determine the PI gain constants. In summary, the PI method allows fast response to abrupt grades or mountains and stable operation under light grades or hills. Figure 14.2 shows the traditional PI cruise control diagram.

14.2.3 Output Controls

When the error signal has been computed, an output signal to the servo actuators is generated to increase, hold, or decrease the throttle position. The servo is updated at a rate that is within the servo's mechanical operating specifications, which could be several milliseconds. The error signal can be computed at a much faster rate and, therefore, gives extra time for some averaging of the vehicle speed sensor signal.

Throttle positioning is traditionally either a vacuum type servo or motor. The vacuum supply to the vacuum servo/actuator is discharged as a failsafe measure whenever the brake system is engaged in addition to the normal turn-off of the actuator driver coils. Electric servo type motors require more complex drive electronics and some type of mechanical failsafe linked backed to the brake system.

14.3 CRUISE CONTROL SOFTWARE

The cruise error calculation algorithm can be designed around traditional math models such as PI or fuzzy logic.

14.3.1 Fuzzy Logic Examples

Fuzzy logic allows somewhat easier implementation of the speed error calculation because its design syntax uses simple linguistics. For example: IF speed difference negative and small, THEN increase throttle slightly.

The output is then adjusted to slightly increase the throttle. The throttle position update rate is determined by another fuzzy program which looks for the driver's cruise performance request (slow, medium, or fast reaction), the application type (small, medium, or large engine size), and other cruise system factory preset parameters. Figure 14.3 shows one part of a fuzzy logic design for computing normal throttle position. Other parts would compute the effects of other inputs, such as resume, driver habits, engine type, and the like.

Other program design requirements include verification that the input signals fall within expected boundaries. For example, a broken or intermittent speed sensor could be detected.

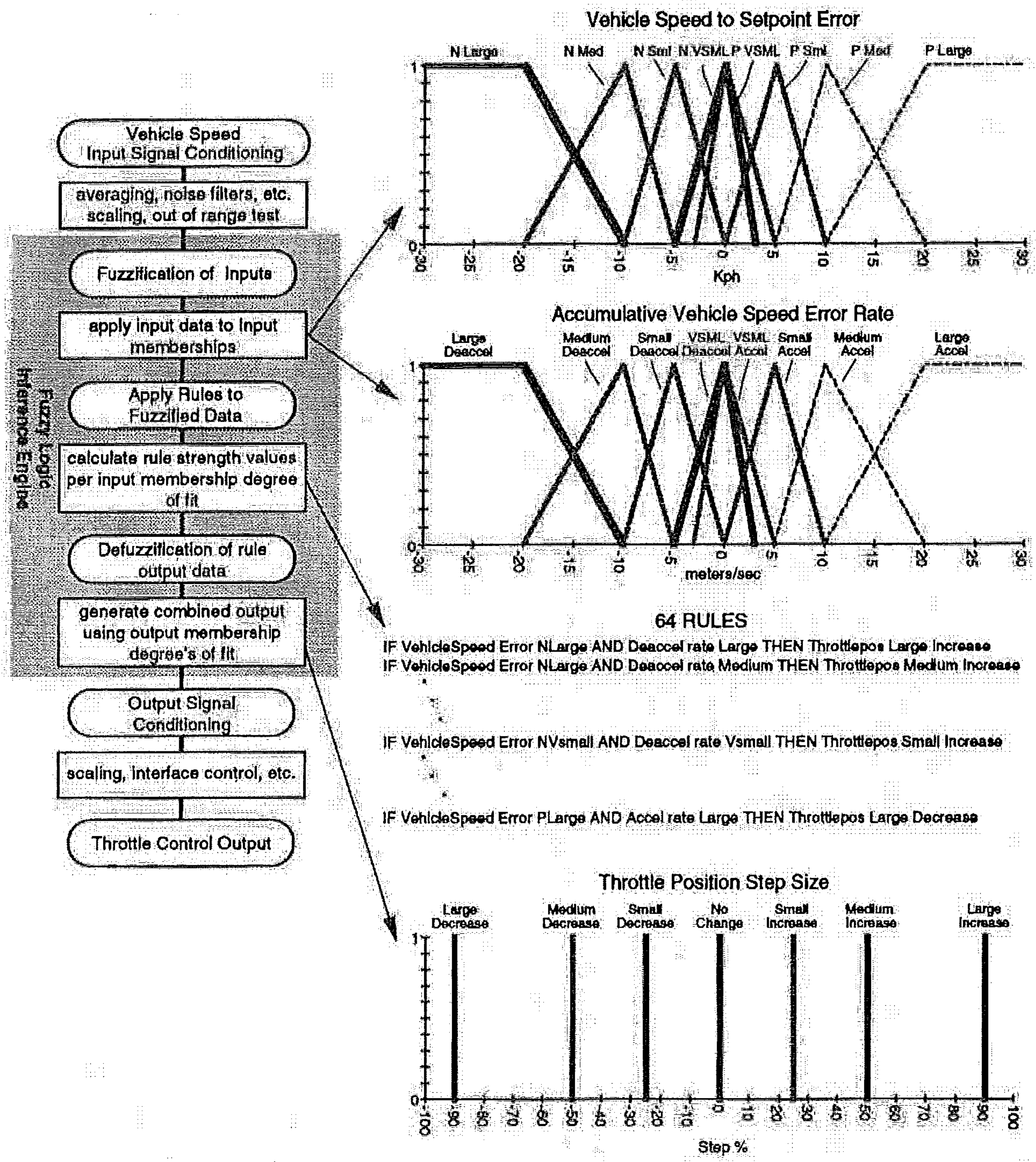

FIGURE 14.3 Fuzzy speed error program flow.

A heavily loaded vehicle with a small engine may not be able to maintain a high setpoint speed up a steep grade, and the cruise control needs to be disengaged to protect the engine from sustained full-throttle operation under a heavy load. This could be preset to occur 20 percent below the setpoint speed. Another program can test the vehicle speed to resume setpoint speed and prevent unsafe acceleration under certain conditions. For example, if a high-performance vehicle (>200-kW or 268-hp engine) has a setpoint speed of 125 km/h (78 mi/h), and drives from the freeway into heavy city traffic doing 48 km/h (30 mi/h) and the vehicle's driver fortuitously hits the cruise resume switch at this low speed, the cruise control invokes a near full-throttle action, and an accident is likely. A fuzzy design can limit the acceleration upon resume using simple rules such as IF resume and big speed error, THEN increase throttle slightly.

14.3.2 Adaptive Programming

The response time and gain of the cruise system can be adjusted to match individual drivers. For example, some drivers may prefer to allow the vehicle to slow down somewhat when climbing a grade and then respond quickly to maintain a setspeed; other drivers may prefer a constant speed at all times, while still other drivers may prefer a very slow responding cruise system to maximize fuel efficiency. The cruise system can be adapted either by a user selection switch (slow, medium, fast) or by analyzing the driver's acceleration/deacceleration habits during noncruise operation. Once these habits are analyzed, they can be grouped into the three previously mentioned categories. One drawback of a totally automatic adaptive cruise system is when various drivers with vastly different driving preferences operate the vehicle on the same trip. The cruise system would have to be "retrained" for each driver.

14.4 CRUISE CONTROL DESIGN

Many of the required elements of a cruise control can be integrated into one single-chip MCU device. For example, the actuator drivers can be designed in the MCU if their power requirements are on the low side.

14.4.1 Automatic Cruise System

Figure 14.4 shows an experimental system design for a cruise control based upon a semicustom 8 or 16-bit single-chip MCU that incorporates special high-power output driver elements and a built-in voltage regulator.

14.4.2 Safety Backup Examples

The design of a cruise control system should include many safeguards:

- A test to determine vehicle speed conditions or command inputs that do not fall within the normal conditions for operation of the cruise control function.
- A test to determine if the vehicle speed has decreased below what the cruise routine can compensate for.
- Speed setpoint minimums and maximums (30 km/h min to 125 km/h max, for example) are checked and, if exceeded, will cause the cruise function to turn off.
- Speedometer cable failure is detected by checking for speed sensor electrical output pulses over a 100-ms time period and, if these pulses are absent, the system is disengaged.
- Software program traps should also be scattered throughout the program and, if memory permits, at the end of each program loop. These will catch an out-of-control program and initiate a vector restart.

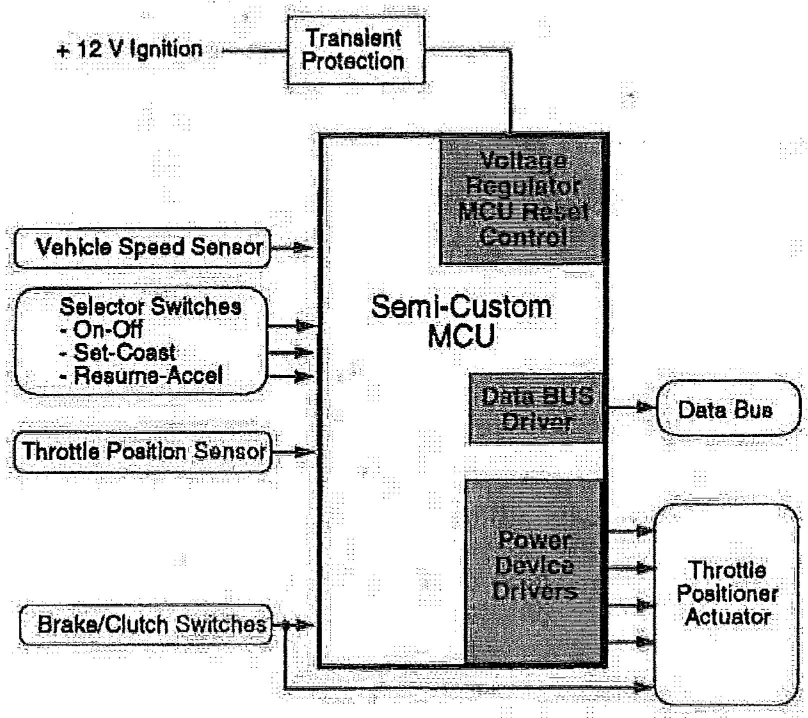

FIGURE 14.4 Automatic cruise control.

14.4.3 EMI and RFI Noise Problems

As with any electronic design, consideration must be given to suppressing RFI (radio frequency interference) from the circuit, besides minimizing effects of external EMI (electromagnetic interference) and RFI to the circuit's normal operation. It is not uncommon that the circuit must operate in RF fields up to 200 V/m intensity. This requires careful layout of the module's PCB (printed circuit board) and RF filters on all lines going in or out of the module. The module case may even have to contain some type of RF shielding. Minimizing generated RFI from the cruise circuit can be accomplished by operating the MCU's crystal oscillator at a minimal power level (this is controlled mostly by the MCU internal design), careful PCB trace layout of the MCU oscillator area, metal shielding over the MCU, ground planes on the PCB under the MCU, and setting the actuator switching edge transition times to over 10 ms. (See Chaps. 27 and 28.)

14.5 FUTURE CRUISE CONCEPTS

Several research projects are underway to develop a crash avoidance system that could be interconnected with a cruise system. The development of a low-cost distance sensor that can measure up to a few hundred meters away with a tight focal point in all weather conditions is proving to be a challenge. When a practical vehicular distance sensor is available, the cruise control can be programmed to maintain either constant speed or constant distance to another vehicle. Other methods of cruise control could include receiving a roadside signal that gives an optimum speed value for the vehicle when travelling within certain traffic control areas.

14.5.1 Road Conditions Integration with IVHS

The IVHS (Intelligent Vehicle-Highway System) network may be a more practical approach to setting optimum cruise speed values for groups of vehicles. The IVHS can monitor road conditions, local weather, etc., and broadcast optimal speed data values for vehicles in its zone. (See Chap. 29.)

GLOSSARY

Analog input Sensors usually generate electrical signals that are directly proportional to the mechanism being sensed. The signal is, therefore, analog or can vary from a minimum limit to a maximum limit. Normally, an 8-bit MCU A/D input using a 5-V reference, the analog input resolution is 1 bit, which is 1/256 of 5 V or 0.0193 V.

Defuzzification The process of translating output grades to analog output values.

Fuzzification The process of translating analog input values to input memberships or labels.

Fuzzy logic Software design based upon a reasoning model rather than fixed mathematical algorithms. A fuzzy logic design allows the system engineer to participate in the software design because the fuzzy language is linguistic and built upon easy-to-comprehend fundamentals.

Inference engine The internal software program that produces output values through fuzzy rules for given input values. The inference process involves three steps: fuzzification, rule evaluation, and defuzzification.

Input memberships The input signal or sensor range is divided into degrees of membership, i.e., low, medium, high or cold, cool, comfortable, warm, hot. Each of these membership labels is assigned numerical values or grades.

Output memberships The output signal is divided into grades such as off, slow, medium, fast, and full-on. Numerical values are assigned to each grade. Grades can be either singleton (one value) or Mandani (a range of values per grade).

Rule evaluation Output values are computed per the input memberships and their relationship to the output memberships. The number of rules is usually set by the total number of input memberships and the total number of output memberships. The rules consist of IF inputvarA is x, AND inputvarB is y, THEN outvar is z.

Semicustom MCU An MCU (microcontroller unit) that incorporates normal MCU elements plus user-specified peripheral devices such as higher-power port outputs, special timer units, etc. Mixed semiconductor technologies, such as high-density CMOS (HCMOS) and bipolar analog, are available in a semicustom MCU. Generally, HCMOS is limited to 10 V, whereas bipolar-analog is usable to 60 V.

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CHAPTER 22
ON- AND OFF-BOARD DIAGNOSTICS

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22.1 WHY DIAGNOSTICS?

The desire for greater safety, driving comfort, and environmental compatibility is leading to a rapid increase in electronic control units and sensors in upper class, medium-sized, and compact vehicles. Additional functions and their corresponding equipment in today's cars create a bewildering tangle of cables and confusing functional connections. As a result, it has become more and more difficult to diagnose faults in such systems and to resolve them within a reasonable period.

22.1.1 Diagnostics in the Past and Today

On-board diagnosis has been limited thus far to a few error displays and fault storage achieved by relatively simple means. It has been left more or less to each manufacturer to decide to what extent diagnosis would be carried out. Diagnosis always means the working together of man and machine and consists essentially of three major components: registration of the actual condition, knowledge of the vehicle and its nominal condition, and strategy—how to find the smallest exchangeable deficient component by means of combining and comparing both the nominal and actual conditions.

All three points are inseparably connected. Only the means to the end have changed over time. The oldest and simplest method of diagnosis is that done with the help of our sense organs, but the limits of this kind of diagnosis are obvious. In fact, the objective in the development of diagnostic techniques is the extension of human abilities with the aid of diagnostic tools in order to be able to measure more precisely and more directly, to compare more objectively, and to draw definite conclusions.

The development of control techniques was essentially determined by the following items: the development of automotive engineering; the structure of workshops—that is, essentially the relation between the costs of labor and materials; and the development of electronics and data processing.

For a long time, motor diagnosis was limited to ignition control and timing. In the 1960s, new exhaust-gas measuring instruments for fuel injection adjustment were developed, but the mechanic still had to make the diagnosis. In the 1980s, the introduction of electronics in the vehicle was followed by a new generation of measuring instruments in the workshops. Not

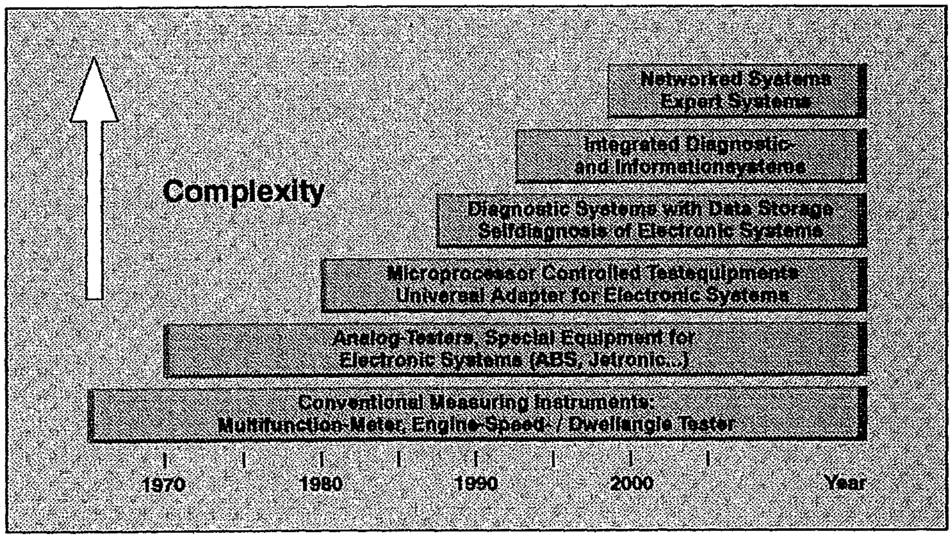


FIGURE 22.1 Evolution of diagnostic test equipment.

only were separate measurements combined with comprehensive test procedures, but also the information about the nominal condition of the vehicle was stored in a data memory.[1] A view of the development is shown in Fig. 22.1.

As more and more electronic systems were added to cars, the more difficult it became to determine the actual condition in case of a defect. Soon a multitude of connecting cables and adapters were required to reach the necessary measuring points. Moreover there was an increasing amount of information needed to make an effective diagnosis. In the majority of workshops, diagnosis is carried out as shown in Fig. 22.2. The most important test points of

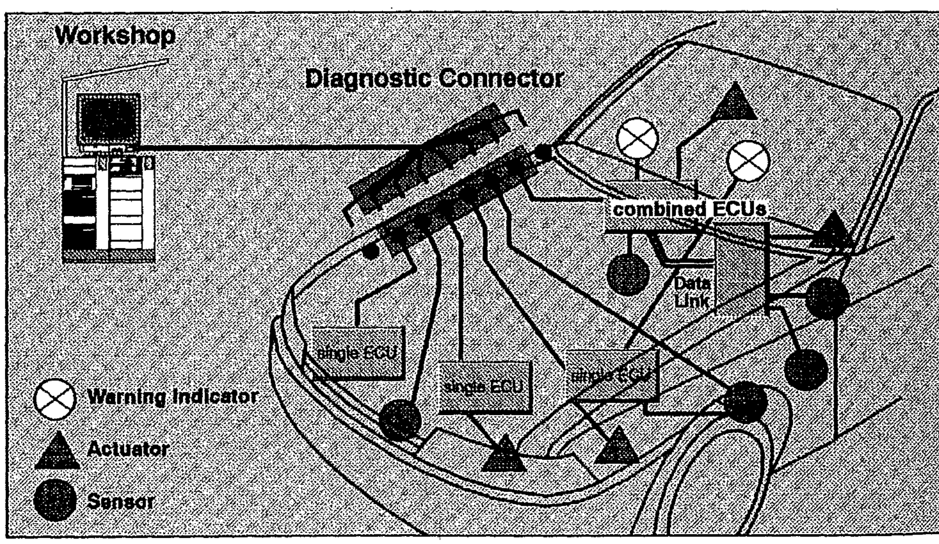


FIGURE 22.2 Present-day diagnostic connector installation in a vehicle.

control units and sensors are tied to a diagnostic connector which is plugged into the measuring instrument with a corresponding adapter for the respective vehicle. Because of the permanently increasing amount of electronic functions, it is necessary to develop connectors with more and more contacts. It is evident that this method soon will become too unwieldy.

Modern electronics in vehicles support diagnosis by comparing the registered actual values with the internally stored nominal values with the help of control units and their self-diagnosis, thus detecting faults. By interconnecting the measuring instruments, a detailed survey of the entire condition of the vehicle is available and an intelligent on-board diagnostic system is able to carry out a more precise and more definite localization of the defect.[2] With the help of an interconnection and standardization of the interface leading to the external tester, the many different complex and expensive adapters have become superfluous. Modern diagnosis will look like what is shown in Fig. 22.3.

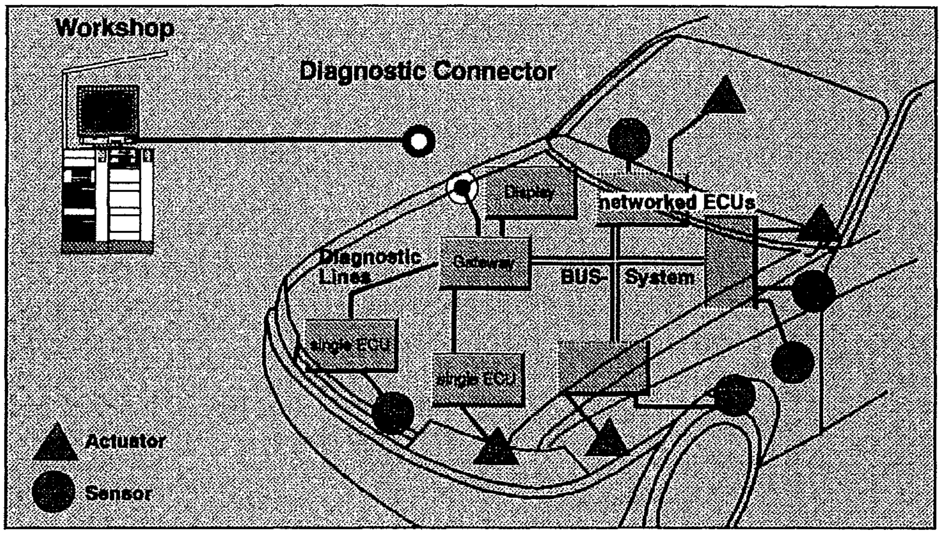


FIGURE 22.3 Future diagnostic connector installation in a vehicle.

Instead of a multiplicity of adapters there is only a single standardized interface, provided by the diagnostic processor. By means of interconnection, the diagnostic processor is provided with all available data and the condition of the vehicle is known. With the help of the diagnostic processor, the external measuring instrument has access to the measuring and diagnostic values of the sensors and is able to directly reach the actuator for measuring purposes.[3]

Such a diagnosis also demands a certain change in the functional structure of a vehicle. Corresponding hierarchical models have already been presented.[4]

22.1.2 Reasons for Diagnostics in Vehicles

Which are the most important reasons for diagnostics as demanded and desired in today's vehicles?

Existing Diagnostic Problems. A number of diagnostic problems must be resolved:

- Early diagnostic information was related only to single components and control units. In case of a defective comprehensive system, every unit, component, sensor, and connecting cable of the system had to be tested and controlled. This was a very time consuming and expensive process.

- Because of the single component and control unit checks, it was impossible to analyze all the additional data correlated with a particular defect.
- In the case of a defect in single sensors or units, the car was often inoperable. Taking into consideration all available information about the vehicle, it is possible to use alternative parameters and procedures in order to achieve at least a so-called limp-home function and sometimes continue the use of the vehicle under only slightly limited operating conditions.
- Usually there was only a global error display with an often ambiguous warning light available for the driver. Drivers desire more detailed information and especially guidelines for what procedures should be followed.
- The multitude of adapter cables, plugs, diagnostic equipment, and communication interfaces in a workshop has become so complex that the effectiveness decreased dramatically, with the repair costs increasing disproportionally.

New Legal Proposals. Worldwide new legal proposals and governmental regulations [e.g., California Air Resources Board (CARB), On Board Diagnostics II (OBDII), Environmental Protection Agency (EPA)] are forcing manufacturers and subcontractors to seek more profitable, effective, and convincing diagnosis of vehicles.

Serial Data Networks. New serial data networks for the connection of control units and vehicle body components, installed in the vehicle, offer the possibility of absolutely new optimum approaches and even anticipate maintenance and diagnosis up to the introduction of autodidactic data processing systems and external data bases.[5,6,7,8]

International Initiatives for Standardization. Initiated by legislative and governmental demands for better diagnostics in the area of emission control, initiatives for standardization in the entire diagnostic field in vehicles were launched during recent years to achieve worldwide standardization of tools, interfaces, connectors, and protocols.

22.1.3 Diagnostic Tasks in Vehicles

In order to minimize the number of defects or even to completely avoid them, a vehicle requires regular checks. In case of an inevitable defect, a clear and directed diagnosis is required and has to be followed by a prompt, reliable, and inexpensive repair. Therefore appropriate diagnostic systems are being developed considering the following targets: simplification of maintenance, fault indication in time, guidelines for the driver in case of a defect, and safer and faster repairs with the help of a specific fault indication.

In addition to technical considerations, environmental aspects are now being taken into consideration as reflected in the diagnostic concepts. In the future, only perfect systems will be accepted, in order to keep environmental pollution to a minimum. It is understandable, therefore, that legislators insist on increased monitoring standards, particularly for exhaust-related components.

As an example of the new monitoring standards, consider the requirements of CARB and EPA in the United States and the resulting consequences for diagnosis. At the moment, the extent of such a detailed monitoring has to be a compromise between the different requirements and the possible technical and economical solutions, but the environmental aspects will gain more and more importance. The increased amount of available data will certainly permit a considerably higher rate of in-depth fault localization and will also allow clear fault identification without interactive outside intervention. Having knowledge of the functional interrelationships and access to all essential data, a picture of the defect can be created with the help of individual pieces of information. The driver and the workshop can then be provided with appropriate instructions. In this context, on-board expert systems are being considered.

For an effective and successful diagnosis today and in the future the following tasks and targets can be defined.

Fault Storage with Boundary Conditions. A very important aspect of modern diagnosis is the clear and reliable analysis of the respective fault. During the self-diagnosis, it is absolutely necessary to store not only the respective fault information but also all relevant marginal parameters in the control unit, e.g., ambient temperature, velocity, engine speed, engine knock, and so on. The additional data can be stored when a defect occurs as well as during specified intervals around the moment of a defect. Such additional data is called "freeze frame" data.[9]

Fault Localization. Mechanics must be able to locate a defective control unit quickly and then determine which component of that control unit is at fault so that it can be replaced.

Data Correlation, Recognition of Imminent Faults. A large amount of data useful for the analysis of a vehicle is now available and even more will be available in the future. These data will have to be evaluated and compared with the help of modern data processing techniques, including fuzzy logic, neural networks, autodidactic systems, and expert systems. These techniques will not only enable the diagnosis of the actual condition of the vehicle but will also determine future maintenance needs. As a result, the reliability and availability of a vehicle will be increased and the possible consequences of a defect kept to a minimum. The driver can also be forewarned about imminent problems and can then take appropriate steps before starting on a trip.

Parameter Substitution. The breakdown of a sensor in modern diagnostic procedures is not necessarily followed by a lack of the respective information. After having diagnosed a fault, the diagnostic computer—with the aid of the available information—is often able to compute an auxiliary parameter to replace the original one. As a result, either a limp-home condition is possible or else the nominal function can be assured but under slightly limited conditions. Simple examples for such a calculated parameter are vehicle speed (considering the gear and the synchronous speed, or the antilock braking information, or the data of the navigation system), motor temperature (considering the outside temperature and the operating time), and the amount of remaining fuel (considering the last actual fuel content and the calculated consumption).

Providing Guidelines. As mentioned earlier, a diagnostic system has to provide clear information to the driver in case of a defect. A global warning indication is not sufficient. The driver needs to learn the extent of the defect and its consequences by appropriate text, graphics, or synthetic voice. In addition, the driver needs to be told the steps that have to be taken (e.g., "refill cooling water," "minimum speed to the next service station, risk of engine breakdown," "stop, brake system out of order").[10]

The diagnostic monitoring system can also be used, if there is no service station nearby, as a substitutional off-board system. The defect is then localized by an interactive working together of the indicating system and an appropriate input medium.

External Diagnostic Access. For off-board diagnosis, the diagnostic system of the vehicle has to provide a standardized access to all relevant components, control units, and stored information. This standardized access might also be used by the vehicle manufacturer, legislator, application engineer, and the end-of-the-line programmer. The access itself has to be controlled with the help of an appropriate mechanism to prevent possible abuse.[11]

Logbook Function. The control unit or the diagnostic computer of the vehicle is supposed to store every repair that has been carried out in the format of a logbook. It should contain the time and name of the workshop, every exchanged and newly installed element, every inspection carried out, and so forth.

22.2 ON-BOARD DIAGNOSTICS

The more complex automobiles became, the greater the number of electronic systems and the more difficult became the registration of the actual condition in case of a defect. To reach the necessary measuring points, many connecting cables and adapters were required. In addition, much data about the different systems and their working together was needed to allow a system-specific diagnosis. Modern electronics with self-diagnosis supports the service mechanic by registrating the actual values, comparing them with the nominal values, and diagnosing faults that are stored for repair purposes. Actually, the internal functions are checked whenever an ECU is turned on.

First, the checksum of the program memory is checked together with its function and the correct version. Then a read and write test of the RAM cells is performed. Special peripheral elements (e.g., AD converters) are also checked within this test cycle. During the entire operating time of the vehicle, the ECUs are constantly supervising the sensors they are connected to. With the help of an adequate interpretation of the hardware, controllers are able to determine whether a sensor has a short circuit to ground or battery voltage, or if a cable to the sensor is interrupted. By comparing the measured values and the stored technical data, a controller is able to determine whether the measured values exceed the limits, drift away, or are still within the tolerable limits. The combination of information provided by other sensors allows the monitoring for plausibleness of the measured values.

Sensors are tested similarly to the way actuators are monitored for short circuits or interruptions of cables. The check is carried out by measuring the electric current or reading the diagnostic output of intelligent driver circuits. The function of an actuator under certain conditions can be tested by powering the actuator and observing the corresponding reaction of the system. If discrepancies to the nominal values are diagnosed, the information is stored in an internal fault memory together with relevant outside parameters, e.g., the motor temperature or the engine speed. Thus, defects that appear once or under certain conditions can be diagnosed. If a fault occurs only once during several journeys, it is deleted. The fault memory can be read later in the workshop and provides valuable information for the mechanic.

In case of a detected defective sensor, the measured values are replaced by nominal values or an alternative value is formed using the information of other sensors to provide at least a limp-home function.

With the help of an appropriate interface, a tester can communicate with the ECUs, read the fault memory and the measured values, and send signals to the actuators. In order to be able to use self-diagnosis as universally as possible, manufacturers aim at the standardization of the interface and the determination of appropriate protocols for data exchange.

Another task of self-diagnosis is the indication of a defect to the driver. Faults are mostly indicated by one or more warning lights on the dashboard. Modern developments aim at more comprehensive information using displays for text and graphics, which provide priority-controlled information for the driver. Legal regulations concerning exhaust-gas gave rise to an essential extension of self diagnosis. The control units have to be able to control all exhaust-relevant functions and components and to clearly indicate a defective function or the exceeding of the permissible exhaust limits. Some of the demanded functions require an enormous amount of additional instructions; therefore, the extent of self-diagnosis already reaches up to 40 percent of the entire software of the control unit.

22.3 OFF-BOARD DIAGNOSTICS

The continual increase in the use of electronics within the broad range of different vehicles represents one of the major challenges for customer service and workshop operations. Modern diagnosis and information systems must cope with this challenge and manufacturers of test equipments must provide instruments that are flexible and easy to handle. Quick and reliable fault diagnosis in modern vehicles requires extensive technical knowledge, detailed vehicle information, and up-to-date testing systems.

Due to the different demands of the service providers, there are many different test equipments on the market. They can be subdivided into two main categories: handheld or portable instruments and stationary equipments. Handheld instruments are commonly used for the control of engine functions like ignition or fuel injection and the request of error codes of the electronic control units (ECUs). Stationary test equipment, on the other hand, covers the whole range of function and performance checks of the engine, gear, brakes, chassis, and exhaust monitoring.

Most of the common testers are used for the diagnosis of the engine. The Bosch MOT 250, for example, offers the following functions:

- Engine speed by means of the top dead center (TDC) transmitter, cylinder 1 or terminal 1 signal
- Ignition timing with TDC sensor or stroboscope
- Dwell angle in percent, degrees, or dwell time
- On/off-ratio in percent
- Injection timing or other times measured at the valve or other suitable measuring points
- Electric cylinder balance in absolute or relative terms
- Voltage to ground or floating potential including lambda-sensor voltages or dynamic voltage at terminal 1
- Current with two test adapters for maximum 20 A and 600 A
- Resistances from milliohms to megohms
- Temperature with oil-temperature sensor

For most variables, a maximum of four blocks of measured variables can be stored and recalled one after the other. Twelve blocks can be stored for the cylinder balance function. A digital storage oscilloscope records and stores up to 32 oscillograms of ignition voltages, alternator ripple, and current or voltage transients in the electric or electronic systems. Two RS232 interfaces are provided for documentation purposes and data exchange.

For repair, service, and maintenance, many different manuals and microfiches are stored in the workshops. It is a time-consuming task to collect all the necessary information, especially when vehicles of different makes have to be repaired. To avoid unnecessary paper, information and communication systems among workshop, dealer, and manufacturer are built up. The corresponding manuals have to be standardized and distributed on electronic data processing media, preferably on CD-ROMs.

Every garage or workshop, equipped with the appropriate data system (basically a tester connected to a PC), will receive servicing aids and updates via telephone line or by periodic receipt of updated CDs. A committee of the SAE is preparing rules for the standardization of manuals. There are already published draft international standards (DIS) for terms and definitions (J1930) used in the manuals, for diagnostic codes/messages (J2012), or electronic access/service information (J2008) (see the following). Most of the available test equipment is capable of storing operator manuals within its memory and offers menu-guided assistance to the service personnel. Automatic vehicle and component identification by the tester and the availability of corresponding data at the workbench eases troubleshooting and repairs.

22.4 LEGISLATION AND STANDARDIZATION

22.4.1 CARB, EPA, OBD II

The following is an abstract of the California Air Resource Board (CARB) Regulations for On-Board-Diagnosis two(OBDII):

> All 1994 and subsequent model-year passenger cars, light-duty trucks, and medium-duty vehicles shall be equipped with a malfunction indicator light (MIL) located on the instrument panel that will automatically inform the vehicle operator in the event of a malfunction of any power train component which can affect emission and which provide input to, or receive output from, the on-board computer(s) or of the malfunction of the on-board computer(s) itself. The MIL shall not be used for any other purpose.
>
> ....
>
> All 1994 and subsequent model-year passenger cars, light-duty trucks, and medium-duty vehicles required to have MIL pursuant to paragraph above shall also be equipped with an on-board diagnostic system capable of identifying the likely area of the malfunction by means of fault codes stored in the computer memory. These vehicles shall be equipped with a standardized electrical connector to provide access to the stored fault codes . . . Starting with model-year 1995, manufacturers of non-complying systems shall be subject to fines pursuant to section 43016 of the California Health and Safety Code for each deficiency identified, after the second, in a vehicle model. For the third deficiency and every deficiency thereafter identified in a vehicle model, the fines shall be in the amount of $50 per deficiency per vehicle for non-compliance with any of the monitoring requirements . . .

Systems to Be Monitored

OBD II Functions. These include catalyst monitoring, misfire monitoring, evaporative system monitoring, secondary air system monitoring, fuel systems monitoring, oxygen sensor monitoring, exhaust-gas-recirculation (EGR) system monitoring, and comprehensive component monitoring.

Catalyst. Legal requirements (CARB excerpt): "The diagnostic system shall individually monitor the front catalyst or catalysts which receive untreated engine out exhaust-gas for malfunction. A catalyst is regarded as malfunctioning when the average hydrocarbon conversion efficiency falls between 50 and 60 percent."

Technical solution: In addition to the oxygen sensor upstream the catalyst, another sensor is mounted downstream.

A properly working catalyst shows a storage effect so that the oscillation of the lambda-controller appears damped at the downstream lambda probe. A worn-out catalyst has a reduced damping effect and the signals of up- and downstream sensors are equivalent.

The ratio of the signal amplitudes is a measure of the conversion efficiency. The electronic system that controls the fuel injection monitors these signals together with other relevant engine conditions to derive the catalyst efficiency.

Misfire Detection. Legal requirements (CARB excerpt): "To avoid catalyst damage, the diagnostic system shall monitor engine misfire and identify the specific cylinder experiencing misfire."

Technical solution: Misfire can be caused by worn-out spark plugs or defective electrical wiring. Unburned fuel reaches the catalyst and may destroy it by overheating. Even the least amount of misfire rates influences the emission and therefore single misfire events must be detected.

The speed of the engine is measured very precisely. In case of misfire, the momentum, which is normally produced by the combustion, is lacking. Thus abnormal variations of speed-changes at steady state conditions may be considered as misfire. To distinguish clearly between misfire and other malfunctions, complicated calculations have to be carried out.

If a certain percentage of misfires within 200 or 1000 revolutions is detected, a fault code is stored in the control unit and the fault is indicated to the driver.

Oxygen Sensor. Legal requirements (CARB excerpt): "The diagnostic system shall monitor the output voltage, the response rate, and any other parameter which can affect emission and all fuel control oxygen sensors for malfunction."

Technical solution: The control unit has a special input circuit for detecting shorts or breaks and monitors the switching frequency of the control loop.

By means of a second lambda probe behind the catalyst, it is possible to monitor the lambda probe in front of the catalyst for its correct position. A lambda probe which is subject to an increased temperature for extensive periods may react slower on variations of the air/fuel mixture, thus increasing the period of the lambda-probe regulation. The diagnostic system of the control unit controls the regular frequency and indicates slow sensors to the driver by means of a warning light.

Heated sensors are monitored for correct heater current and voltage by hardware means within the control unit.

Evaporative System. Legal requirements (CARB excerpt): "The diagnostic system shall control the air flow of the complete evaporative system. In addition, the diagnostic system shall also monitor the complete evaporative system for the emission of HC vapor into the atmosphere by performing a pressure or vacuum check of the complete evaporative system. From time to time, manufacturers may occasionally turn off the evaporative purge system in order to carry out a check."

Technical solution: At idle position, the canister purge valve is activated and the lambda controller is monitored for its reaction. For leak detection of the evaporative system, the output to the active carbon filter is shut off and the canister pressure is decreased to about −1.5 kPa. Then the complete system is turned off and the pressure within the canister is monitored for variation with time. The pressure gradient, together with other parameters like the amount of fuel, may indicate possible leaks.

Secondary Air System. Legal requirements: "Any vehicle equipped with any form of a secondary air delivery system shall have the diagnostic system monitor the proper functioning of the secondary air delivery system and any air switching valve."

Technical solution: The lambda controller is monitored for correlated deviations when the secondary air flow is changed.

Fuel System. Legal requirements: "The diagnostic system shall monitor the fuel delivery system for its ability to provide compliance with emission standards."

Deviations of the stochiometric ratio which last for a longer time are stored within the adaptive mixture controller. If these values exceed defined limits, components of the fuel system obviously do not correspond to the specification.

Exhaust-Gas Recirculation (EGR) System. Legal requirement: "The diagnostic system shall monitor the EGR system on vehicles for low and high flow rate malfunctions."

Technical solution: (1) At overrun, the fuel is cut off and the EGR valve is completely opened. The flow of exhaust gas to the manifold raises the manifold pressure, which is recorded and allows statements about the function of the EGR valve. (2) Another possibility is to control the increase of the manifold intake temperature when the EGR valve is opened.

In a conclusion to the previously described OBD II requirements and technical solutions, we can define the following four quality demands for electronic control units:

- Guarantee for exhaust-gas-relevant components with repair costs >$300 for seven years or 70,000 miles for all 1990 and subsequent model-year vehicles (CARB).
- Guarantee for exhaust-gas-relevant components with repair costs >$200 for eight years or 80,000 miles for all 1994 and subsequent model-year vehicles (EPA/Clean Air Act).
- Guarantee protocols in case of a reclamation rate of exhaust-gas-relevant components higher than 1 percent (CARB).
- Recall of vehicles in case of a calculated reclamation rate of more than 20,000 ppm within a period of five years/50,000 miles (CARB).

22.4.2 International Standardizations

Because of the manifold requirements on modern diagnostics, the national and international standardization committees soon came to the conclusion that with the help of appropriate and, if possible, international agreements about protocols, connectors, tools and auxiliaries, the process of diagnosis can be standardized, thus reducing time and costs.

Figure 22.4 shows how, in a standardized graphic, control units and diagnostic tools are connected and diagnostic data exchanged.

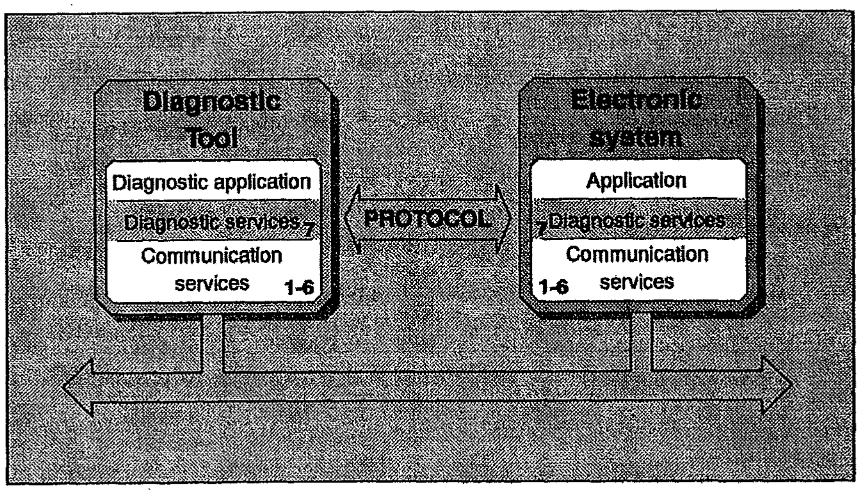


FIGURE 22.4 Standardized testing link according to the OSI model.

For data exchange, electronic systems are structured and described according to a seven-layer model (OSI model, open system interconnection) developed by the ISO (International Standardization Organization). Every unit connected to a data network can be structured with the help of this model—control units as well as diagnostic tools.

The diagnostic services that the controller may use during the diagnostic process are regulated in the seventh layer. Diagnostic service means definite instructions, which actuate determined and standardized diagnostic procedures, e.g. "start diagnostic session," "read diagnostic trouble codes," "read freeze frame data," and so on. There are different sequences of bits and bytes code for such instructions. On the hardware level (plugs, cables, potentials), the sequences are finally transmitted from unit to unit. The ISO and the SAE (Society of Automotive Engineers) developed corresponding standards in the area of service definition

TABLE 22.1 ISO Diagnostic Services

Diagnostic management
StartDiagnosticSession
StopDiagnosticSession
SecurityAccess
TesterPresent
EcuReset
ReadEcuIdentification
DisableNormalMessageTransmission
EnableNormalMessageTransmission
Data transmission
ReadDataByLocalIdentifier
ReadDataByGlobalIdentifier
ReadMemoryByAddress
WriteDataByLocalIdentifier
WriteDataByGlobalIdentifier
WriteMemoryByAddress
SetDataRates
StopRepeatedDataTransmission
Input/output control
InputOutputControlByGlobalIdentifier
InputOutputControlByLocalIdentifier
Stored data transmission
ReadNumberOfDiagnosticTroubleCodes
ReadDiagnosticTroubleCode
ReadDiagnosticTroubleCodesByStatus
ReadStatusOfDiagnosticTroubleCodes
ReadFreezeFrameData
ClearDiagnosticInformation
Remote activation of routine
StartRoutineByLocalIdentifier
StartRoutineByAddress
StopRoutineByLocalIdentifier
StopRoutineByAddress
RequestRoutineResultsByLocalIdentifier
RequestRoutineResultsByAddress
Upload download
RequestDownload
RequestUpload
TransferData
RequestTransferExit

as well as in the area of communication. Table 22.1 shows the diagnostic services as proposed by the ISO.

Figure 22.5 presents the determined standards with some essential technical details as developed for the field of communication.

Unfortunately the whole spectrum of available standards has become very complex and difficult to use. The following explanations try to provide a unified system for the existing standards in the area of diagnosis.

Comparison of Different Protocols

	CAN	J 1850	VAN
Bit Encoding	NRZ + Bit Stuffing	PWM	Man/Enhanced Man
Bit Rate	up to 1 MBPS	10/21/42/83 KBPS	up to 125 KBPS
Data Length	0 to 8 Bytes	0 to 7 Bytes	0 to 28 Bytes
Latency Time	130 µs	1.2 ms	850 µs
Acknowledge	positive Ack. Bit, Error Flag	positive Ack. Bytes	positive Ack. Bit
Error Detection	15 Bit CRC, Monitoring, Frame&Code Check	8 Bit CRC, Monitoring, Frame&Code Check, Out-of-Range Check	15 Bit CRC, Monitoring, Frame&Code Check
Error Handling	Transmission Interrupt, Error Signaling, Fault Confinement	Transmission Interrupt	Transmission Interrupt
Special Features	Fault Confinement	In-Frame Response 6 Message Types	In-Frame Response

FIGURE 22.5 In-vehicle networks.

Figure 22.6 shows a general model for diagnostic concepts. The three main levels comprehensively describe the whole area of diagnostics. The three levels are hierarchically structured, closely linked together with flowing transition from one level to the other. Although there are certain similarities between this model and the seven-layer model of the OSI, both models do not correlate.

The upper level comprises the elements, which are essential for the user or generator of diagnostic applications. The term "user" includes the driver, the legislator, the mechanic, and the manufacturer. This upper level can be subdivided into three main fields of activities: user

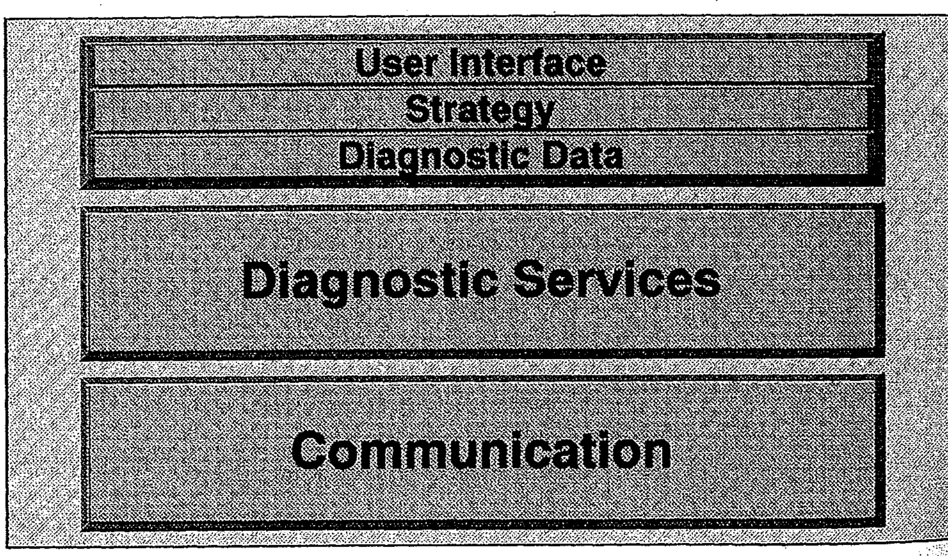


FIGURE 22.6 Model for diagnostic concept.

interface, strategy, and diagnostic data. Although presented as layers, these activities do not correlate hierarchically, but each is associated with a service or group of services.

The "user interface" describes how information flows between the user and the diagnostic service. This includes a functional description of scan tools, handheld testers, monitoring systems, and so on.

The term "strategies" stands for strategic details, which are essential for the diagnosis or repair of a vehicle, including communication access, diagnostic data and information.

The term "diagnostic data" includes the data that are necessary for the diagnosis itself. The details concerning parameters, trouble codes, and so on are described here.

The intermediate level describes the diagnostic services, defining a set of services and a set of commands for general purpose, which allow the diagnosis of a vehicle. The set of commands is supposed to cover the needs of users concerning repair and maintenance as described by the strategies and diagnostic data.

The lowest level deals with the communication area. It describes every technical detail that is necessary for communication and provides the information about how to start communication (initialization). It also specifies the appropriate Baud rate, the suitable protocol, and the necessary hardware (connector, cable, and so on).

This model offers a general description of the essential fields of diagnostic interest and allows the categorization of all ISO and SAE standardization activities in the three main levels of the diagnostic concept model.

Figures 22.7 and 22.8 are presented in the same graphic form (three-level structure). They provide a summary of the concrete standardization activities of the SAE and ISO. Figure 22.7 shows the existing standards or drafts of automotive diagnosis for general purpose.

The user interface for general purposes is undefined. The SAE J2186 (Data Link Security) and the SAE J2008 (Electronic Access/Service Information) are strategic documents, though most strategies are not standardized and diagnostic data is described in documents SAE J2012 (Diagnostic Codes and Messages) and SAE J2190-2 (Parameters—in preparation).

On the level of diagnostic services, the standardization activities can be divided in two fields called service definition and service implementation. The term "service definition" describes a set of useful diagnostic services, which enable the user to run a diagnostic session

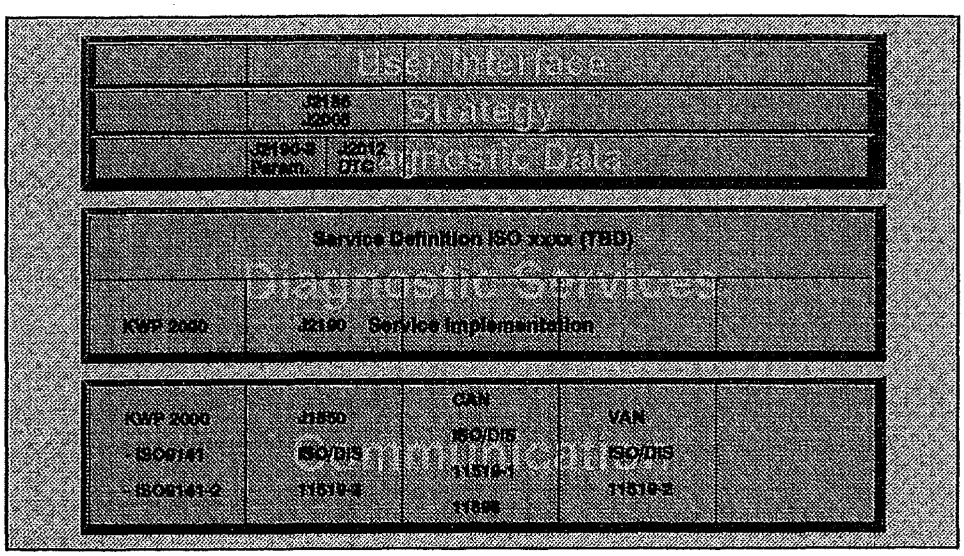


FIGURE 22.7 Realization for general automotive diagnosis.

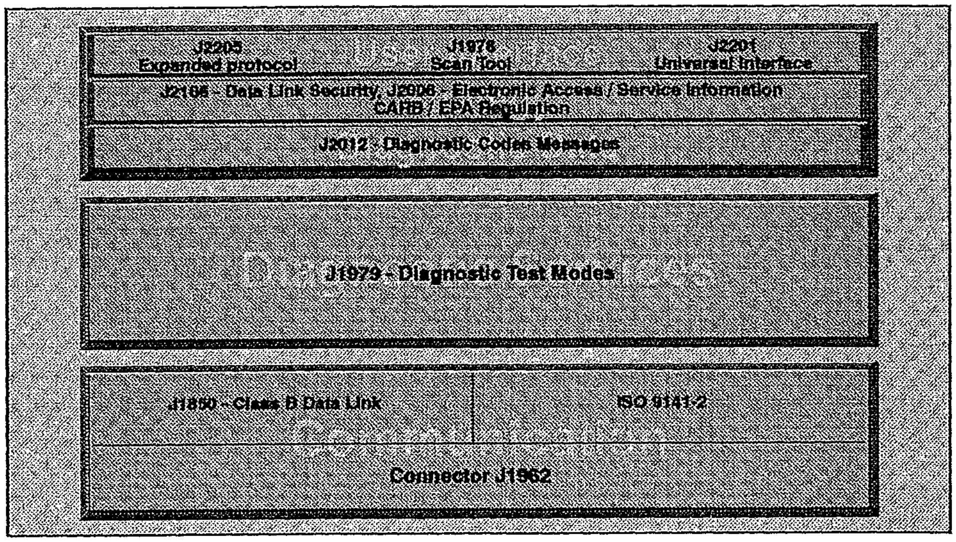


FIGURE 22.8 Realization for CARB and EPA requirements.

independently of the knowledge of any technical detail in the communication area as described in the level below.

This set of diagnostic services for general purpose can now be mapped on different protocols. Any bit representation of the different services can be built up. This is called service implementation. At the moment, there are two implementations available, the SAE J2190 (Diagnostic Test Modes) and the KWP 2000 (ISO Draft: Keyword Protocol 2000). The lowest level (the Communication level) shows the standardized details of communication such as the data formats and the physical layers; e.g., the KWP 2000 uses the physical layer of ISO 9141 or ISO 9141-2, the SAE J2190 uses the SAE J1850 Class B network (ISO/DIS 11519-3). It is shown that communication can also be built up with a CAN or a VAN network.

Figure 22.8 shows the standardization activities for the special requirements of the CARB and the EPA using the same three-level-concept.

The user interface, a generic scan tool, is standardized within the SAE J1978, including the SAE J2205 (Expanded Diagnostic Protocol) and the SAE J2201 (Universal Interface). Some aspects of the diagnostic strategy are described in the SAE J2186 (Data Link Security), the SAE J2008 (Electronic Access/Service Information), and some in the regulations. The diagnostic data is described in the document SAE J2012—Diagnostic Codes and Messages.

The level of diagnostic services defines one SAE J1979 standard—Diagnostic Test Modes. This standard is a closely linked combination of a service definition and a service implementation (referring to the SAE as "modes").

In the field of communication, the possible networks are described in the SAE J1850 (Class B Data Network) and the ISO 9141-2 (CARB Requirements for Interchange of Digital Information).

A standard for the physical connector (SAE J1962) has also been developed. Figure 22.9 shows the status of diagnostic standards for trucks and buses and for passenger cars in Europe and in the United States. It shows also a time schedule for the development of standards. A comparison of the communication and diagnostic services levels has already been realized. The titles of the different SAE and ISO numbers are shown in Tables 22.2 and 22.3, where all ISO and SAE papers, relevant for diagnostics, are listed. Table 22.3 offers a detailed list of trucks and bus activities (J1939).

	TRUCK AND BUS				CARS			
	Time →				Time →			
	ISO (Europe)	USA	ISO (Europe)	USA	ISO (Europe)	USA	ISO (Europe)	USA
Diagnostic Services	1)	SAE J1587 2)	ISO-TF1	SAE J1939 4) (J1587)	1)	1)	ISO-TF1	SAE J2190 J1979
Communication	ISO9141 3)	SAE J1708	KWP 2000 ISO9141	SAE J1939 4) (J1708)	ISO9141 3)	SAE J1850 ?	KWP 2000 + ISO9141 -CARB	SAE J1850 + ISO9141 -CARB

FIGURE 22.9 Status of diagnostic standards.

22.5 FUTURE DIAGNOSTIC CONCEPTS

As yet, most vehicle manufacturers have installed a diagnostic connector in the engine compartment in order to offer essential electric signals for diagnostic purposes. Due to the multitude of different equipments and philosophies of car makers, the connectors have different shapes and contact arrangements. Therefore, a workshop has to keep a lot of different expensive cables and adaptors in store.

For future diagnostic systems, the connection between control unit and vehicle is supposed to be realized with the help of a standardized connector. A connector for the legally demanded exhaust-gas diagnosis was defined by an SAE draft (J1962), concerning form, contact arrangement, and installation position. (Fig. 22.10)

With this connector and a so-called generic scan tool, anyone is able to read the fault-memory in regard to exhaust-gas-relevant defects. The interconnection of the control units allows the access to the entire electronics of the vehicle.

The necessary protocols are partly defined and developed further in standardization committees of the ISO. At the moment, there are two actual standards available:

1. *ISO 9141-2:* Determination of the requirements on hardware and communication protocols. The requirements on hardware are essentially determined by the maximum Baud rate of data transfer and the maximum number of control units simultaneously connected with the diagnostic cable.

   Communication is started by means of a trigger address, and is followed by a synchronization byte of the control unit(s), which is necessary for the automatic setting of the Baud rate. The trigger address calls either a particular control unit or a function, that may also address several control units.

   After transmission of the synchronization byte, the control unit waits for the tester to set the Baud rate, then sends two key-bytes that inform the tester about the suitable data transfer protocol. The tester responds with the last inverted key-byte, in order to confirm the correct receipt. The connection between tester and control unit is now established.

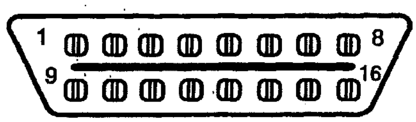
TABLE 22.2 ISO and SAE Documents

ISO 9141		Road Vehicles—Diagnostic System—Requirements for Interchange of Digital Information
ISO/DIS 9141-2		Road Vehicles—Diagnostic System—Part 2: CARB Requirements for Interchange of Digital Information
ISO/DIS 11519-1		Road Vehicles—Low-Speed Serial Data Communication—Part 1: General Definitions
ISO/DIS 11519-2		Road Vehicles—Low-Speed Serial Data Communication—Part 2: Low Speed Controller Area Network (CAN)
ISO/DIS 11519-3		Road Vehicles—Low-Speed Serial Data Communication—Part 3: Vehicle Area Network (VAN)
ISO/DIS 11519-4		Road Vehicles—Low-Speed Serial Data Communication—Part 4: Class B Data Communication Network Interface (J1850)
ISO/DIS 11898		Road Vehicles—Interchange of Digital Information—Controller Area Network (CAN) for High-Speed Communication
ISO/WD 14229		Diagnostic Systems—Diagnostic Services Specification
ISO/WD 14230		Diagnostic Systems—Keyword Protocol 2000 (3 parts: 1: Physical Layer, 2: Data Link Layer, 3: Implementation)
SAE J 1213/1	IR	Glossary of Vehicle Networks for Multiplexing and Data Communications
SAE J 1583	IR	Controller Area Network (CAN), An In-Vehicle Serial Communication Protocol
SAE J 1587	RP	Joint SAE/TMC Electronic Data Interchange Between Microcomputer Systems in Heavy-Duty Vehicle Applications
SAE J 1699	RP	J 1850 Verification Test Procedures
SAE J 1708	RP	Serial Data Communications Between Microcomputer Systems in Heavy-Duty Vehicle Application
SAE J 1724		Vehicle Electronic Identification (New Task Force)
SAE J 1850	RP	Class B Data Communication Network Interface
SAE J 1930	RP	Electrical/Electronic Systems Diagnostic Terms, Definitions, Abreviations and Acronyms
SAE J1939/xx		Truck + Bus, Details next page
SAE J 1962	RP	Diagnostic Connector
SAE J 1978	RP	OBD II Scan Tool
SAE J 1979	RP	E/E Diagnostic Test Modes
SAE J 2008	RP	Electronic Access/Service Information
SAE J 2012	RP	Diagnostic Trouble Code Definitions
SAE J 2037	IR	Off-Board Diagnostic Message Formats
SAE J 2054	IR	E/E Diagnostic Data Communications
SAE J 2056/1	RP	Class C Application Requirement Considerations (Part 2: IR: Survey of Known Protocols, Part 3: IR: Selection of Transmission Media)
SAE J 2057/1	IR	Class A Application/Definition (Part 3: IR: Class A Multiplexing Sensors, Part 4: IR: Class A Multiplexing Architecture Strategies)
SAE J 2106	IR	Token Slot Network for Automotive Control
SAE J 2112	IR	Diagnostic Technician Questionnaire Summary
SAE J 2178	RP	Class B Data Communication Network Messages (Part 1: Detailed Header Formats and Physical Address Assignments, Part 2: Data Parameter Definitions, Part 3: Frame Ids for Single Byte Forms of Headers, Part 4: Message Definition for Three Byte Headers)
SAE J 2186	RP	E/E Data Link Security
SAE J 2190	RP	Enhanced E/E Diagnostic Test Modes
SAE J 2201	RP	Universal Interface for OBD II Scan Tool
SAE J 2205	RP	Diagnostic Specific Functionality Protocol
SAE J 2216	RP	Application of the Clean Air Act Amendment of 1990 (Section 207, Paragraph M5)

RP = Recommended Practice, IR = Information Report

TABLE 22.3 SAE Truck and Bus Documents

SAE J 1939	RP	Serial Control and Communication Vehicle Network (Class C)
SAE J 1939/01		Truck and Bus Control and Communication Vehicle Network (Class C)
SAE J 1939/02		Agricultural Equipment Control and Communication Network
SAE J 1939/1x		Physical Layer, x refers to a specific version
SAE J 1939/11		Physical Layer, 250 kBaud, Twisted Shielded Pair
SAE J 1939/12		Physical Layer, 125 kBaud, Twisted Pair
SAE J 1939/13		Physical Layer, 250 kBaud, Twisted Pair with Ground
SAE J 1939/14		Physical Layer, 1 MBaud, Fiber Optic
SAE J 1939/15		Physical Layer, 50 kBaud, German Agricultural
SAE J 1939/21		CAN 29 Bit Identifier Data Link Layer
SAE J 1939/3x		Network Layer, x refers to a specific version
SAE J 1939/31		Truck + Bus Network Layer
SAE J 1939/4x		Transport Layer, x refers to a specific version
SAE J 1939/5x		Session Layer, x refers to a specific version
SAE J 1939/6x		Presentation Layer, x refers to a specific version
SAE J 1939/7x		Application Layer, x refers to a specific version
SAE J 1939/71		Truck, Bus, Agricultural and Construction Equipment Application Layer
SAE J 1939/72		Virtual Terminal
SAE J 1939/73		Application Layer—Diagnostics
SAE J 1939/81		Network Management
SAE J 1939/??		Tractor-Trailer-Interface



PIN #	Assignment
1	discretionary
2	BUS + Line of SAE J1850
3	discretionary
4	Chassis Ground
5	Signal Ground
6	discretionary
7	K Line of ISO 9141-2
8	discretionary
9	discretionary
10	BUS - Line of SAE J1850
11	discretionary
12	discretionary
13	discretionary
14	discretionary
15	L Line of ISO 9141-2
16	Unswitched Vehicle Battery Positive

Note: Assignment of pins 1, 3, 6, 8, 9, 11, 12, 13, and 14 is left to the discretion of the vehicle manufacturer

FIGURE 22.10 SAE J1962 diagnostic connector.

2. *Interface according to the SAE J1850 (Class B Data Communication Network Interface):* The SAE J1850 defines means and methods for serial data exchange for automotive application at the physical and data link layer of the OSI model. It is used for networked systems and for diagnostic purposes.

   Two implementations are characterized: pulse-width modulation (PWM) at 41.6 kbps transmitted on twisted pair wires, and variable pulse-width modulation (VPM) at 10.4 kbps, transmitted on a single wire.[12]

A generic scan tool, as mentioned, therefore, has to handle the three different interfaces.

A new protocol, *Keyword 2000,* is prepared by the ISO committees. It is supposed to combine the protocols that have been used up to now.

With the introduction of more and more diagnostic functions and networked systems in the vehicle, the functional structure will be modified (Fig. 22.11).

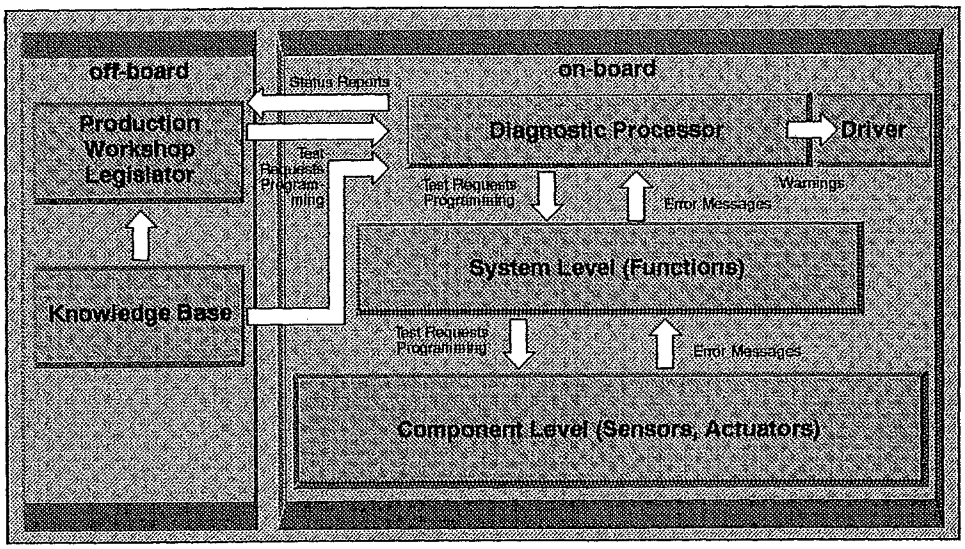


FIGURE 22.11 Logical structure for future diagnosis.

A diagnostic processor on top of a hierarchical structure of functions has access to every system via the network. It can request status information of the functions of the levels below, or of the sensors and actuators, and receives warning messages if problems are detected by the self-diagnosis of the different subsystems. The diagnostic processor serves as a man-machine interface to the driver and as a gate to the outside. It is the only secure access to the entire system of the vehicle.

GLOSSARY

CAN Controller Area Network (standardized protocol developed by Bosch for networked systems).

CARB California Air Resources Board.

CD-ROM Compact disk read only memory, a data storage medium.

DIS Draft International Standard.

ECU Electronic control unit.

EGR Exhaust-gas recirculation.

EPA Environmental Protection Agency.

Freeze frame Faults stored together with various related parameters.

HC Hydrocarbon.

ISO International Standardization Organization.

ISO 9141-2 Standardized protocol for data exchange between ECUs and testers.

Lambda controller Electronic system for controlling the air/fuel ratio.

Lambda sensor A sensor for air/fuel ratio (oxygen sensor).

MIL Malfunction indicator lamp (indicates emission-related faults to the driver).

OBDII On Board Diagnostics II.

Off-board diagnosis Diagnosis performed by means outside a vehicle.

On-board diagnosis Diagnosis performed by means within a vehicle.

OSI Open System Interconnection.

PC Personal computer.

PWM Pulse-width modulation.

RS 232 Standardized data link (hardware).

Scan tool Small tester that can be connected to the diagnostic connector to interrogate emission-related fault codes.

SAE Society of Automotive Engineers.

TDC Top dead center.

Terminal 1 Connection to a signal related to ignition timing.

VAN Vehicle Area Network (French proposal for network protocol).

VPM Variable pulse-width modulation.

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FRIEDER HEINTZ studied electrical communication techniques from 1954 to 1959 at the University of Karlsruhe. Afterwards he was engaged in research and development of process-control computers with Siemens AG in Karlsruhe, Munich, and New York. Since 1969, he has been the head of the advanced engineering department for measurement and information techniques at Robert Bosch GmbH. For 20 years, he has managed national and international working groups for diagnosis and serial data transfer in vehicles within the ISO (International Organization for Standardization).

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EXHIBIT 12

US005477452A

United States Patent [19]

Milunas et al.

[11] **Patent Number: 5,477,452**

[45] **Date of Patent: Dec. 19, 1995**

[54] **UPSHIFT INDICATOR FOR MANUAL TRANSMISSION**

[75] Inventors: **Rimas S. Milunas**, Rochester Hills; **William J. Bolander**, Clarkston, both of Mich.

[73] Assignee: **Saturn Corporation**, Troy, Mich.

[21] Appl. No.: **92,273**

[22] Filed: **Jul. 15, 1993**

[51] **Int. Cl.**[6] **F16H 61/00**; F16H 59/14; F16H 61/04

[52] **U.S. Cl.** **364/424.1**; 364/442; 364/424.01; 340/439; 340/441; 340/461; 340/870.13; 340/456; 477/120; 477/107; 73/117.3; 73/118.1; 74/DIG. 7; 434/71

[58] **Field of Search** .... 364/424.1, 426.01, 364/426.03, 442; 180/197; 73/117.3; 123/417, 416, 481, 351, 333; 74/866, 336 R, 856, 861; 340/439, 441, 461, 870.13, 456, 438, 466, DIG. 7; 434/71, 62, 64, 65, 63, 66, 67, 68, 69; 477/61, 120, 118, 905, 107

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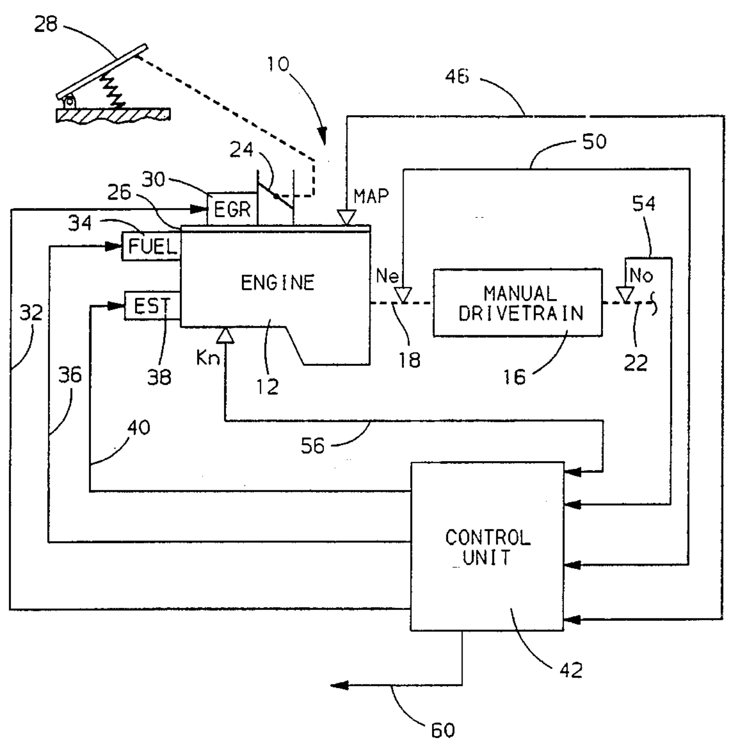
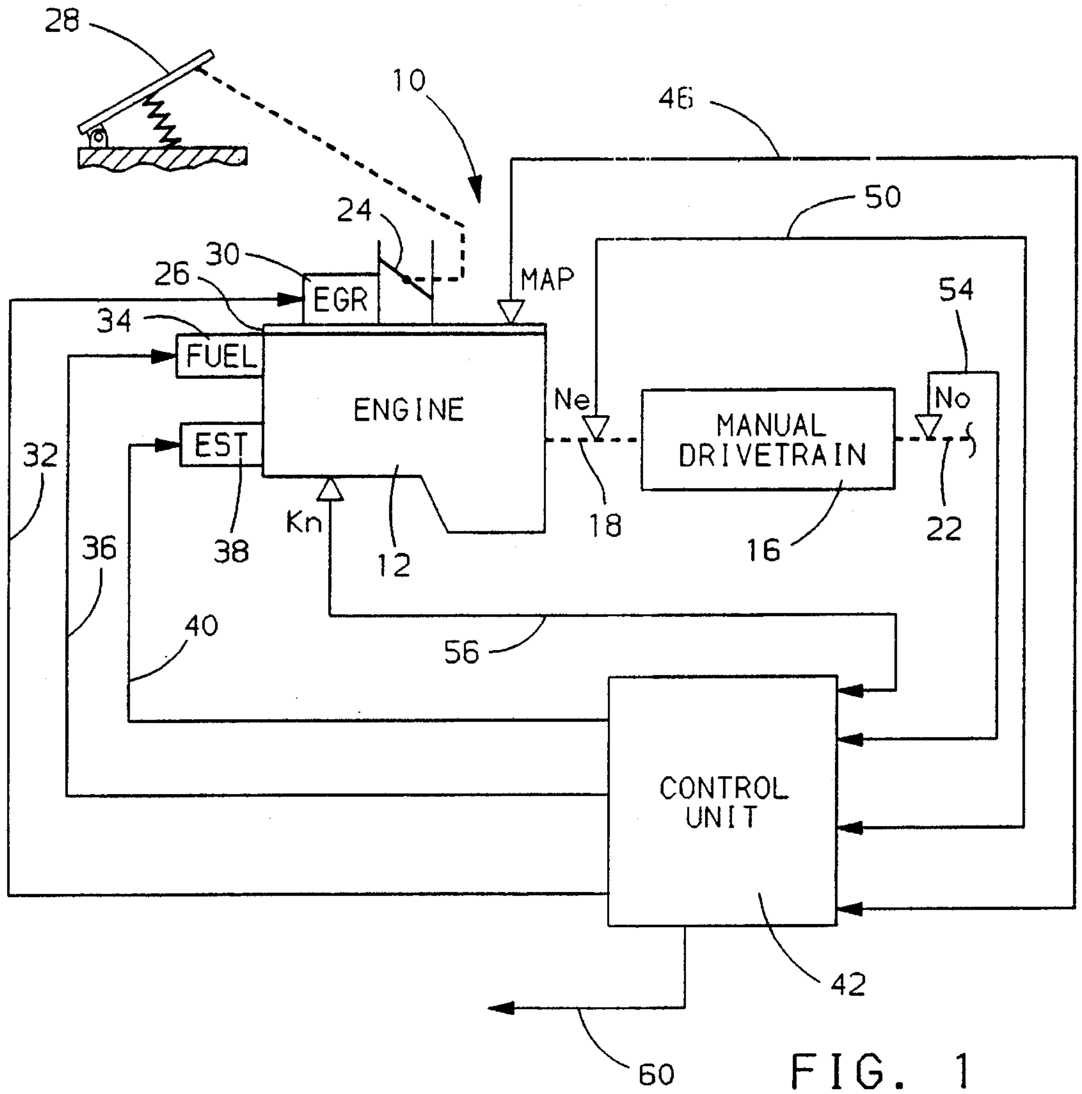
Assistant Examiner—Jacques H. Louis-Jacques
Attorney, Agent, or Firm—Vincent A. Cichosz

[57] **ABSTRACT**

A motor vehicle has a manual transmission and means for indicating to the operator a point in operation for upshifting to the next higher gear from the present gear. A method of determining the shift point is provided based upon actual operating parameters of the motor vehicle effecting current wheel torque and predicted wheel torque in the next higher gear. Calibration to a single value representing the ratio of predicted wheel torque to current wheel torque allows simple balancing between fuel economy and performance.

7 Claims, 5 Drawing Sheets

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10
46
50
24
30
26
EGR
MAP
54
34
FUEL
ENGINE
Ne
MANUAL
DRIVETRAIN
No
32
EST
Kn
18
16
22
36
38
12
40
56
CONTROL
UNIT
42
60

FIG. 1

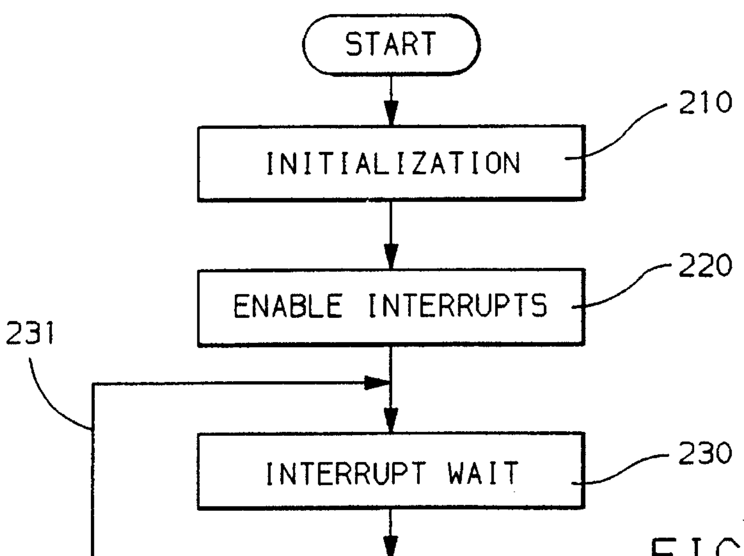

START
210
INITIALIZATION
220
ENABLE INTERRUPTS
231
INTERRUPT WAIT
230

FIG. 2

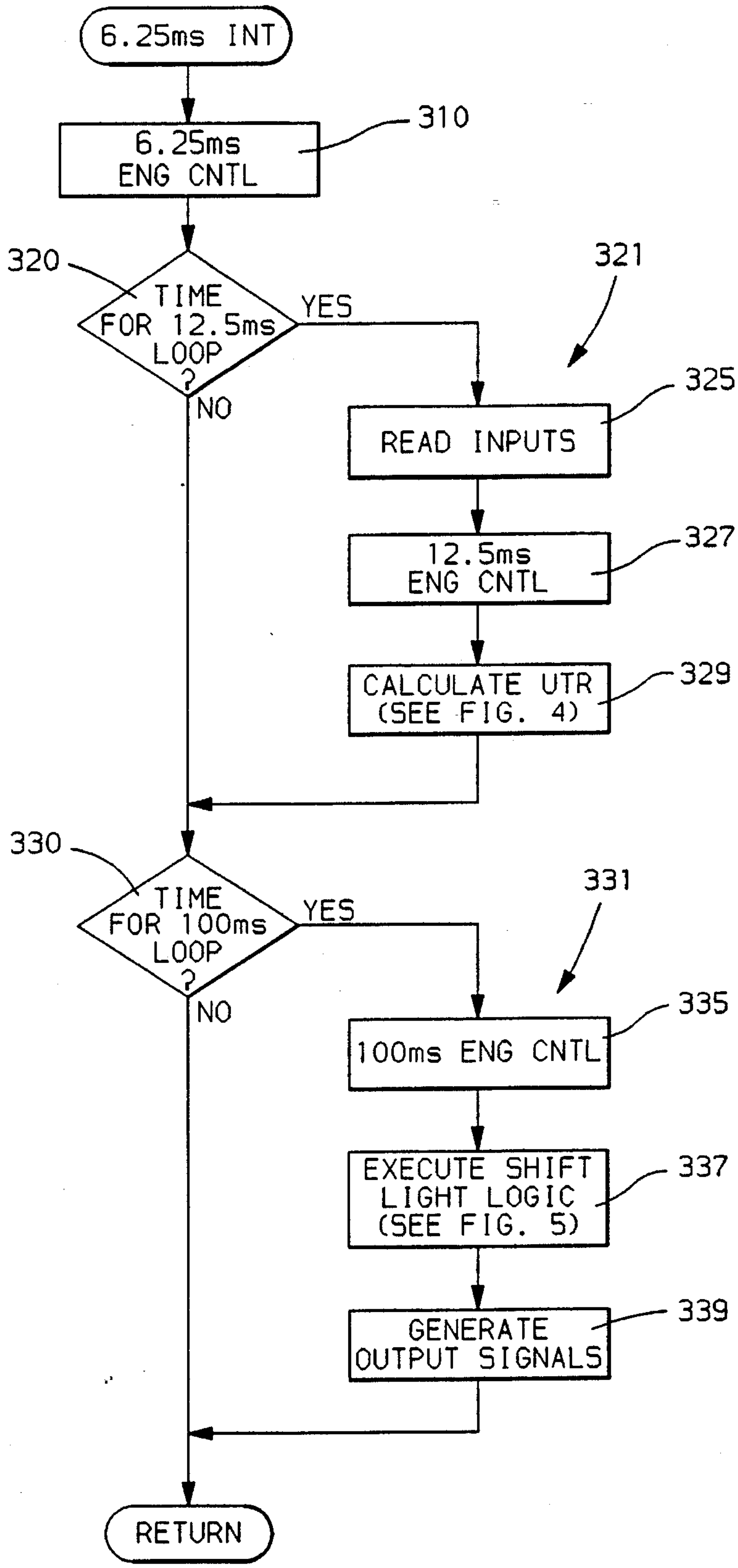
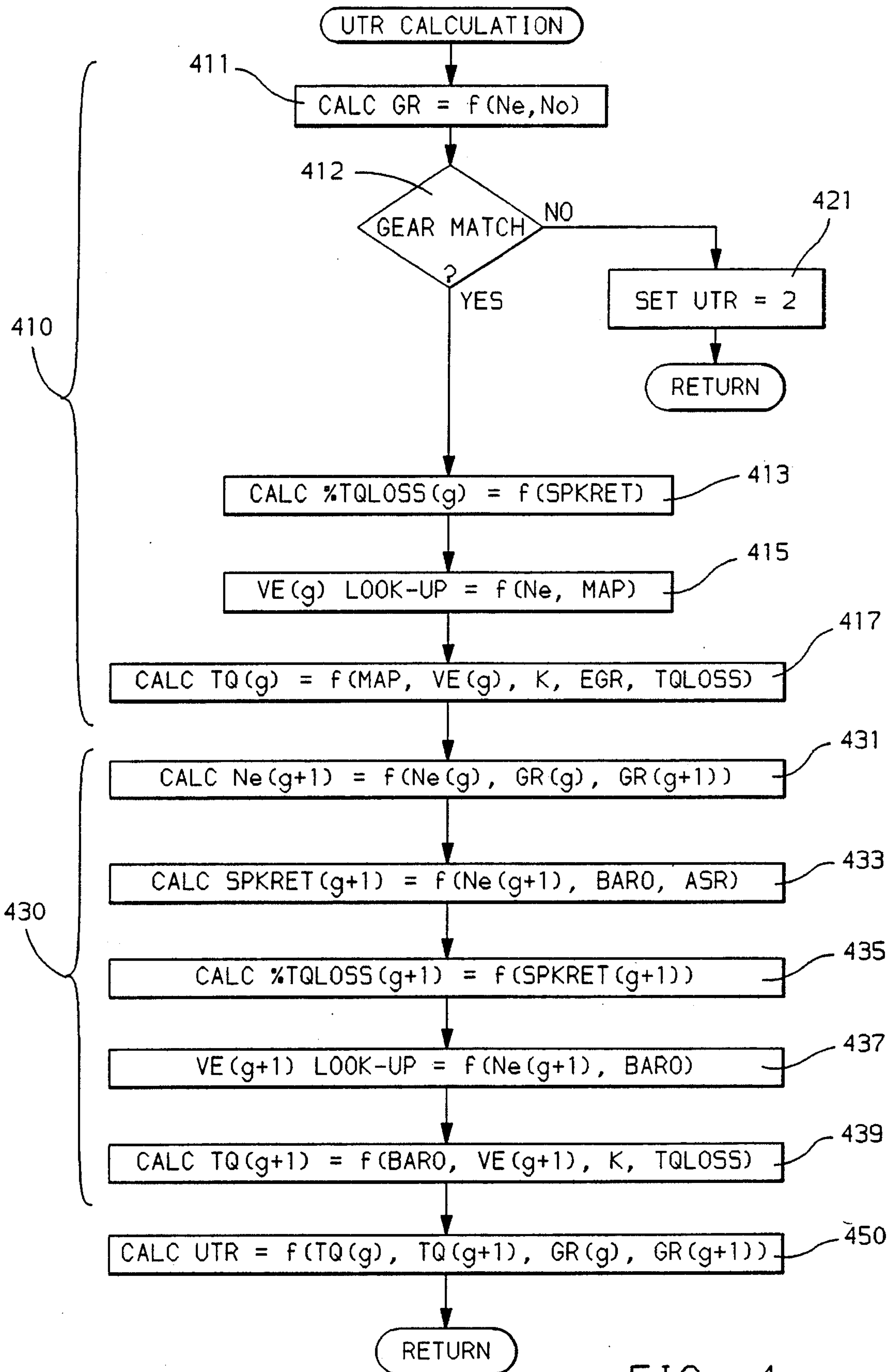

6.25ms INT
6.25ms ENG CNTL
310
320
TIME FOR 12.5ms LOOP ?
YES
NO
321
READ INPUTS
325
12.5ms ENG CNTL
327
CALCULATE UTR (SEE FIG. 4)
329
330
TIME FOR 100ms LOOP ?
YES
NO
331
100ms ENG CNTL
335
EXECUTE SHIFT LIGHT LOGIC (SEE FIG. 5)
337
GENERATE OUTPUT SIGNALS
339
RETURN

FIG. 3



UTR CALCULATION
411
CALC GR = f(Ne,No)
412
GEAR MATCH ?
NO
YES
421
SET UTR = 2
RETURN
410
CALC %TQLOSS(g) = f(SPKRET)
413
VE(g) LOOK-UP = f(Ne, MAP)
415
CALC TQ(g) = f(MAP, VE(g), K, EGR, TQLOSS)
417
CALC Ne(g+1) = f(Ne(g), GR(g), GR(g+1))
431
CALC SPKRET(g+1) = f(Ne(g+1), BARO, ASR)
433
430
CALC %TQLOSS(g+1) = f(SPKRET(g+1))
435
VE(g+1) LOOK-UP = f(Ne(g+1), BARO)
437
CALC TQ(g+1) = f(BARO, VE(g+1), K, TQLOSS)
439
CALC UTR = f(TQ(g), TQ(g+1), GR(g), GR(g+1))
450
RETURN

FIG. 4

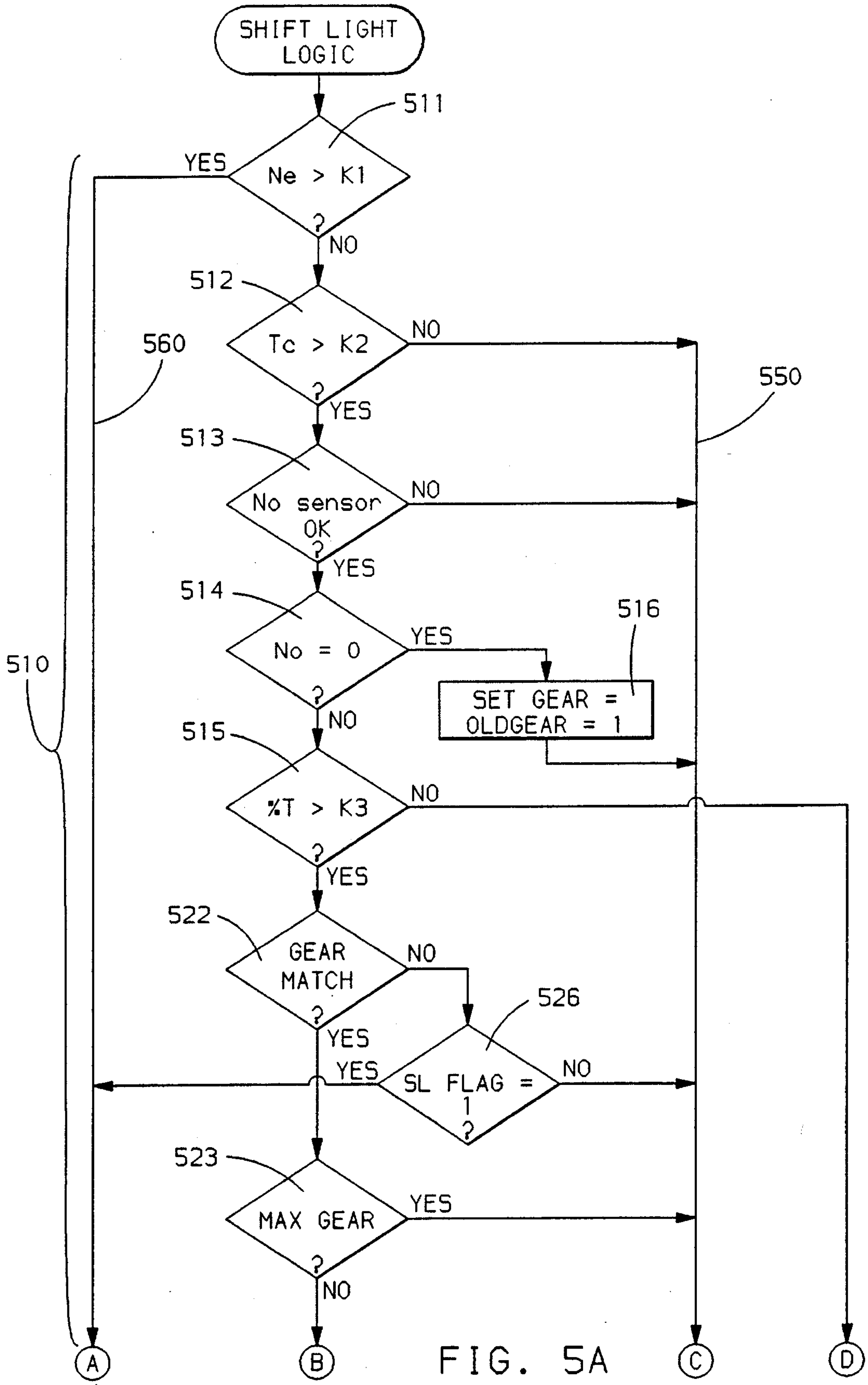

SHIFT LIGHT LOGIC
511
Ne > K1 ?
YES
NO
512
Tc > K2 ?
NO
YES
560
550
513
No sensor OK ?
NO
YES
514
No = 0 ?
YES
516
SET GEAR = OLDGEAR = 1
NO
510
515
%T > K3 ?
NO
YES
522
GEAR MATCH ?
NO
526
YES
YES
SL FLAG = 1 ?
NO
523
MAX GEAR ?
YES
NO
A
B
C
D

FIG. 5A

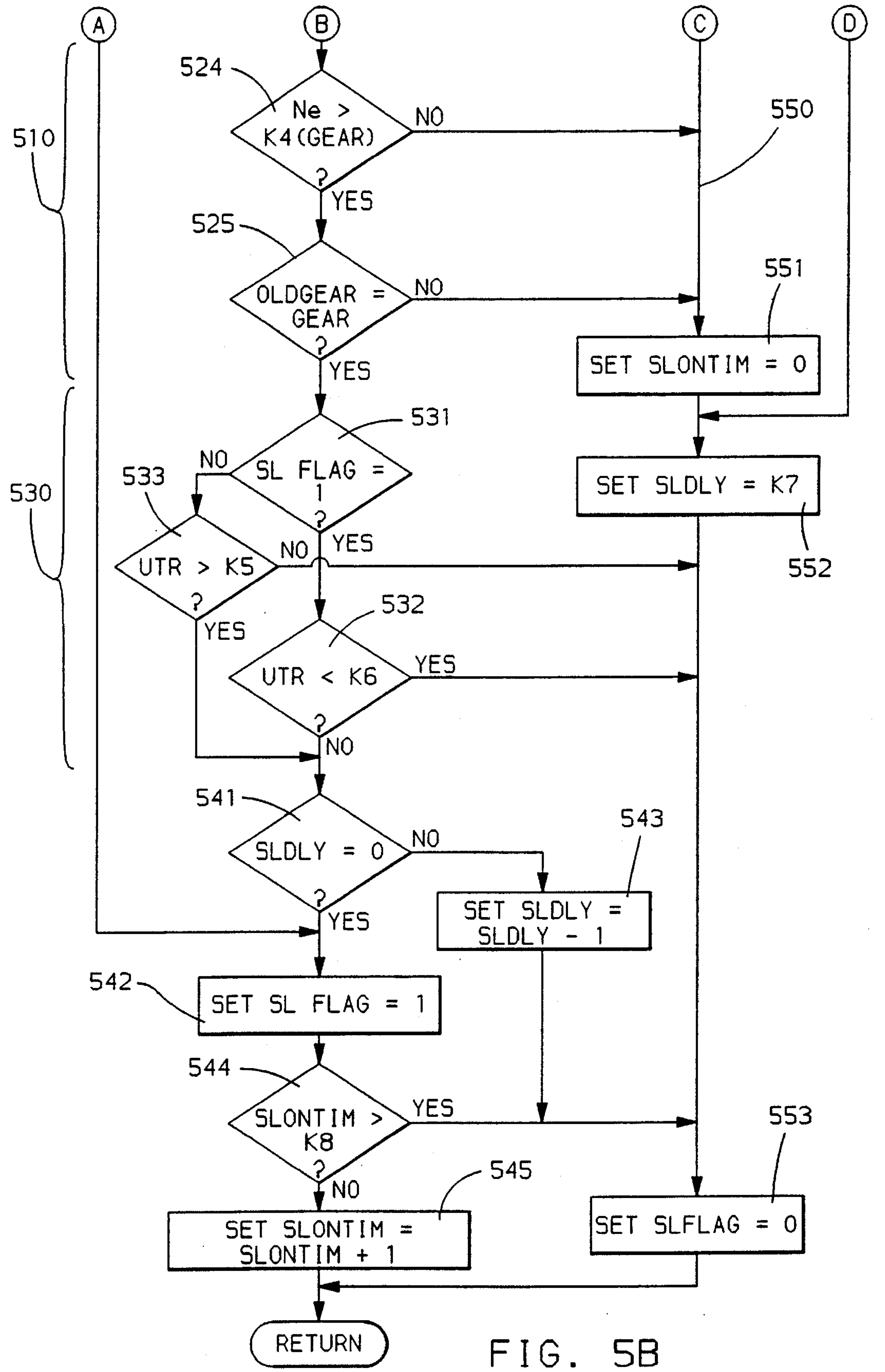

A
B
C
D
510
524
Ne > K4(GEAR) ?
NO
550
YES
525
OLDGEAR = GEAR ?
NO
551
YES
SET SLONTIM = 0
531
530
533
NO
SL FLAG = 1 ?
SET SLDLY = K7
UTR > K5 ?
NO
YES
552
YES
532
UTR < K6 ?
YES
NO
541
543
SLDLY = 0 ?
NO
SET SLDLY = SLDLY - 1
YES
542
SET SL FLAG = 1
544
SLONTIM > K8 ?
YES
553
NO
545
SET SLONTIM = SLONTIM + 1
SET SLFLAG = 0
RETURN

FIG. 5B

UPSHIFT INDICATOR FOR MANUAL TRANSMISSION

This invention relates to a shift indicator for a manual transmission automobile designed to induce the operator to shift at predetermined points.

BACKGROUND OF THE INVENTION

Shift indicators are commonly used on manual transmission vehicles to assist non-expert drivers in determining when it is appropriate to shift the transmission to a higher gear in order to maximize driving fuel economy. A system calibrated such that absolute maximum fuel economy would be obtained if a shift occurs at the point indicated by a shift indicator may exhibit a noticeable sag in axle torque at the shift and therefore result in an unpleasant shift feel to the operator. In such situations, operators quickly learn to ignore the shift indicator thus rendering it ineffective for its intended purpose of maximizing fuel economy. Fuel economy figures required to be displayed on new vehicles for sale in the United States are arrived at through a customer usage weighting of the fuel economy obtained on vehicles tested using the upshift indicator light and fuel economy obtained without using the upshift indicator light. It is therefore desirable to balance the pleasability of the shift at the point indicated by the shift indicator with the fuel economy benefits at that shift point since this will tend to result in higher customer usage, higher actual fuel economy and higher fuel efficiency ratings for a particular vehicle.

Conventional shift indicator calibration typically involves setting manifold absolute pressure (MAP) thresholds at a variety of speeds. Such a method can be time consuming and result in non-optimal shift points. Additionally, as actual engine torque changes due to spark retardation for control of engine knock as may be practiced in the engine control, the calibrated shift points based on MAP thresholds may no longer be appropriate, thereby exacerbating the aforementioned axle torque sag thus leading to operator disregard of the shift indicator and reduced fuel economy.

SUMMARY OF THE INVENTION

An objective of the present invention is therefore directed toward an improved method of determining shift points and indicating the same to a vehicle operator in order to maximize real driving fuel economy by balancing fuel economy with maximum shift pleasability.

Another object of the invention is to adapt shift indication for actual engine torque conditions.

A further object is to simplify the calibration of shift indicator systems and allow for flexible indexing of the system according to desired fuel economy versus performance profiles.

The control of the present invention calculates a term referred to as Upshift Torque Ratio (UTR) which represents the ratio of predicted wheel torque in the next highest gear to present wheel torque in the current gear. The UTR is compared to a predetermined calibration threshold value to determine if upshift indication is appropriate. The calibration threshold determines the characteristics and balance of the shift in terms of fuel economy and performance. A threshold value close to unity provides a shift point which will achieve maximum fuel economy, while a threshold value higher than unity will provide for increased performance shifting.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** shows a motor vehicle manual transmission drivetrain, spark ignition internal combustion engine and computer based engine control unit.

FIGS. **2–4**, **5**A and **5**B are flow diagrams representative of computer program instructions executed by the computer based engine control unit of FIG. **1** in carrying out the control of this invention.

DETAILED DESCRIPTION OF THE DRAWINGS

Referring to FIG. **1**, the reference numeral **10** generally designates a motor vehicle drivetrain comprising a spark ignition internal combustion engine (engine) **12**, engine output shaft **18** and the combination of conventional manual clutch, gearbox and final drive assembly (manual drivetrain) **16**. Output shaft **22** drives the vehicle wheels (not shown) for propelling the vehicle at a speed directly proportional to its rotation.

A throttle **24** controls the ingestion of combustion air through the engine intake manifold designated by the numeral **26**. Throttle **24** is positioned in a conventional manner by an operator-manipulated accelerator pedal **28**, as indicated. An exhaust gas recirculation (EGR) actuator **30** additionally returns a controlled amount of exhaust gases to the manifold **26** in accordance with an EGR control signal on line **32**. Engine fueling is controlled by a conventional fuel injection apparatus generally designated by the reference numeral **34** in accordance with a fuel pulse width signal on line **36**.

The engine ignition function is carried out with a conventional spark ignition system (not shown) which cooperates with a conventional electronic spark timing (EST) unit **38** to initiate combustion in the various engine cylinders in accordance with a spark timing signal on line **40**. Spark timing signals are generated by computer based engine control unit **42** in a predetermined manner in accordance with various operating parameters (including sensed engine knock) of the drivetrain **10** in a manner well known to those skilled in the art. Control unit **42** receives inputs required by the present embodiment including manifold absolute pressure (MAP) on line **46**, engine speed (Ne) on line **50** and output speed (No) on line **54**. Knock sensing means Kn are also shown providing signal input via line **56** to control unit **42**. Control unit **42** indicates via line **60** the state of an upshift indicator light or equivalent visual display such as is found in conventional instrumentation in a motor vehicle. Line **60** may provide a logic signal to a instrument cluster for further processing or may drive a lamp directly via a power driver in control unit **42**. Control unit **42** may be mechanized with a conventional state of the art microcomputer controller including a central processing unit, memory and input-output devices.

FIGS. **2–4**, **5**A ad **5**B depict flow diagrams representative of computer program instructions executed by the computer based engine control unit **42** of FIG. **1** in carrying out the upshift indication function of this invention. The flow diagram of FIG. **2** represents an executive or main loop program which initiates the operation of a number of subroutines for performing various engine control related tasks. The flow diagrams of FIGS. **3–5** represent the subroutines which are pertinent to the upshift indication function of this invention.

Referring now more particularly to the main loop flow diagram of FIG. **2**, reference numeral **210** generally designates a set of program instructions executed at the beginning of each period of vehicle operation. The instructions initialize various registers, timers, flags and variables stored in control unit **42**. After initialization at **210**, the routine proceeds to instruction block **220** and enables all software timer and hardware interrupts for executing subroutines to carry out various engine control functions. Step **230** is next encountered and represents an interrupt wait loop together with return line **231** wherein the control performs various conventional background functions such as engine diagnostic routines and reading and conditioning oxygen sensor inputs while awaiting a timer or hardware interrupt to call subroutines for performing various specific engine control functions according to predetermined schedules or triggering events.

In the present preferred embodiment, a timer interrupt (6.25 INT) occurs at 6.25 millisecond intervals and causes the execution of the program steps shown in FIG. **3**. Instruction block **310** is first executed for performing various predetermined engine control functions appropriate for the frequency of the 6.25 ms interval. Decision block **320** is next executed to determine if a set of less frequently executed instructions generally designated by numeral **321** is to be executed. This may be caused to occur, for example, by well known and practiced techniques such as the expiration of a timer, requisite multiple passes through the 6.25 ms INT routine or separate timer interrupt having priority to execute and return control to the current 6.25 ms INT routine. Decision block **320** indicates an exemplary frequency for execution of instruction set **321** of every 12.5 ms which in the present embodiment is caused to occur every second pass through the 6.25 ms interrupt. If it is not time for execution of instruction set **321**, control passes to decision block **330**. Assuming it is time for execution of instruction set **321**, control unit **42** at instruction block **325** reads and conditions the various input signals applied to lines **46**–**56**, and calculates various terms used in subsequent steps, including spark retard, barometric pressure (BARO) and percent exhaust gas recirculation (%EGR). Instruction block **327** next performs various predetermined engine control functions appropriate for the frequency of the 12.5 ms interval. Block **329** refers to the computation of the Upshift Torque Ratio (UTR) which is set forth in detail in the flow diagram of FIG. **4** as shown.

Decision block **330** is next executed to determine if a set of even less frequently executed instructions generally designated by numeral **331** is to be executed. This may be caused to occur in any appropriate manner similar to those discussed for decision block **320** as are well known and practiced in the art. Decision block **330** indicates a frequency for execution of instruction set **331** of every 100 ms. If it is not time for execution of instruction set **331**, the 6.25 ms interrupt routine is complete and control returns to the background routine of FIG. **2**. Assuming it is time for execution of instruction set **331**, control unit **42** at instruction block **335** perform various predetermined engine control functions appropriate for the frequency of the 100 ms interval. Block **337** refers to the execution of the shift light logic routine which is set forth in detail in the flow diagrams of FIGS. **5**A and **5**B as indicated. Finally, control unit **42** outputs a signal online **60** shown in FIG. **1** for indicating the state of the upshift indicator light as well as various other output signals for instrument cluster displays such as vehicle speedometer, oil pressure and coolant temperature for example.

Referring now to FIG. **4**, a preferred routine for calculating the Upshift Torque Ratio (UTR CALCULATION) for use in upshift indication according to the present invention is illustrated. The parenthetical designations (g) and (g+1) where appended to variables as used herein designate current gear and next highest gear values, respectively. Where no parenthetical designations are used, current values are referenced. A set of steps generally designated by numeral **410** is first executed to determine a current value of engine torque. Upon entry of UTR CALCULATION, Block **411** calculates the current gear ratio "GR(g)" from current engine speed "Ne(g)" and output speed "No" according to the following expression:

$$GR(g)=Ne(g)/No$$

A check is made at decision block **412** to determine if the calculated gear ratio matches a known gear ratio and, if no match is recognized, passes processing to block **421** which sets upshift torque ratio (UTR) to a default value of two in the present embodiment and then exits the UTR CALCULATION routine. THE DEFAULT VALUE IS essentially a "don't care" value that won't be used for further processing as will be seen in later discussion of FIG. **5**A, decision block **522**. GR(g) will match a given gear provided the manual clutch is engaged and slip thereacross is minimal. Where the clutch is disengaged, as may be the case where the operator has initiated a shift, a gear match may not occur. If the gear ratio matches a known gear, block **413** calculates the percent torque loss "%TQLOSS" in the current gear due to the current amount spark retard. The present embodiment assumes spark retard is a controlled engine parameter used, for example, to control engine knock in a manner known in the art. Spark retard is preferably accounted for in this embodiment since it may have a significant effect on engine torque, especially at low and moderate engine speeds where both the incidence of engine knock is most prevalent and more fuel efficient upshifting will typically occur. The percent torque loss is determined through application of the expression:

$$\%TQLOSS(g)=SPKRET(g)/SPKRET(100\%\ tqloss)$$

where SPKRET(g) is the current amount of spark retard and SPKRET(100% tqloss)is the amount of spark retard needed for 100% torque loss. Spark retard may be determined from empirically determined calibration tables. Spark retard may be a value adaptively derived as shown, for example, in U.S. Pat. No. 5,090,382 issued Feb. 25, 1992 and assigned to Saturn Corporation.

Engine volumetric efficiency "VE(g)" is next referenced from a calibration table a function of engine speed Ne(g) and MAP at block **415**. Current engine torque "TQ(g)" is then determined at block **417** according to the expression:

$$TQ(g)=[(MAP(g)*VE(g)*K)*(EGR(g))-Tf]*(TQLOSS)$$

where K is a calibration constant predetermined during fuel metering and related to actual engine displacement, operating temperature, combustion efficiency, fuel/air energy content and the universal gas constant; EGR(g) is a gain substantially corresponding to the complement of current percent exhaust gas recirculation (1−%EGR); Tf is a torque offset related to engine mechanical friction at current engine speed and the term TQLOSS represents a gain substantially corresponding to the complement of the percent torque loss attributed to the current spark retard (1−%TQLOSS(g)).

A set of steps generally designated by the numeral **430** is next executed for the purpose of calculating a predicted value of engine torque available in the next higher gear at the current output speed. Preferably, the predicted torque value corresponds to a maximum available torque (wide open throttle) in the next higher gear which simplifies the associated predicted torque calculation. The present embodiment exemplifies calculation of a predicted maximum engine torque.

Block **431** first calculates a predicted engine speed in the next higher gear Ne(g+1) based on current engine speed Ne(g), the current gear ratio GR(g) and the gear ratio in the next higher gear GR(g+1). It is an assumption at this step that output speeds at current and next higher gears No(g), No(g+1) would be substantially equivalent and therefore predicted engine speed is a simple function of the current engine speed, current gear ratio and next higher gear ratio in accordance with the following relationship:

$$Ne(g+1)=Ne(g)*GR(g+1)/GR(g)$$

Predicted spark retard in the next higher gear SPKRET(g+1) is calculated at block **433** from predicted engine speed Ne(g+1), BARO and any amount of adaptive spark retard (ASR) such as may be appropriately applied according to, for example, previously reference U.S. Pat. No. 5,090,382. Since the maximum engine torque available in the next higher gear is being determined, BARO is preferably used in lieu of a predicted value of MAP since BARO substantially represents a maximum torque condition. Alternatively, a predicted value for MAP could be used.

Predicted percent torque loss in the next higher gear "%TQLOSS(g+1)" due to predicted spark retard is calculated at block **435** according to the following relationship in a manner similar to that provided at step **413**:

$$\%TQLOSS(g+1)=SPKRET(g+1)/SPKRET(100\%\ tqloss)$$

where SPKRET(g+1) is the predicted amount of spark retard (including any amount of adaptive spark retard) as calculated at block **433** and SPKRET(100% tqloss) is the amount of spark retard needed for 100% torque loss.

Block **437** next references predicted volumetric efficiency "VE(g+1)" in the next higher gear as a function of predicted engine speed Ne(g+1) and BARO. Again, BARO is utilized in lieu of a predicted MAP value since maximum engine torque conditions are assumed. The final step in the set designated **430** for calculating predicted engine torque in the next higher gear is designated **439** and calculates predicted engine torque "TQ(g+1)" according to the expression:

$$TQ(g+1)=[BARO*VE(g+1)*K)-Tf]*(TQLOSS)$$

where K is the calibration constant previously disclosed with regard to block **417**; Tf is the torque offset related to engine mechanical friction at the predicted engine speed Ne(g+1) and the term TQLOSS represents a gain substantially corresponding to the complement of the percent torque loss attributed to the predicted spark retard (1−%TQLOSS(g+1)). It is here noted that BARO again is used in lieu of MAP in the preceding expression. Consistent with the assumption of maximum engine torque (wide open throttle), the percent exhaust gas recirculation becomes zero in the present embodiment. The gain attributed zero %EGR is therefore unity in the present embodiment thereby accounting for the absence of an explicit EGR gain term in the expression of the predicted engine torque.

Finally, block **450** establishes the current and predicted wheel torques as the product of respective engine torques and corresponding gear ratios, and establishes the ratio of predicted wheel torque to current wheel torque to establish the UTR in accordance with the expression:

$$UTR=(TQ(g+1)*GR(g+1))/(TQ(g)*GR(g))$$

In the present embodiment, of course, the UTR represents the ratio of maximum predicted wheel torque to current wheel torque. Thereafter, program control returns to decision block **330** illustrated in FIG. **3**.

The UTR calculated provides a single dynamic parameter derived from continually updated inputs having measurable impact upon the wheel torque available in the current gear and from predicted wheel torque available in the next higher gear. Preferably, as illustrated in the present embodiment, dynamic torque reducing influences such as exhaust gas recirculation control and spark retard for engine knock control are factored into the torque calculations to provide for finely tuned torque estimations responsive to dynamic driving conditions. It is contemplated that other factors influencing engine torque, for example fuel composition in variable fuel vehicles, may likewise be factored into the expressions where appropriate.

A measure of the ratio of predicted wheel torque in the next higher gear to current wheel torque in the present gear (UTR) provides information for control of an upshift indicator in a manner less complicated and more accurately representative of dynamic driving conditions than conventional MAP threshold techniques. Additionally, the present invention utilizing UTR is suitable for customizing shift point indications according to any desired fuel economy/performance profile. When the UTR is less than one, the vehicle will decelerate and possibly exhibit undesirable driveline disturbance if an upshift is completed. With a UTR substantially equal to one, the operator may need to increase the throttle position in the next higher gear to maintain speed. Moreover, a UTR near one indicates an upshift point which will yield maximum fuel economy. As the UTR increases beyond one, more performance oriented shifts to the next higher gear are possible. Therefore, a calibration threshold against which the UTR is compared will determine the operation of an upshift indicator and corresponding shift feel and economy at that indicated shift point. The calibration threshold can readily be chosen to match the desired fuel economy/performance profile of the vehicle. The calibration may be so chosen to maximize actual fuel economy by indicating that an upshift is appropriate at a point where the pleasability of the shift yields high operator usage at relatively high levels of fuel economy.

Turning to FIG. **5**, and exemplary flow chart is illustrated for utilizing the UTR previously calculated for upshift indication according to the invention. The SHIFT LIGHT LOGIC routine of FIGS. **5A** and **5B** is executed at step **337** of the 6.25 ms interrupt routine set forth in FIG. **3** and comprises a set of entry condition steps (blocks **511** through **525**) designated generally by numeral **510** and a set of shift threshold steps (**531** through **533**) designated generally by numeral **530**. The purpose of the SHIFT LIGHT LOGIC routine is to establish the state of the shift light flag "SL FLAG" which in turn controls the state of the shift light. First, engine speed Ne is checked at block **511** to determine if it exceeds a predetermined maximum allowable engine speed threshold K1. If the threshold is exceeded then an upshift is required regardless of the value of UTR and control is therefore passed via line **560** to block **542** where the shift light flag is set to one (SL FLAG=1). If the threshold at block **511** is not exceeded, decision block **512** is encountered.

Decision block **512** performs a check of coolant temperature against a predetermined threshold K2. Where the threshold is not exceeded, the engine has not attained a predetermined operating temperature and control passes to line **550** to bypass shift threshold steps **530**. Where the coolant temperature threshold is satisfied, decision block **513** is next executed.

Decision block **513** determines if the output speed sensor is operational. If the speed sensor is not operational, control passes to line **550** to bypass shift threshold steps **530**. An operational output speed sensor allows control to pass to decision block **514** where a check is performed to determine if the vehicle is at a standstill (No=0). Where the vehicle is at rest, block **516** sets GEAR and OLDGEAR to the lowest gear value of 1 representing first or starting gear; thereafter, bypass of shift threshold steps **530** occurs via line **550**. If the vehicle is not at rest, decision block **515** is next encountered.

Throttle position "%T" is checked at block **515** against a closed position threshold K3. Closed throttle is indicative of vehicle coast, a state of operation wherein the engine is not imparting torque to the drive wheels and thus does not necessitate an upshift. Closed throttle may also be indicative of the operator purposefully using the drivetrain to decelerate the vehicle. Therefore, where a closed throttle is detected, control bypasses the upshift threshold steps **530** and proceeds with execution of block **552**. A non-closed-throttle position is indicative of the engine imparting torque to the drive wheels—operation which may benefit from a gear upshift—and therefore control remains in the entry condition steps **510** by executing block **522**.

A check is performed at block **522** to determine if the current calculated gear ratio GR(g) matches a known gear ratio associated with a GEAR value (i.e. 1–5). As mentioned in connection with step **412** in FIG. **4**, an already initiated shift may account for a no gear match condition. If no match occurs control passes to decision block **526** thereby bypassing the remaining entry condition steps **510** and any shift threshold steps **530**. Block **526** decides if the shift light is active by checking SL FLAG and if so passes control to line **560** to maintain the current SL FLAG state as one. Where block **526** decides that the shift light is inactive, control passes to line **550** to likewise maintain the current SL FLAG state as zero. Therefore, a no gear match condition maintains the current state of SL FLAG and bypasses processing of shift threshold steps **530**. A gear match at block **522** passes control to decision block **523**.

The current matched gear is checked at block **523** to determine if it is the highest gear available in which case no upshift is possible. If GEAR is equal to the highest gear available then upshift threshold steps **530** are bypassed via line **550**. If higher gears are available then processing continues at step **524** with a check if the engine speed Ne exceeds a predetermined threshold speed K4(GEAR) which is a function of the current gear and represents a minimum engine speed appropriate for upshift to the next gear. Where the threshold engine speed is not exceeded, upshift threshold steps **530** are bypassed via line **550**. Where the threshold engine speed has been satisfied, a final entry condition step is performed at block **525** to determine if the current gear status is steady state. If the current gear does not equal the last gear (GEAR≠OLDGEAR), then a steady state condition is not present and line **550** is once again used to bypass execution of the upshift threshold steps **530**. A steady state wherein the last known gear equals the current gear allows processing to pass into the upshift threshold steps **530**.

With the exception of throttle entry condition at block **515**, any failed decision block in the entry condition steps **510** routes processing to block **551** which initializes a shift light on counter "SLONTIM". Block **552** is thereby next encountered and initializes a shift light delay counter "SLDLY" to a predetermined threshold value K7. Block **552** is alternatively encountered as a first step after failed throttle entry condition at block **515** thereby bypassing block **551** and corresponding reset on SLONTIM thereat. This is done for the purpose of preventing continual resetting the timer and cycling of the shift light during closed throttle engine braking on a downhill grade and also for preventing resetting of the timer if closed throttle is momentarily encountered. The exact purpose and usage of SLONTIM and SLDLY will be explained at a later point. Finally, it follows that since an entry condition was not satisfied in steps **510**, the shift light flag is set to zero (SL FLAG=0) to thus establish the shift light state as OFF.

Upshift threshold steps **530** are accessed at decision block **531** whereat a determination as to the shift light state is made according to the status of SL FLAG. If the shift light is off (SL FLAG=0) then the routine branches to the left and executes block **533**. Block **533** compares UTR to a first predetermined torque ratio threshold K5 which if not exceeded causes execution of block **553** thereby maintaining the shift light flag at a value of zero. If the result of decision block **533** is that UTR exceeds the threshold K5, then processing passes to block **541**. Returning to block **531**, if the shift light is on (SL FLAG=1) then block **532** is executed to compare UTR to a second predetermined torque ratio threshold K6. In the case where UTR is less than the threshold K6, then block **553** is executed and sets the shift light flag to zero. Alternatively, where UTR equals or exceeds the threshold K6, decision block **541** is executed. The preceding steps of upshift threshold steps **530** comprise separate checks of UTR against one of two torque ratio thresholds K5 or K6 wherein K5>K6, the threshold check being determined according to the state of the SL FLAG. A degree of hysteresis is thereby introduced to stabilize the state of the SL FLAG and corresponding shift light state.

Decision block **541** is executed from either block **533** or **532** when it is appropriate according to the predetermined torque thresholds for the SL FLAG to be set to one (SL FLAG=1). Block **541** checks shift light delay counter SLDLY for expiration, thereby introducing a delay into the routine prior to setting the SL FLAG at block **542** according to a predetermined number of passes through upshift threshold steps **530** and on to block **541** without intervening failure at any preceding entry condition step **511** though **525** to minimize shift light busyness. Where the shift light delay counter has not expired, it is decremented at block **543** and passes control to block **553** thus setting the shift light flag to zero (SL FLAG=0). An expired shift light delay counter as determined at block **541** causes processing to proceed to block **542** where the shift light flag is set to one (SL FLAG=1). Thereafter execution of block **542**, decision block **544** is encountered and checks if the shift light on counter SLONTIM exceeds a predetermined threshold K8. Where the threshold K8 is exceeded, the shift light flag is set to zero at block **553** thereby limiting the indicator light on time to prevent any annoyance continual illumination may cause to operators who choose to ignore it. Where the threshold K8 has not been exceeded, the shift light on counter SLONTIM is incremented at block **545**.

When SHIFT LIGHT LOGIC routine shown in FIG. **5** returns control to block **339** in FIG. **3**, the state of SL FLAG is used to establish an output signal on line **60** of control unit **42** to cause illumination of a shift indicator light as previously described.

While the invention has been exemplified with respect to a preferred embodiment as disclosed herein, it is contemplated that various modifications and alterations will be apparent to one having ordinary skill in the art and therefore the embodiment is intended to be taken by way of example and not limitation. Accordingly, the invention is intended to embrace all alternatives, modifications and variations which are within the scope of the appended claims.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. In a motor vehicle having an engine and a manual transmission for imparting torque to at least one wheel and an upshift indication means for indicating a shift point by prompting a vehicle operator to shift from a current gear to a next higher gear, a method of shift point indication comprising the steps of:

calculating a torque ratio of a predicted wheel torque in accordance with the next higher gear to a present wheel torque in accordance with the current gear;

comparing the torque ratio to a predetermined threshold; and

outputting a signal when said torque ratio exceeds said predetermined threshold to thereby indicate said shift point.

2. A method of shift point indication according to claim **1** wherein said predicted wheel torque substantially corresponds to a maximum wheel torque.

3. A method of shift point indication according to claim **1** wherein said predetermined threshold corresponds to a torque ratio whereat a shift to the next higher gear will maximize fuel economy.

4. In a motor vehicle having an engine and a manual transmission for imparting torque to at least one wheel and an upshift indication means for indicating a shift point by prompting a vehicle operator to shift from a current gear to a next high gear, a method of shift point indication comprising the steps of:

calculating a current engine torque value in the current gear in accordance with predetermined engine parameters;

calculating a predicted engine torque value in the next higher gear in accordance with said predetermined engine parameters;

establishing a current wheel torque value from said current engine torque value in the present gear and a gear ratio corresponding thereto;

establishing a predicted wheel torque value from said predicted engine torque value in the next higher gear and the gear ratio corresponding thereto;

calculating a torque ratio of said predicted wheel torque to said current wheel torque;

comparing said torque ratio to a predetermined threshold; and

outputting a signal when said torque ratio exceeds said predetermined threshold to thereby indicate said shift point.

5. A method of shift point indication according to claim **4** wherein said predetermined engine parameters comprise spark retard.

6. A method of shift point indication according to claim **4** wherein said predetermined engine parameters comprise exhaust gas recirculation.

7. A method of shift point indication according to claim wherein said predetermined engine parameters comprise fuel composition.

* * * * *

EXHIBIT 13

United States Patent [19]

Habu et al.

[11] **Patent Number: 4,559,599**

[45] **Date of Patent: Dec. 17, 1985**

[54] **OPTIMUM SHIFT POSITION INDICATION USING SUCCESSIVE TWO-DIMENSIONAL DATA MAPS**

[75] Inventors: **Nobuo Habu; Kouichi Osawa; Yuuichi Kato; Michio Furuhashi; Taiyo Kawai; Junichi Saiki; Toshio Ito,** all of Susono; **Tsutomu Nakamura,** Kariya, all of Japan

[73] Assignees: **Nippondenso Co., Ltd.,** Kariya; **Toyota Jidosha Kabushiki Kaisha,** Toyota, both of Japan

[21] Appl. No.: **474,324**

[22] Filed: **Mar. 11, 1983**

[30] **Foreign Application Priority Data**

Mar. 18, 1982 [JP] Japan 57-43655

[51] **Int. Cl.**[4] **B60K 41/18;** G09B 19/16; G07C 5/08

[52] **U.S. Cl.** .... **364/424.1;** 340/52 D; 364/442; 434/71

[58] **Field of Search** .... 364/424.1, 442; 434/71; 340/52 R, 52 D, 52 F

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Primary Examiner—Felix D. Gruber
Attorney, Agent, or Firm—Cushman, Darby & Cushman

[57] **ABSTRACT**

A shift indication apparatus having an engine rotation sensor, a throttle valve sensor, and a shift position sensor, a microcomputer having a ROM and RAM for storing data corresponding to the engine speed, throttle valve openings, and the shift positions therein, and an indicator for indicating preferable shift positions to be performed by a driver in which a torque data map and a fuel consumption rate data map have stored in the ROM for calculating various torque and fuel consumption rates so as to obtain preferable shift positions relating to optimum fuel consumption rate in accordance with said data detected. With this construction, it becomes possible for a driver to run his car in accordance with the indications of the shift operation on the indicator so as to enable the economical running of the car to be realized.

12 Claims, 4 Drawing Figures

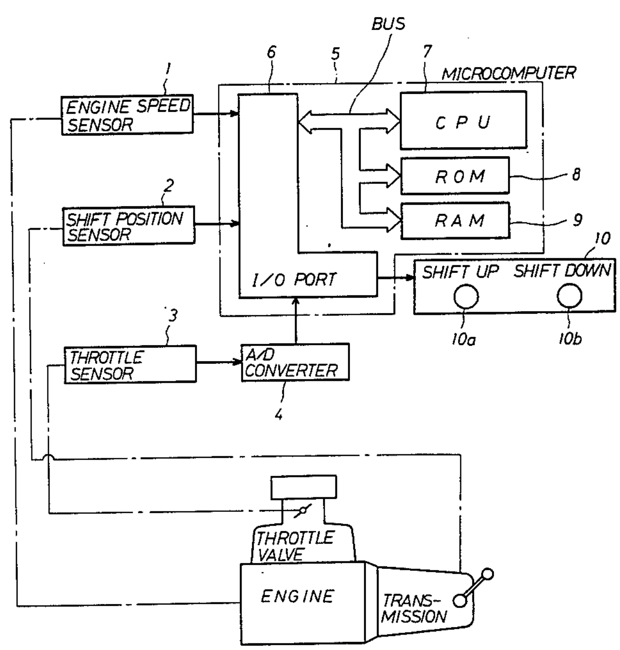


FIG. 1

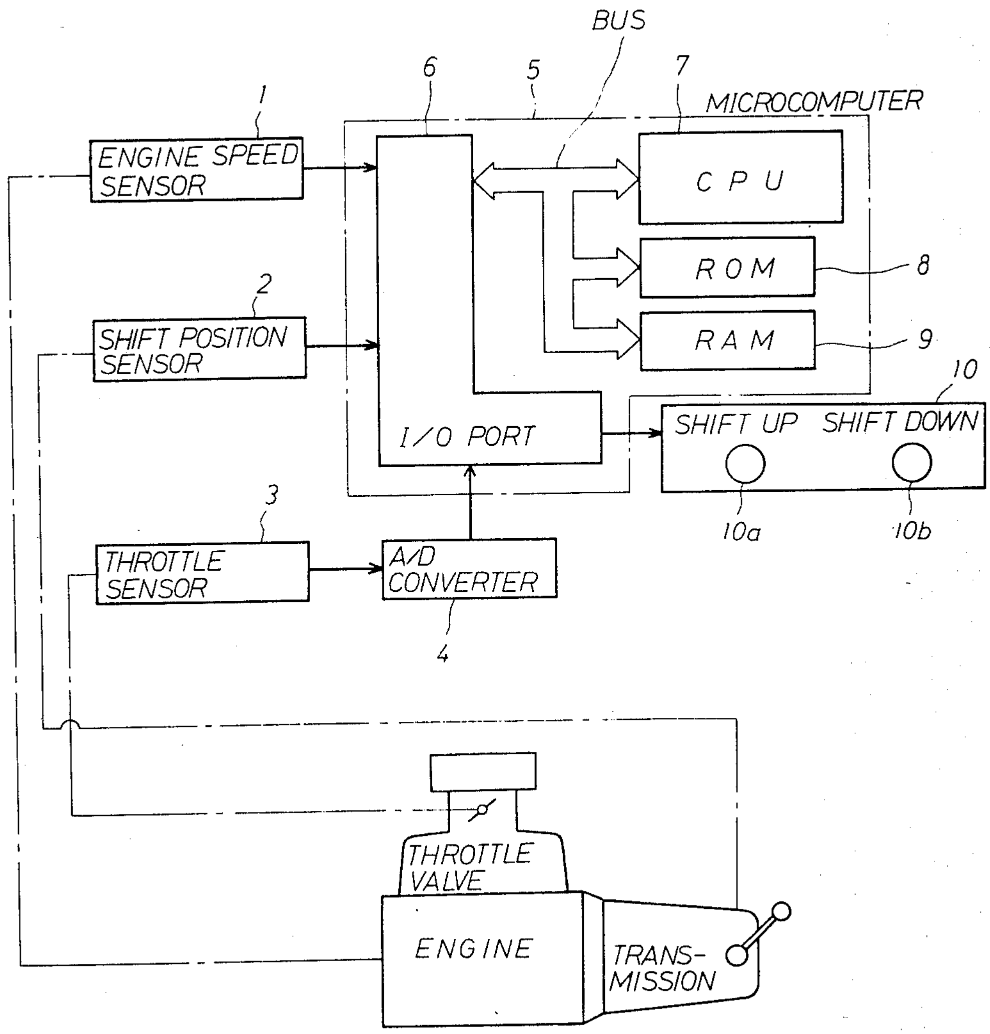

BUS
6
5
7
MICROCOMPUTER
1
ENGINE SPEED SENSOR
C P U
R O M
8
2
SHIFT POSITION SENSOR
R A M
9
10
I/O PORT
SHIFT UP
SHIFT DOWN
3
10a
10b
THROTTLE SENSOR
A/D CONVERTER
4
THROTTLE VALVE
ENGINE
TRANS-MISSION

FIG. 2

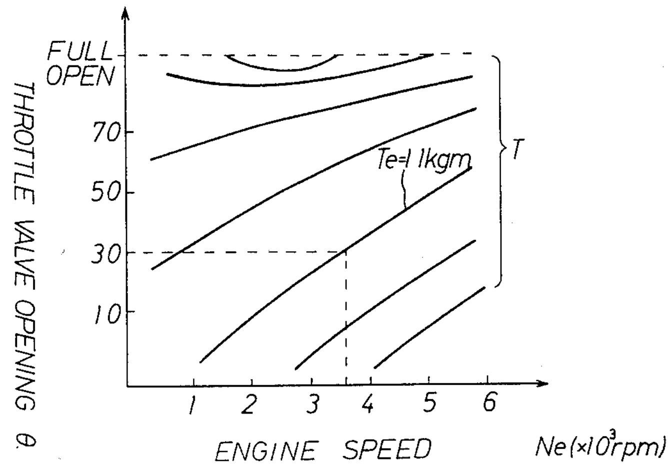
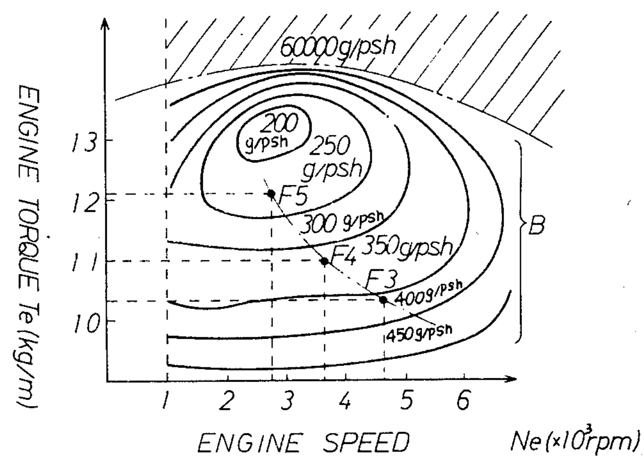

FULL OPEN
70
50
30
10
THROTTLE VALVE OPENING θ
Te=11kgm
T
1 2 3 4 5 6
ENGINE SPEED
Ne(×10³rpm)

FIG. 3


60000g/psh
200 g/psh
250 g/psh
F5
300 g/psh
F4
350g/psh
F3
400g/psh
450g/psh
B
13
12
11
10
ENGINE TORQUE Te(kg/m)
1 2 3 4 5 6
ENGINE SPEED
Ne(×10³rpm)

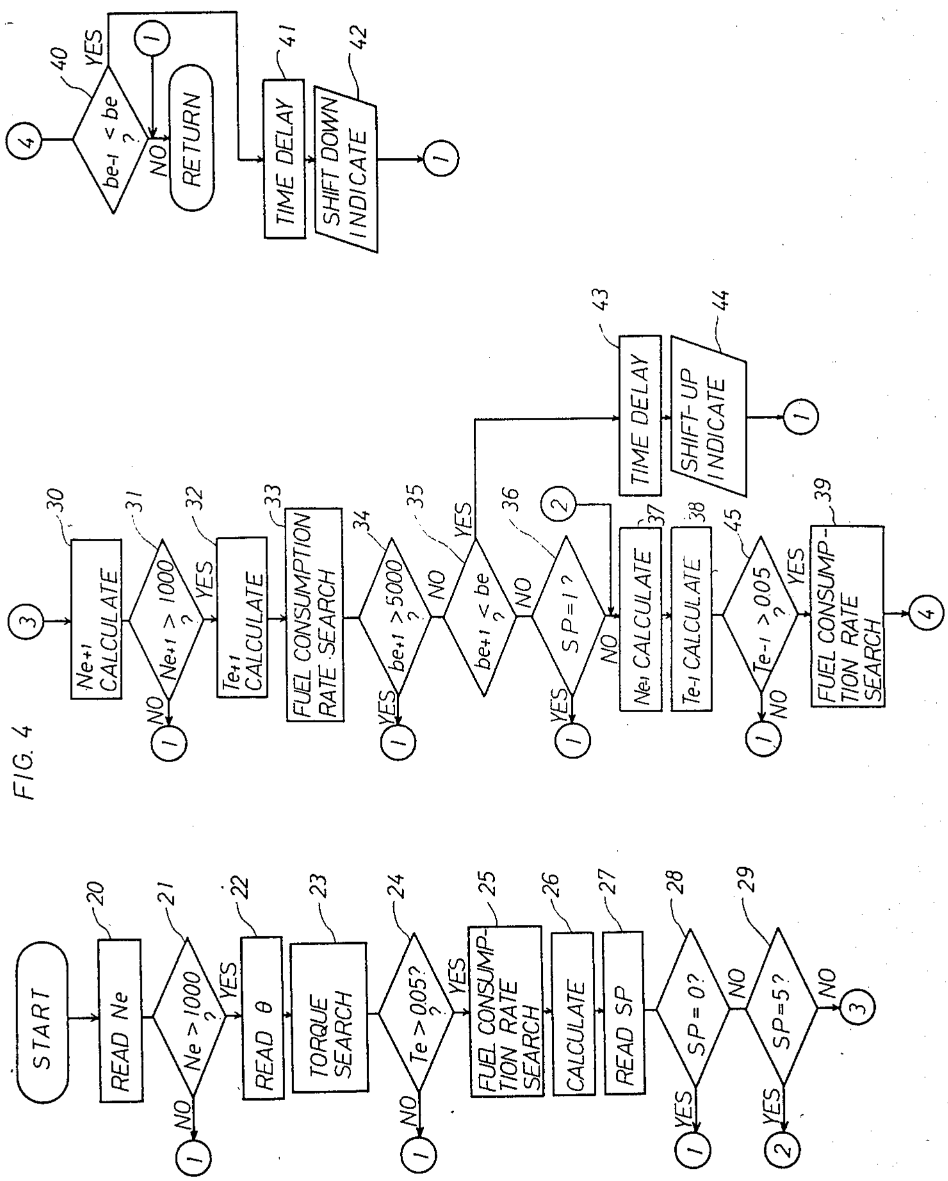

START
READ Ne
Ne > 1000 ?
READ θ
TORQUE SEARCH
Te > 0.05? ?
FUEL CONSUMPTION RATE SEARCH
CALCULATE
READ SP
SP = 0?
SP = 5?
Ne+1 CALCULATE
Ne+1 > 1000 ?
Te+1 CALCULATE
FUEL CONSUMPTION RATE SEARCH
be+1 > 5000 ?
be+1 < be ?
SP = 1 ?
Ne-1 CALCULATE
Te-1 CALCULATE
Te-1 > 0.05 ?
FUEL CONSUMPTION RATE SEARCH
TIME DELAY
SHIFT-UP INDICATE
be-1 < be ?
RETURN
TIME DELAY
SHIFT DOWN INDICATE
YES
NO
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45

FIG. 4

OPTIMUM SHIFT POSITION INDICATION USING SUCCESSIVE TWO-DIMENSIONAL DATA MAPS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a shift indication unit which can be used for an automotive vehicle having a manual transmission and for indicating to a driver change-speed operations to be performed relating to preferable shift position with respect to optimum fuel consumption, and a method of performing the optimum speed change operation so as to reduce fuel cost.

2. Description of the Prior Art

Recently, the situation and circumstances surrounding supply of oils have deteriorated, and various research and development activities have been made in response in an attempt to improve efficient utilization of energy in each technical field in industry. The situation is the same in the autombile industry, where various research and development for improving engines to have better thermal efficiencies and for pursuing better methods for performing effective combustion of fuel for vehicles with less fuel consumption rate have been undertaken. However, there is a problem that unless operations including acceleration operation and shift operation are included, it is not possible for driving operation to sufficiently demonstrate the improved fuel consumption performance thus reached.

SUMMARY OF THE INVENTION

It is therefore a main object of the present invention to provide a shift indication apparatus which is capable of performing optimum running with a good fuel consumption rate by indicating to a driver preferable shift positions for the optimum fuel consumption during the running of the automotive vehicle.

It is another object of the present invention to provide a shift indication apparatus having a microcomputer including a speed change instruction indicator and a ROM in which predetermined torque and fuel consumption maps are stored so as to calculate and indicate on the indicator preferable shift positions corresponding to the optimum fuel consumption rate.

It is still another object of the present invention to provide a speed change operation and indication unit having a microcomputer comprising a ROM and a RAM into which data corresponding to the current engine speed and current shift position as well as throttle valve opening are stored and expected torque and fuel consumption rates are calculated from the data read from the RAM together with the predetermined maps.

According to one feature of the present invention, the shift indication apparatus is characterized in that the unit comprises sensors for detecting the engine speed and the opening of a throttle valve, means for calculating an expected or assumed fuel consumption rate in order to generate the same driving horsepower as that in the current car running conditions at a certain shift position adjacent to the particular shift position of the transmission at that time, means for comparing the current fuel consumption rate with the assumed fuel consumption rate so as to select a preferable shift position with the optimum fuel consumption rate, and means for indicating to the driver shift operation instructions to the preferable shift position.

These and other objects and advantages of the present invention will become more apparent from the following detailed description with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an overall construction of one embodiment of the shift indication apparatus according to the present invention,

FIG. **2** is one example of the characteristic curves of a torque data map stored in the ROM in the microcomputer in FIG. **1** and

FIG. **3** is one example of the characteristics of a fuel consumption data map stored in the ROM in the microcomputer in FIG. **1**.

FIG. **4** is a programmed flow chart of the speed change operation indicating unit of FIG. **1** for the purpose of explaining the operation of the unit according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. **1**, the shift indication apparatus with a manual transmission according to the present invention comprises an engine speed sensor **1** for detecting the engine speed and for producing pulse signals of a frequency proportional to the engine speed, a shift position sensor **2** for detecting the shift positions of the transmission, a throttle sensor **3** for detecting the opening degree of the throttle valve by means of, for instance, a potentiometer, an A/D converter **4** for converting analog signals from the throttle valve sensor **3** into digital signals, a microcomputer **5** for performing various calculations in accordance with the different signals from the sensors, and an indicator **10** for indicating the result of the calculations.

The microcomputer **5** further comprises an input-/output port (I/O port) **6**, a central processing unit (CPU) **7**, a read only memory (ROM) **8**, and a random access memory (RAM) **9**. In the microcomputer **5**, there is provided a bus BUS which communicates the I/O port **6** and the CPU **7**, ROM **8**, and RAM **9**.

The engine speed sensor **1** is mounted in a distributor (not shown) and the output of the sensor is connected to the input of the I/O port **6** so as to transmit the output pulses to the microcomputer **5** through the I/O port **6** and to store the data corresponding to the engine speed into the RAM **9**. The output of the shift sensor **2** is connected to the input of the I/O port **6** so as to transmit the output signals thereof to the microcomputer **5** through the I/O port **6** and to store the data from the shift sensor **2** into the RAM **9**. Similarly, the output of the throttle sensor **3** is connected through the A/D converter **4** to the input of the I/O port **6** so as to transmit the output signals thereof to the microcomputer **5** through the A/D converter **4** and to store the data corresponding to the throttle value opening into the RAM **9** after converting from the analog signals into the digital signals. The input of the indicator **10** is connected to the output of the I/O port **6** so as to indicate each preferable shift position corresponding to the optimum fuel consumption rate in accordance with various parameters calculated.

The indicator **10** includes a shift-up indicating lamp **10*a*** and a shift-down indicating lamp **10*b***.

The indicator **10** may be assembled by light emiting diodes (LED) so as to perform shift-up and shift-down indications by up and down directed arrow marks. Alternatively, the indicator **10** may also be replaced with other voice combining circuit so as to announce the shift operations by voice instead of the indications.

Before explaining the operation of the apparatus according to the present invention, reference must be made to the torque data map shown in FIG. **2** and the fuel consumption rate data map shown in FIG. **3**. The torque data map indicative of torque curves T as shown in FIG. **2** has been stored in the ROM **8** in advance. The fuel consumption rate data map indicative of equal fuel consumption rate curves B as shown in FIG. **3** has been also stored in the ROM **8** in advance. In FIG. **2**, each equal torque curve T was prepared by plotting and connecting equal torque points on the graph with respect to the engine speed vs. throttle valve opening. In FIG. **3**, each fuel consumption rate curve B was prepared by plotting and connecting equal fuel consumption rate points on a graph obtained in advance by experiment data with respect to the engine speed and the torques thus calculated.

In operation, the microcomputer **5** functions in such a manner that it determines current torque from the torque data map stored in the ROM **8** and other data corresponding to the engine speed detected by the sensor **1** and throttle valve opening detected by the throttle sensor **3**, determines expected fuel consumption rate from the fuel consumption rate data map also stored in the ROM **8** and the torque thus determined as well as the engine speed, and compares the fuel consumption rate thus determined with an assumed fuel consumption rate when speed change operation is performed from the current shift position to the adjacent shift position in accordance with a control program, whereby an instruction signal for changing suitable shift position relating to optimum fuel consumption rate is generated from the microcomputer and it is indicated on the indicator **10**.

The operation of the shift indication apparatus will now be made with reference to the control program flow chart shown in FIG. **4**.

First of all, the engine speed sensor **1** produces pulse signals proportional to the engine speed during running of the automotive vehicle and transmits these signals to the microcomputer **5**. In this case, as shown in FIG. **4**, the operation of a main routine is started at a predetermined timing, e.g. periodical timing pulses from a timer (not shown) and the detection of the engine speed N_e from the sensor **1** is carried out and it is stored into the RAM **9** at the step **20**. Then, the engine speed N_e is read from the RAM **9** and it is compared with a predetermined number N (=1000 rpm) to determine whether or not the N_e exceeds the value 1000 at the step **21**. If the result of the decision is YES, the next step **22** is executed. That is, in the step **22**, the reading in of the opening of the throttle valve is performed through the throttle sensor **3** and the A/D converter **4**. In the above case, if the result of the decision in step **21** is NO, the main routine is terminated by determining that the shift operation is not necessary and the engine speed N_e is read again at the predetermined timing and now the operation returns to the step **20**.

In the step **22**, the throttle valve opening θ is detected by the throttle sensor **3** and is then stored in the RAM **9** after conversion from the analog signals into the digital signals through A/D converter **4**. The next step **23**, i.e. the torque search step is executed. In this step, the torque T_e is determined from the torque curves T on the torque data map as shown in FIG. **2** and which has been stored in the ROM **8** in the microcomputer **5**, in accordance with the detected data corresponding to the engine speed N_e and the throttle valve opening θ. In this case, assuming that the engine speed N_e is 3600 rpm and the throttle valve opening θ is 30 degrees, the torque value T_e=11 kg·m is determined from the cross point on the torque curve T in the torque data map.

Then in the next step **24**, i.e. the torque determination step is executed. In this step **24**, a decision is made as to whether or not the value of the torque T_e thus calculated in the step **23** is larger than 0.05 kg·m, i.e. the vehicle speed is in the middle of speed reduction or it is close to the speed reduction. If the result of the decision is YES, the next step, fuel consumption search step **25**, is executed, if the result of the the decision is NO, the operation of the main routine terminates. In the step **25**, the fuel consumption data is read from the equal fuel consumption rate curves B on the fuel data map shown in FIG. **3** which has been stored in the ROM **8** and fuel consumption rate is searched from the calculated torque T_e and the engine speed N_e.

Namely, if the shift position is in the fourth speed, as the torque T_e is 11 kg·m and the engine speed is 3600 rpm, the point F4 is obtained on the fuel consumption rate curves B in the fuel consumption rate data map. Since the point F4 is in the area of the fuel consumption rate B_e=300 g/psh to 350 g/psh, the fuel consumption rate of the fourth speed is determined as 300 g/psh to 350 g/psh in this case.

Then the next horsepower calculation step **26** is executed. In this step **26**, the horsepower P is calculated in accordance with the following equation.

$$P = N_e \times T_e / 716.2$$

P=driving power in ps

where

N_e=the engine speed in rpm

T_e=torque in *kg·m*

In the step **27**, the detected data from the shift position sensor **2** is stored in the RAM **9** in the microcomputer **5** through the I/O port **6**.

In the step **28**, a neutral position decision is performed. That is, the decision is made whether or not the shift position stored in the step **27** is in the neutral position, i.e. whether or not SP=0 is determined. If it is not the neutral in this case, the step **29** for deciding the fifth speed is executed. On the other hand, if the result of the decision is neutral, the main routine operation is terminated as it is not necessary to indicate the speed change operation.

In the step **29**, since the shift position SP is determined as the fifth speed or the upmost shift position, the assumed processing for shifting up operations shown in the steps **30** through **36** is skipped and now the operation moves to the calculating step for the number of engine rotations at the time of the shifting down in the step **37**.

On the other hand, if the result of the decision in the step **29** is such that the shift position SP is not at the fifth speed, the next step **30** is executed. In this step **30**, the engine speed N_{e+1} is calculated in the case of one shift-up. In this case, the equation for calculating the engine speed N_{e+1} is as follows;

$$N_{e+1} = N_e \times \text{gear ratio of shift position } SP_{+1} / \text{gear ratio of shift position SP}$$

where, each unit indicates: N_e = rpm, N_{e+1} = rpm, and the gear ratio is a physical quantity which one of ordinary skill understands is dictated by the physical embodiment of the gears used (and which ratios are stored as data for use with a particular embodiment).

After executing this step, the operation now moves to the step **31** for deciding the engine speed N_{e+1}. In this step **31**, a decision is made as to whether or not the engine speed N_{e+1} at the one step shifting up position SP_{+1} is larger than 1000 rpm. In this case, if the result of the decision is NO, the processing for the main routine is terminated as the shift operation is not necessary. However, if the result of the decision is such that the engine speed N_{e+1} is larger than 1000 rpm, the operation now moves to the next step **32**. In this step **32**, the calculation of the torque T_{e+1} at the one step shifting up position SP_{+1} is performed.

The calculation of the torque is performed in accordance with the following equation.

$$T_{e+1} = P \times 716.2 / N_{e+1}$$

where, each unit indicated

T_{e+1} = kg/m

P = ps, and

N_{e+1} = rpm.

And now the operation moves to the next step **33**. In this step **33**, the assumed fuel consumption rate is searched from the data map stored in the ROM **8** in the microcomputer **5**. Namely, one cross point is sought from the engine speed N_{e+1} which was calculated in the step **30** and the torque T_{e+1} calculated in the step **32** on the data map shown in FIG. **4**. From the fuel consumption rate indicated in the equal fuel consumption rate curves B surrounding this point in the coordinate positions, the assumed fuel consumption rate b_{e+1} can be found. For instance, assuming that the engine speed N_{e+1} = 2800 rpm and the torque T_{e+1} = 12.1 kg·m, the cross point F5 can be obtained from the data map and this point F5 belongs to the area of the fuel consumption rate of 200 g/psh to 250 g/psh in the equal fuel consumption rate curves B. Accordingly, since the one step shifting up position SP_{+1}, i.e. the current shift is the fourth speed, the assumed fuel consumption rate b_{e+1} when shifting up to the fifth speed, becomes 200 g/psh to 250 g/psh.

The assumed fuel consumption rate b_{e+1} thus searched (i.e., derived) in step **33** is compared with a predetemined value in the next decision step **34**. That is, the fuel consumption rate b_{e+1} is determined whether or not it is larger than 5000 g/psh. In this case, a large number such as 60000 g/psh is inputted in the area above the full opened torque in FIG. **4**. Accordingly, if the result of the decision is NO, the assumed fuel consumption rate b_{e+1} is compared and is determined in the next step **35** as to whether or not it is smaller than the current fuel consumption rate b_e which was searched (i.e., derived) in the step **25**.

If the result of the decision is YES, that is, the assumed fuel consumption rate b_{e+1} is smaller than the current fuel consumption rate b_e, the operation now moves to the step **43** and the operation for indicating the shift-up condition is performed in the step **44** after some delay time. Namely, in this step, the speed change operation indicating signal is applied to the indicator or display **10** from the microcomputer **5** through the I/O port **6**. As a result, a particular lamp in this case, a shift-up indicating lamp in the indicator **10**, is illuminated, thus indicating to the driver that the speed change from current shift position to the one step shifting up position SP_{+1} is preferable. In this case, it is preferable to provide some delay time as shown in the step **43** so as to prevent the driver from confusion due to intermittent illuminations of the lamp of the indicator **10** within a short time when the fuel consumption rate is on the critical border lines.

On the other hand, if the result of the decision in the step **35** is NO, that is, the assumed fuel consumption rate b_{e+1} is larger than the current fuel consumption rate b_e, the operation now moves to the step **36**. In this step **36**, the decision is made whether or not the current shift position SP is the first speed. If the result of the decision is YES indicating that the current shift position is the first speed, the processing for the main routine is terminated as no shift-down operation is required, while if the result of the decision is NO, the operation now moves to the next step **37** for calculating the engine speed N_{e+1} at the one step shifting down position SP_{-1}. In this step, the engine speed N_{e+1} at the time of shifting down from the current shift position SP to the one step shifting down position SP_{-1} is calculated by the following equation;

$$N_{e-1} = N_e \times \text{gear ratio of shift position } SP_{-1} / \text{gear ratio of shift position SP}$$

where, each unit of each parameter indicates

N_{e-1} = rpm

N_e = rpm.

From the engine speed N_{e-1} calculated here and the driving power which was calculated in the step **26**, the torque T_{e-1} is calculated by the following relationship in step **38**;

$$T_{e-1} = P \times 716.2 / N_{e-1}$$

where, each unit of each parameter indicated

T_{e-1} = kg·m,

P = ps,

N_{e-1} = rpm.

The torque thus calculated is compared with a predetermined value such as 0.05 kg·m in the step **45**. If the result of the decision in step **45** is YES, the operation now moves to the fuel consumption rate search step **39**, where the assumed fuel consumption rate b_{e-1} in the one step shifting down position SP_{-1} is searched from the data map in FIG. **3** as in the step **33**. Namely, if the engine speed N_{e-1} is 4600 rpm and the torque T_{e-1} is 12 kg·m which were calculated in the steps **37** and **38**, the cross point F3 is determined on the data map in FIG. **4**. Accordingly, in step **39**, from the area of the equal fuel consumption rate curve B of 350 g/psh to 400 g/psh on which the cross point F 3 is situated, the assumed fuel consumption rate b_{e-1} is searched to be found in the one step shifting down position SP_{-1}.

With the one step shifting down position SP_{-1} thus obtained, i.e. the current shift position SP being as the fourth speed, the assumed fuel consumption rate when shifting down to the third speed which is in the shift position SP_{-1} thereunder, becomes 350 g/psh to 400 g/psh, and then the next step **40** is executed. In this step **40**, the fuel consumption rate b_e in the current shift position SP which was searched in the step **25** is compared with the assumed fuel consumption rate b_{e-1}. Namely, the decision making is performed whether or not the assumed fuel consumption rate b_{e-1} is smaller than the current fuel consumption rate b_e. If the result of the decision is NO which means that the b_{e-1} is larger than the b_e, the processing for the main routine is terminated. On the other hand, if the result of the decision is YES, meaning that the assumed fuel consumption rate b_{e-1} is smaller than the current fuel consumption rate b_e, the operation moves to the next step **41**, where some time delay processing is performed, and then the operation now moves to the step **42**.

In this step **42**, shift-down display is performed. Namely in this case, the shift down display instruction signal from the microcomputer **5** is applied to the indicator **10** through the I/O port **6** and the shift-down indication lamp in the indicator **10** is illuminated, thus indicating to the driver that speed change operation from the current shift position to the one step shifting down position SP_{-1} is preferable.

In this manner, the operations as indicated in each step are repeatedly performed and the assumed fuel consumption rate b_{e+1} in the one step shifting up position and the assumed fuel consumption rate b_{e-1} in the one step shifting down position from the current shift position are calculated respectively, and each assumed fuel consumption rate is compared with the current fuel consumption rate b_e, respectively. In this case, if the current fuel consumption rate b_e is better than the assumed fuel consumption rate b_{e+1} or the assumed fuel consumption rate b_{3-1}, the indicator **10** is not energized. However, only when either one of the assumed fuel consumption rates above is better than the current fuel consumption rate b_e, the corresponding shift-up lamp or shift-down lamp in the indicator **10** is illuminated, thus indicating the necessity of the speed change operation. As a result, the driver can actually perform the speed change operations in accordance with the indications so that the optimum speed running of the car can be carried out with a preferable shift position in the optimum fuel consumption rate.

In the preferred embodiment according to the present invention described in the foregoing, the range of each area indicative of the equal fuel consumption rate curves B has been indicated as 50 g/psh. However, if the range of each area is defined more narrow or the distances between the points is interpolated by calculation, it is possible to indicate more accurate speed change operations.

As stated in the foregoing, in the speed change operation and indication system according to the present invention, the optimum fuel consumption rate is calculated from the data corresponding to the number of engine rotation and the throttle valve opening, an assumed fuel consumption rate is calculated for generating the same driving power as that in the current running conditions in the shift position adjacent to a particular shift position at that time, and the current fuel consumption rate is compared with the assumed fuel consumption rate, whereby the optimum shift operation indications are displayed to the driver.

With this construction, it is possible for a driver to run his car in accordance with the indication of the speed change operation on an indicator so as to maintain the optimum fuel consumption of the automotive vehicle, thus enabling the economical running of the car to be realized.

While the invention has been described in its preferred embodiments, it is to be understood that various changes and modifications may be made within the purview of the appended claims without departing from

the true scope and spirit of the invention in its broader aspects.

What is claimed is:

1. An electronically controlled system in an internal combustion engine for indicating shift position for a manual transmission thereof so as to maintain optimum fuel consumption by the engine, comprising:

first detecting means for detecting current engine speed;

second detecting means for detecting current throttle position;

third detecting means for detecting current shift position;

first determining means for determining current engine torque based on said current engine speed and current throttle position in accordance with a first two-dimensional map of engine speed and throttle position;

second determining means for determining current fuel consumption rate based on said current engine speed and determined current engine torque in accordance with a second two-dimensional map of engine speed and engine torque, said second map including isometric curves representing curves of equal fuel consumption rates;

calculating means for calculating driving force of the engine in accordance with current engine speed and current engine torque, said calculating means further including:

first comparing means for comparing said current fuel consumption rate obtained by said second determining means with an assumed one-step-transmission upshifted fuel consumption rate determined by one-step-transmission upshifted engine speed and one-step-transmission upshifted engine torque defined by said second map,

second comparing means for comparing said current fuel consumption rate obtained by said second determining means with an assumed one-step-transmission downshifted fuel consumption rate determined by one-step-transmission downshifted engine speed and one-step-transmission downshifted engine torque defined by said second map,

outputting means for outputting a first signal indicative of one-step upshifting, a second signal indicative of one-shift downshifting, or a third signal indicative of stopping both one-step upshifting and downshifting, respectively, whenever said first comparing means determines said assumed fuel consumption rate of one-step upshifting is less than the currently detected fuel consumption rate, said second comparing means determines said assumed fuel consumption rate of one-step downshifting is less than the currently detected fuel consumption rate, or both values of fuel consumption rate calculated in said first and second comparing means are detemined greater than the currently detected fuel consumption rate; and

representing means for alternatively representing whichever of said three signals are output by said outputting means.

2. A system in claim **1** wherein

said first comparing means comprises first determination means for determining whether the current gear position is highest gear or neutral position, and for enabling said comparison of said fuel consumption rate if the current shift position is not determined to be said highest gear or said neutral position; and

said second comparing means comprises second determination means for determining whether said current shift position is first gear, and for enabling said comparison of said fuel consumption rate if it is determined the current shift position is not said first gear.

3. A system in claim 1 wherein

said first comparing means comprises first calculating means for calculating one-step upshifted assumed engine speed obtained from the value of the current engine speed, multiplied by a known gear ratio for one-step-transmission upshifted, divided by the known value for the gear ratio corresponding to the current shift position, and for calculating assumed engine torque obtained from the value of current driving force divided by said assumed engine speed multiplied by a constant;

said second comparing means comprises second calculating means for calculating one-step downshifted assumed engine speed obtained from the value of the current engine speed, multiplied by a known gear ratio for one-step-transmission downshifted, divided by the known value for the gear ratio corresponding to the current shift position, and for calculating the assumed engine torque obtained from the value of current driving force divided by said assumed engine speed multiplied by a constant.

4. A system as in claim 1, wherein said representing means makes an indication to keep the shift position unchanged whenever said engine speed detected by said first detecting means is greater than a predetermined value.

5. A system as in claim 1, further comprising:

first permitting means for permitting said second determining means to determine said fuel consumption rate whenever the value of said engine torque determined by said first determining means is greater than a predetermined value; and

second permitting for permitting said second determining means to determine said assumed fuel consumption rate whenever the value of said assumed engine torque calculated by said second comparing means is greater than said predetermined value.

6. A system as in claim 1, wherein said representing means represents changes in said first, second and third signals, indicative of upshifting, downshifting and keeping shift position unchanged, respectively, after a predetermined time delay.

7. A method for indicating shift position for a manual transmission associated with an internal combustion engine so as to maintain optimum fuel consumption by the engine, comprising the steps of:

detecting the current engine speed;

detecting the current throttle position;

detecting the current shift position;

determining current engine torque based on said current engine speed and current throttle in accordance with a first two-dimensional map of engine speed and throttle position;

determining current fuel consumption rate based on said current engine speed and determined current engine torque in accordance with a second two-dimensional map of engine speed and engine torque in accordance with a second two-dimensional map of engine speed and engine torque, said second map including isometric curves representing curves of equal fuel consumption rates;

calculating driving force of the engine in accordance with current engine speed and current engine torque;

comparing said current fuel consumption rate with an assumed one-step upshifted fuel consumption rate determined by one-step upshifted engine speed and one-step upshifted engine torque defined by said second map;

comparing said current fuel consumption rate with an assumed one-step downshifted fuel consumption rate determined by one-step downshifted engine speed and one-step downshifted engine torque defined by said second map;

outputting a first signal indicative of one-step upshifting, a second signal indicative of one-step downshifting, or a third signal indicative of stopping both one-step upshifting and downshifting, respectively, if the assumed fuel consumption rate of one-step upshifting is less than the current detected fuel consumption rate, the assumed fuel consumption rate of one-step downshifting is less than the current detected fuel consumption rate, or both values of fuel consumption rate are determined greater than the current detected fuel consumption rate;

representing to an operator of said engine the respective three signals for executing upshifting, downshifting and keeping the shift position unchanged.

8. A method as in claim 7, wherein

the first comparing step includes determining whether the current gear position is the highest gear or neutral position, and for enabling said comparison of said fuel consumption rate if the current shift position is not determined to be said highest gear or said neutral position; and

the second comparing step includes determining whether said current shift position is the first gear, and for enabling said comparison of said fuel consumption rate if it is determined the current shift position is not the first gear.

9. A method as in claim 7, wherein

the first comparing step includes calculating one-step upshifted assumed engine speed obtained from the value of the current engine speed, multiplied by a known gear ratio for one-step upshifted, divided by the known value for the gear ratio corresponding to the current shift position, and calculating assumed engine torque obtained from the value of current driving force divided by said assumed engine speed multiplied by a constant; and

the second comparing step includes calculating one-step downshifted assumed engine speed obtained from the value of the current engine speed, multiplied by a known gear ratio for one-step downshifted, divided by the known value for the gear ratio corresponding to the current shift position, and calculating the assumed engine torque obtained from the value of current driving force divided by said assumed engine speed multiplied by a constant.

10. A method as in claim 7, wherein the representing step includes the step of indicating to keep the shift position unchanged when the engine speed is greater than a predetermined value.

11. A method as in claim 7, further including the steps of:

permitting the determining of the fuel consumption rate whenever the value of engine torque determined in the first determining step is greater than a predetermined value; and

permitting the determining of assumed fuel consumption rate whenever the value of assumed engine torque determined in the second comparing step is greater than the predetermined value.

12. A method as in claim 7 wherein the representing step includes the step of representing the first, second and third signals indicative of upshifting, downshifting and keeping shift position unchanged, respectively, after a predetermined time delay.

* * * * *

EXHIBIT 11

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(54) Bezeichnung: Einrichtung zur Erzielung eines verbrauchsgünstigen Betriebs einer Brennkraftmaschine

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27. Juni 1979

ANSPRÜCHE

1. Einrichtung zur Erzielung eines verbrauchsgünstigen Betriebs einer mit einem Schaltgetriebe ausgerüsteten Brennkraftmaschine, insbesondere der Antriebsmaschine eines Fahrzeugs, dadurch gekennzeichnet, daß als UND-Schaltung im Ansteuerkreis (2) eines Signalgebers (4) ein drehzahl- und ein lastabhängiger Schalter (6,8) liegen, die nur beim Auftreten von Betriebspunkten der Maschine in einem vorgegebenen vollastfernen Betriebsbereich (I) im Leistungs-Drehzahl-Diagramm den Ansteuerkreis (2) schließen.

2. Einrichtung nach Anspruch 1, dadurch gekennzeichnet, daß die UND-Schaltung ferner einen nur bei eingelegtem höchsten Getriebegang den Ansteuerkreis (2) unterbrechenden gangabhängigen Schalter (10) enthält.

3. Einrichtung nach Anspruch 1 oder 2, dadurch gekennzeichnet, daß der vollastferne Betriebsbereich (I) im Diagramm oberhalb einer vorgegebenen Drehzahl (n_1) von etwa 20 bis 50 % der maximalen Drehzahl liegt.

4. Einrichtung nach einem der Ansprüche 1 bis 3, dadurch gekennzeichnet, daß der vollastferne Betriebsbereich (I) im Diagramm unterhalb der Linie (b) für etwa 50 bis 70 % der Maximalstellung des Leistungssteuerglieds liegt.

5. Einrichtung nach einem der Ansprüche 1 bis 4, dadurch gekennzeichnet, daß der Signalgeber (4) eine Leuchte mit der Darstellung eines nach oben weisenden Pfeils ist.

6. Einrichtung zur Erzielung eines verbrauchsgünstigen Betriebs einer mit einem Schaltgetriebe ausgerüsteten Brennkraftmaschine, insbesondere der Antriebsmaschine eines Fahrzeugs, insbesondere nach einem der Ansprüche 1 bis 5, dadurch gekennzeichnet, daß als UND-Schaltung im Ansteuerkreis (3) eines Signalgebers (5) ein drehzahl- und ein lastabhängiger Schalter (6,9) liegen, die nur beim Auftreten von Betriebspunkten der Maschine in einem vorgegebenen vollastnahen Betriebsbereich (II) im Leistungs-Drehzahl-Diagramm zwischen dem ansteigenden Ast der Vollastlinie (a) und einer benachbarten Linie (c) für eine konstante Stellung des Leistungssteuerglieds den Ansteuerkreis (3) schließen.

7. Einrichtung nach Anspruch 6, dadurch gekennzeichnet, daß die UND-Schaltung ferner einen nur bei eingelegtem ersten Getriebegang den Ansteuerkreis (3) unterbrechenden gangabhängigen Schalter (11) enthält.

8. Einrichtung nach Anspruch 6 oder 7, dadurch gekennzeichnet, daß der vollastnahe Betriebsbereich (II) im Diagramm unterhalb einer vorgegebenen Drehzahl (n_2) von etwa 40 bis 70 % der maximalen Drehzahl liegt.

9. Einrichtung nach einem der Ansprüche 6 bis 8, dadurch gekennzeichnet, daß der dem vollastnahen Betriebsbereich (II) zugeordnete lastabhängige Schalter (9) ein Kickdown-Schalter ist.

10. Einrichtung nach einem der Ansprüche 5 bis 9, dadurch gekennzeichnet, daß der dem vollastnahen Betriebsbereich (II) zugeordnete Signalgeber (5) eine Leuchte mit der Darstellung eines nach unten weisenden Pfeils ist.

11. Einrichtung nach einem der Ansprüche 1 bis 5 und einem der Ansprüche 6 bis 10, dadurch gekennzeichnet, daß beide Ansteuerkreise (2,3) eine gemeinsame Spannungsquelle (1) enthalten und die drehzahlabhängigen Schalter durch einen Umschalter (6) gebildet sind.

12. Einrichtung nach Anspruch 11, dadurch gekennzeichnet, daß der Umschalter (6) drei Schaltstellungen besitzt, von denen er die mittlere, zu keinem der Ansteuerkreise (2,3) führende Schaltstellung bei Drehzahlwerten einnimmt, die zwischen den die beiden Betriebsbereiche (I,II) im Diagramm begrenzenden Drehzahlen (n_1, n_2) liegen.

13. Einrichtung nach Anspruch 5 und/oder 10, dadurch gekennzeichnet, daß der bzw. die Signalgeber (33) integriert ist bzw. sind in eine Kraftstoffverbrauchsanzeige (31).

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27. Juni 1979

Einrichtung zur Erzielung eines verbrauchsgünstigen Betriebs einer Brennkraftmaschine

Die Erfindung betrifft eine Einrichtung gemäß dem Oberbegriff der Patentansprüche 1 und 6. In erster Linie ist dabei an den Einsatz bei einer Antriebsmaschine eines Kraftfahrzeugs gedacht, jedoch ist die Erfindung grundsätzlich auch bei stationären Brennkraftmaschinen mit Vorteil anwendbar, die mit unterschiedlichen Leistungen und Drehzahlen betrieben werden.

Der Kraftstoffverbrauch einer mit einem Schaltgetriebe ausgerüsteten Brennkraftmaschine hängt wesentlich von der Lage ihres Betriebspunkts im Last-Drehzahl-Diagramm der Maschine ab. Dabei lassen sich grundsätzlich zwei Fälle unterscheiden: Die Lage des Betriebspunktes der Maschine in einem vollastfernen Betriebsbereich unter Einschaltung eines der unteren oder mittleren Getriebegänge führt zwar zur Sicherstellung der gewünschten Leistung, jedoch mit einem sehr hohen Kraftstoffverbrauch. Es ist daher zweckmäßig, in den nächsthöheren bzw. den höchsten Getriebegang hochzuschalten und so einen vollastnäheren Betriebspunkt einzustellen. Im zweiten Fall liegt zwar ein vollastnaher Betriebspunkt vor, aber trotz Vollgasstellung (Maximalstellung) des Leistungssteuerglieds, worunter im Rahmen der Erfindung bei Vergasermaschinen die Drosselklappe und bei Einspritzmaschinen der Einspritzregler zu verstehen ist, läßt sich die gewünschte Leistung bei eingelegtem höheren oder höchsten Gang nicht erreichen; außerdem ist diese Betriebsweise der Maschine ebenfalls nicht verbrauchsgünstig.

Gemeinsam ist diesen beiden Fällen, daß der Nachteil eines hohen Kraftstoffverbrauchs durch Hoch- bzw. Herunterschalten des Getriebes ohne Verringerung der Leistung der Maschine vermieden werden kann. Wie sich aber in der Praxis beispielsweise bei Autofahrern immer wieder zeigt, herrscht insbesondere bei ungeübten Fahrern, beispielsweise solchen, die vorher ein Fahrzeug mit automatischem Getriebe gefahren haben, Unklarheit über den Einfluß der Lage des Betriebspunktes der Maschine auf den Kraftstoffverbrauch sowie Unsicherheit darüber, wann ein Gangwechsel sinnvoll ist.

Der Erfindung liegt die Aufgabe zugrunde, eine Einrichtung zu schaffen, die die Bedienungsperson der mit einem Schaltgetriebe ausgerüsteten Brennkraftmaschine, also beispielsweise den Fahrer eines Kraftfahrzeugs, bei der Einstellung eines verbrauchsgünstigen Betriebspunktes der Maschine durch Schaltvorgänge unterstützt. Die erfindungsgemäße Lösung dieser Aufgabe ist gekennzeichnet durch die Merkmale der selbständigen Patentansprüche.

Ein wesentlicher Vorteil der Erfindung ist darin zu sehen, daß die Einrichtung ein zum Umschalten aufforderndes Signal liefert, das aus dem der Maschine zugehörigen Leistungs-Drehzahl-Diagramm gewonnen ist, so daß subjektive Gesichtspunkte, etwa das - häufig falsche - "Gefühl" des Fahrers eines Kraftfahrzeugs, ausgeschlossen sind.

Die Erfindung wird im folgenden anhand der Zeichnung erläutert. Es stellen dar:

Fig. 1 das Leistungs-Drehzahl-Diagramm einer mit einem Schaltgetriebe ausgerüsteten Brennkraftmaschine mit zwei hinsichtlich des Kraftstoffverbrauchs ungünstigen Betriebsbereichen,

Fig. 2 das Schaltbild eines Ausführungsbeispiels der erfindungsgemäßen Einrichtung und

Fig. 3 eine vorteilhafte Ausgestaltung des Signalgebers.

Betrachtet man zunächst Figur 1, so ist über der Maschinendrehzahl n die Leistung N der Maschine aufgetragen. a ist die Kurve der Vollastleistung, b eine Linie konstanter Stellung des Leistungssteuerglieds, also beispielsweise eine Linie konstanten Drosselklappenwinkels bei einer Vergasermaschine. Als Maß hierfür kann außer dem Drosselklappenwinkel selbst auch der Saugrohrunterdruck dienen. In der Regel wird die Linie b, die einen ersten unerwünschten Betriebsbereich I begrenzt, etwa zwischen 50 und 70 % der Maximalstellung des Leistungssteuerglieds liegen. c ist ebenfalls eine Linie konstanter Stellung des Leistungssteuerglieds bzw. konstanten Saugrohrunterdrucks, die jedoch - im Gegensatz zum Bereich I - einen vollastnahen, ebenfalls unerwünschten Betriebsbereich II begrenzt. Dabei kann die Linie c der Kickdown-Stellung eines Gaspedals entsprechen. Die Betriebsbereiche I und II werden ferner abgegrenzt durch Drehzahlwerte n_1 bzw. n_2, von denen der erste in der Regel zwischen etwa 20 bis 50 % der maximalen Drehzahl und der zweite zwischen etwa 40 und 70 % der maximalen Drehzahl liegt.

Die Zahlenwerte für die Grenzen der beiden Betriebsbereiche I und II sind verständlicherweise vom Einzelfall abhängig. Generell kann man sagen, daß diese beiden Betriebsbereiche so liegen, daß durch Schaltvorgänge Betriebspunkte im Leistungs-Drehzahl-Diagramm gewonnen werden können, die hinsichtlich des Kraftstoffverbrauchs günstiger liegen.

Betrachtet man zunächst den vollastfernen Betriebsbereich I, so läßt sich die erwünschte Leistung mit geringerem spezifischen Kraftstoffverbrauch nach Hochschalten in den nächsthöheren Gang bei einem Betriebspunkt erzielen, der in dem Diagramm nach Figur 1 links von dem Betriebsbereich I liegt. Die erfindungsgemäße Einrichtung erzeugt demgemäß ein die Bedienungsperson, also in der Regel den Fahrer, zum Hochschalten aufforderndes Signal, das in Figur 1 durch den nach oben weisenden Pfeil innerhalb des Betriebsbereichs I angedeutet ist.

Die Lage des Betriebspunktes der Maschine in dem vollastnahen Betriebsbereich II, also in Figur 1 links von der Drehzahl n_2, hat zunächst den grundsätzlichen Nachteil, daß die gewünschte höhere Leistung trotz Vollgasstellung des Gaspedals bzw. des Leistungssteuerglieds nicht erreicht wird. Erst nach Zurückschalten auf den nächst niedrigen Gang wird bei höheren Drehzahlen die gewünschte höhere Leistung erreicht. Ein weiterer Nachteil der Lage des Betriebspunktes im Betriebsbereich II ist der relativ hohe Kraftstoffverbrauch. Bei Lage des Betriebspunktes im Betriebsbereich II erzeugt die erfindungsgemäße Einrichtung ein dem Fahrer zum Zurückschalten aufforderndes Signal, was in Figur 1 durch den nach unten weisenden Pfeil am Betriebsbereich II angedeutet ist. An dieser Stelle sei eingefügt, daß es zweckmäßig sein kann, dem Gaspedal in der Kickdown-Stellung (Linie c) einen Druckpunkt zuzuordnen.

Figur 2 zeigt nun eine Ausführungsform der erfindungsgemäßen Einrichtung, die mit besonders geringem Aufwand unterschiedliche Signale erzeugt je nachdem, ob der jeweilige Betriebspunkt der Maschine im Betriebsbereich I oder im Betriebsbereich II liegt.

Die Spannungsquelle 1 ist den beiden in jeweils einem Ansteuerkreis 2 bzw. 3 liegenden Signalgebern 4 und 5 gemeinsam. Beide Signalgeber sind Leuchten mit der Darstellung eines nach oben bzw. unten weisenden Pfeils, der die Bedienungsperson bei Betätigung des jeweiligen Signalgebers zum Hochschalten bzw. Herunterschalten auffordert.

Die beiden Ansteuerkreise 2 und 3 werden selektiv geschlossen durch den drehzahlabhängigen Umschalter 6, dem ein der jeweiligen Maschinendrehzahl n entsprechendes Signal zugeführt wird und der so ausgelegt ist, daß sein Schaltarm 7 bei Drehzahlen, die größer sind als die vorgegebene Drehzahl n_1 (siehe Figur 1), in Figur 2 nach oben, dagegen bei Drehzahlen, die kleiner sind als die vorgegebene Drehzahl n_2, nach unten schwenkt aus einer neutralen Mittelstellung, die er also einnimmt, wenn Drehzahlwerte zwischen n_1 und n_2 vorliegen.

Die Gewinnung des Drehzahlsignals erfolgt mit bekannten Sensoranordnungen, die daher hier im einzelnen nicht beschrieben zu werden brauchen. So läßt sich die Drehzahl digital auf induktivem Wege über magnetische Unsymmetrien an der Schwungscheibe der Maschine oder aus der Frequenz der Zündsignale bei einer fremdgezündeten Maschine bestimmen. Bekannt ist ferner die Gewinnung von Drehzahlsignalen aus der von einer Wechselstrom-Lichtmaschine des mit der Maschine ausgerüsteten Fahrzeugs abgegebenen Spannung.

Zur Definition der beiden Betriebsbereiche I und II sind in den Ansteuerkreisen 2 und 3 in Figur 2 ferner lastabhängige Schalter 8 und 9 vorgesehen, von denen der erste nur unterhalb der in Figur 1 mit b bezeichneten Linie und der Schalter 9 nur oberhalb der Linie c in Figur 1 geschlossen ist. Der Schalter 9 kann demgemäß ein Kickdown-Schalter sein.

Die Schalter 6 und 8 bzw. 6 und 9 liegen in Reihe und bilden somit eine UND-Schaltung im jeweiligen Ansteuerstromkreis für einen der Signalgeber 4 und 5. Da ein Hochschalten nur möglich ist beim Betrieb in einem vom höchsten Gang abweichenden Gang, wäre es unzweckmäßig, durch den Signalgeber 4 ein zum Hochschalten aufforderndes Signal zu erzeugen, wenn bereits der höchste Gang eingelegt ist. Entsprechend ist ein Zurückschalten nur möglich, wenn nicht der unterste Gang eingelegt ist. Auch hier wäre es unzweckmäßig, durch den Signalgeber 5 ein Signal zu erzeugen, wenn infolge der getroffenen Gangwahl der durch die Signalgabe verlangte Schaltvorgang nicht möglich ist. Daher enthalten die beschriebenen UND-Schaltungen jeweils einen gangabhängigen Schalter 10 bzw. 11.

Die Kopplung mit dem Schaltgetriebe bzw. dem Schalthebel ist so getroffen, daß der Schalter 10 nur bei eingelegtem höchsten Getriebegang, dagegen der Schalter 11 nur bei eingelegtem ersten Gang geöffnet ist; bei den jeweils anderen Gängen sind diese Schalter geschlossen und bereiten daher einen geschlossenen Ansteuerkreis für den ihnen jeweils zugeordneten Signalgeber 4 bzw. 5 vor.

Wie ohne weiteres aus Figur 2 ersichtlich, erfolgt bei einem innerhalb des Betriebsbereichs I (siehe Figur 1) liegenden Betriebspunkt der Maschine eine Signalgabe nur durch den Signalgeber 4, dagegen bei einem Betriebspunkt innerhalb des Betriebsbereichs II eine Signalgabe nur durch den Signalgeber 5.

Es ist zweckmäßig, zusätzlich zu dieser Einrichtung bei einem Fahrzeug eine Anzeige des wegbezogenen Kraftstoffverbrauchs vorzusehen. Derartige Anzeigevorrichtungen sind an sich bekannt; sie arbeiten in der Regel mit Ausnutzung des Saugrohrunterdrucks als Maß für den Kraftstoffverbrauch. Eine entsprechende Einrichtung zeigt beispielsweise die DE-OS 27 31 065. In diesem Falle ist es zweckmäßig, die in Figur 2 mit 4 und 5 bezeichneten Signalgeber zu integrieren in das Instrument der Verbrauchsanzeige, wie dies in Figur 3 angedeutet ist. Der Zeiger 30 der Kraftstoffverbrauchsanzeige überstreicht im normalen Fahrbetrieb die Skala 31, steht dagegen im Leerlaufbetrieb und bei Vollastbeschleunigungen hinter der Abdeckung 32. In die Skala eingelassen ist der Pfeil 33, der einen Bestandteil eines zum Hochschalten auffordernden Signalgebers darstellt, der also dem Signalgeber 4 in Figur 2 entspricht.

Bei der bisherigen Beschreibung der Erfindung war ihre Anwendung bei einem Schaltgetriebe in den Vordergrund gestellt worden, bei dem alle Gänge von Hand eingelegt werden. Die Erfindung ist sinngemäß jedoch auch bei automatischen Schaltgetrieben mit Vorteil verwendbar, die beispielsweise mit "1" und "2" bezeichnete Stellungen ihres Wählhebels aufweisen, in denen höhere Gänge gesperrt sind. Auch bei einem derartigen Getriebe kann es zweckmäßig sein, durch Einsatz der Erfindung den Fahrer aufzufordern, den Wählhebel in eine andere Stellung zu bringen.

-10-
Leerseite

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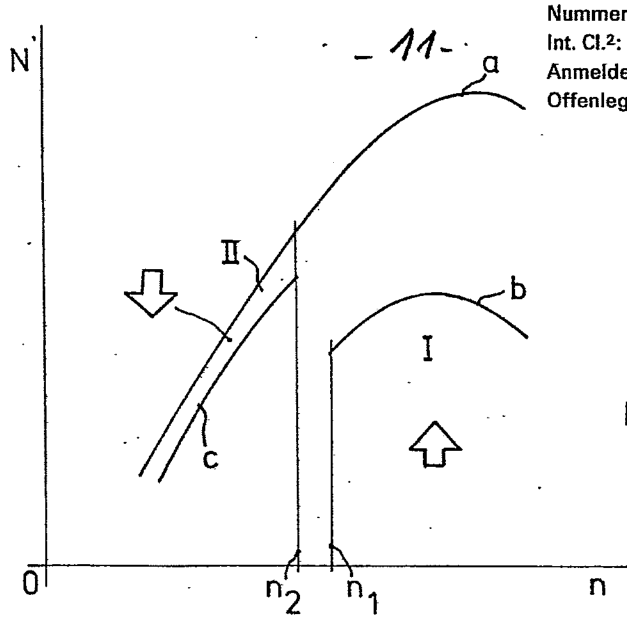

Fig.1

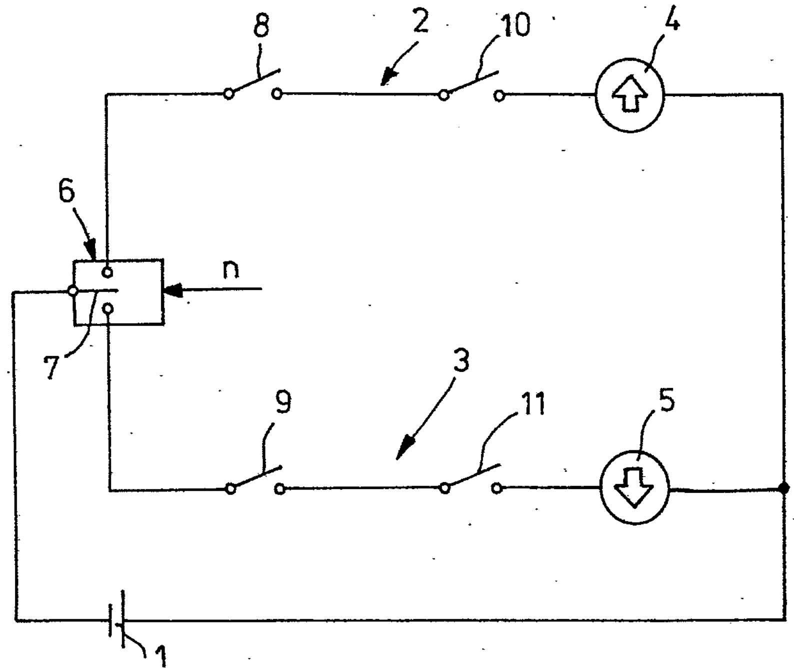

Fig.2

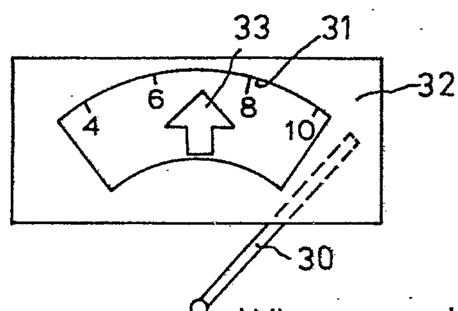

Fig.3

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030063/0283

K 2766

27.6.79

DECLARATION

I, Judith E. Taddeo, declare that I am an ATA-certified translator of German to English and that I have carefully translated the attached English language translation from the original document:

German patent application 29 26 070, entitled
Einrichtung zur Erzielung eines verbrauchsgünstigen Betriebs einer Brennkraftmaschine
[Device for Achieving an Operation of an Internal Combustion Engine that is Advantageous in Terms of Consumption],

filed at the German Patent Office on June 28, 1979 in German, and that the attached translation is an accurate English version of this original to the best of my knowledge and belief.

I certify under penalty of perjury that the foregoing is true and correct.

Date: January 15, 2014

Signature

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(54)	Title	Device for Achieving an Operation of an Internal Combustion Engine that is Advantageous in Terms of Consumption
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DE 29 26 070 A 1

● 12.80 030 063/283 6/60

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27. Juni 1979

CLAIMS

1. A device for obtaining an operation of an internal combustion engine equipped with a conventional transmission, which operation is advantageous in terms of fuel consumption, especially the drive machine of a vehicle,
wherein an engine-speed-dependent and a load-dependent switch (6, 8) are situated as AND-circuit in the control circuit (2) of a signal transmitter (4), which close the control circuit (2) only in the presence of operating points of the engine in a predefined operating range remote from full load (I) in the output/engine speed diagram.

2. The device as recited in Claim 1,
wherein the AND-circuit furthermore includes a gear-dependent switch (10) which interrupts the control circuit (2) only if the highest gear is engaged.

3. The device as recited in Claim 1 or 2,
wherein the operating range remote from full load (I) lies above a predefined engine speed (n_1) of approximately 20 to 50% of the maximum engine speed in the diagram.

4. The device as recited in one of Claims 1 through 3,
wherein the operating range remote from full load (I) lies below the line (b) for approximately 50 to 70 % of the maximum setting of the output control element in the diagram.

5. The device as recited in one of Claims 1 through 4, wherein the signal transmitter (4) is a light that displays an arrow pointing up.

6. The device for obtaining an operation of an internal combustion engine equipped with a conventional transmission, which operation is advantageous in terms of fuel consumption, especially the drive machine of a vehicle, in particular as recited in one of Claims 1 through 5, wherein an engine-speed-dependent switch and a load-dependent switch (6, 9) are situated as AND-circuit in the control circuit (3) of a signal transmitter (5), which close the control circuit (3) only in the presence of operating points of the machine in a predefined operating range close to full load (II) in the output/engine speed diagram, between the rising branch of the full-load line (a) and an adjacent line (c) for a constant position of the output control element.

7. The device as recited in Claim 6, wherein the AND-circuit furthermore includes a gear-dependent switch (11), which interrupts the control circuit (3) only if the first gear is engaged.

8. The device as recited in Claim 6 or 7, wherein the operating range close to full load (II) lies below a predefined engine speed (n_2) of approximately 40 to 70 % of the maximum engine speed in the diagram.

9. The device as recited in one of Claims 6 through 8, wherein the load-dependent switch (9) assigned to the operating range close to full load (II) is a kickdown switch.

10. The device as recited in one of Claims 5 through 9, wherein the signal transmitter (5) assigned to the operating range close to full load (II) is a light which displays an arrow pointing down.

11. The device as recited in one of Claims 1 through 5 and in one of Claims 6 through 10,
wherein both control circuits (2, 3) include a shared voltage source (1), and the engine-speed-dependent switches are embodied as change-over switch (6).

12. The device as recited in Claim 11,
wherein the change-over switch (6) has three switch positions, the switch assuming the middle position, which does not lead to any of the control circuits (2, 3), at engine speed values that lie between the engine speeds (n_1, n_2) delimiting the two operating ranges (I, II) in the diagram.

13. The device as recited in Claim 5 and/or 10,
wherein the signal transmitter(s) (33) are/is integrated into a fuel consumption display (31).

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Device for Achieving an Operation of an Internal Combustion Engine that is Advantageous in Terms of Consumption

The invention relates to a method according to the definition of the species in Claims 1 and 6. In the first place, the use in a drive machine of a motor vehicle is envisioned, but in principle, the invention may also be used to advantage in stationary internal combustion engines that are operated at different outputs and different engine speeds.

The fuel consumption of an internal combustion engine equipped with a standard transmission essentially depends on the position of its operating point in the load/engine speed diagram of the engine. Basically, two scenarios can be distinguished in this context: The position of the operating point of the engine in an operating range remote from full load with an engagement of one of the lower or middle gears may actually ensure the desired output, but it is accompanied by very high fuel consumption. Therefore, it is useful to switch to the next higher or to the highest gear and to thereby adjust an operating point closer to full load. In the second case, an operating point close to full load may be present, but despite the full throttle setting (maximum setting) of the output control element, which means the throttle valve in carburetor engines and the injection controller in injection engines in the framework of the invention, the desired output is unable to be achieved with an engagement of a higher or the highest gear; apart from that, this operating mode of the engine is likewise not advantageous from the aspect of consumption.

Both cases have in common that the disadvantage of high fuel consumption due to upshifting and downshifting of the gears can be avoided without reducing the output of the engine. However, in practice it has become abundantly clear, for instance in the case of drivers of cars, especially unpracticed drivers such as drivers who previously have driven cars with automatic transmission, that there is frequently confusion about the influence that the position of the operating point of the engine can have on the fuel consumption, and also confusion as to when a change in gear may be useful.

The present invention is based on the objective of providing a device that assists the operator of the internal combustion engine equipped with a conventional transmission, i.e., the driver of a motor vehicle, for example, in setting an operating point of the engine that is advantageous in terms of consumption, by way of gear shift operations. The means for attaining the object according to the invention is characterized by the features of the independent claims.

An essential advantage of the invention is that the device supplies a signal that requests a switchover and is obtained from an output/engine speed diagram associated with the engine, so that subjective aspects, such as the frequently incorrect "feel" of the vehicle driver, are excluded.

The present invention is explained in detail below, using the drawing. The figures show:

Figure 1 the output/engine speed diagram of an internal combustion engine equipped with a conventional transmission, showing two operating ranges that are disadvantageous from the aspect of consumption;

Figure 2 the circuit diagram of an exemplary embodiment of the device according to the invention; and

Figure 3 an advantageous development of the signal transmitter.

As can be seen when viewing Figure 1 to begin with, output N of the engine has been plotted across engine speed n. a is the curve of the output at full load, b is a line that represents a constant setting of the output control element, i.e., a line that represents a constant throttle valve angle in a carburetor engine. As a measure thereof, in addition to the throttle valve angle itself, it is also possible to use the induction manifold vacuum. Line b which delimits a first undesired operating range I will generally lie between roughly 50 and 70% of the maximum setting of the output control element. c is likewise a line of a constant setting of the output control element or a constant induction manifold vacuum; however, in contrast to range I, it delimits an operating range II close to full load that is likewise undesirable. Line c could correspond to the kickdown setting of an accelerator pedal. The operating ranges I and II are further delimited by engine speed values n_1 or n_2, the first of which usually lies between approximately 20 to 50% of the maximum engine speed, and the second usually lies between approximately 40 and 70% of the maximum engine speed.

The numerical values of the limits of the two operating ranges I and II are of course dependent on the individual situation. In general, it can be said that these two operating ranges lie in such a way that by shift operations, it is possible to achieve operating points in the output/engine speed diagram that are more favorable in terms of fuel consumption.

Looking initially at operating range I remote from full load, the desired output at a lower specific fuel consumption is able to be achieved after upshifting into the next higher gear, at an operating point that lies to the left of operating range I in the diagram of Figure 1. Accordingly, the device of the present invention generates a signal that asks the operator, i.e., normally the driver, to shift to a higher gear, which is indicated in Figure 1 by the upward pointing arrow within operating range I.

The position of the operating point of the engine in operating range II close to full load, i.e., to the left of engine speed n_2 in Figure 1, first of all has the basic disadvantage that the desired higher output is not obtained despite the fact that the accelerator pedal or the output control element is in the full throttle position. Only after shifting to the next lower gear will the desired higher output be achieved at higher engine speeds. Another disadvantage of the position of the operating point in operating range II is the relatively high fuel consumption. When the operating point lies in operating range II, the device according to the present invention generates a signal that asks the driver to downshift, which is indicated by the downward pointing arrow at operating range II in Figure 1. It should be added at this point that it may be useful to assign a pressure point to the accelerator pedal in the kickdown position (line c).

Figure 2 shows a specific development of the device according to the invention, which generates different signals at an especially low outlay, depending on whether the particular operating point of the engine lies in operating range I or in operating range II.

Voltage source 1 is shared by both signal transmitters 4 and 5 situated in a control circuit 2 and 3, respectively. Both signal transmitters are lights displaying an arrow that points up or down, which asks the operator to shift up or down upon actuation of the respective signal transmitter.

The two control circuits 2 and 3 are selectively closed by engine-speed dependent change-over switch 6, to which a signal that corresponds to the individual engine speed n is forwarded and which is developed in such a way that at engine speeds that are greater than predefined engine speed n_1 (see Figure 1), its shift lever 7 pivots upwardly in Figure 2, but at engine speeds that are smaller than predefined engine speed n_2, it pivots in the downward direction from a neutral center position, which it therefore assumes when engine speed values between n_1 and n_2 are present.

The engine speed signal is obtained with the aid of known sensor systems, which therefore need not be described in further detail here. For example, the engine speed is able to be ascertained digitally in inductive manner via magnetic asymmetries at the flywheel of the engine, or from the frequency of the ignition signals in an engine having externally supplied ignition. It is furthermore known to obtain engine speed signals from the voltage that is output by an AC alternator of the vehicle equipped with the engine.

Furthermore, to define the two operating ranges I and II, load-dependent switches 8 and 9 are provided in control circuits 2 and 3 in Figure 2, the first of which is closed only below the line denoted by b in Figure 1, and switch 9 is closed only above the line denoted by c in Figure 1. Switch 9 thus may be a kickdown switch.

Switches 6 and 8 or 6 and 9 are set up in series and consequently form an AND-circuit in the control current circuit of one of signal transmitters 4 and 5. Since upshifting is possible only in an operation using a gear that differs from the highest gear, it would not be useful for signal transmitter 4 to generate a signal requesting upshifting in a case where the highest gear is already engaged. Conversely, downshifting is possible only if the lowest gear is not engaged. Here, too, it would be impractical for signal transmitter 5 to generate a signal if the shift operation requested by the signal output would be impossible due to the gear selection made. For this reason, each of the described AND-circuits includes a gear-dependent switch 10 and 11, respectively.

The coupling with the conventional transmission or the gear lever is implemented in such a way that switch 10 is open only when the highest gear is engaged, while switch 11 is open only when first gear is engaged; the switches are closed for the respective other gears, and thus prepare a closed control circuit for the individual signal transmitter 4 or 5 that is assigned to them.

As is readily apparent from Figure 2, in an operating point of the engine that lies within operating range I (see Figure 1), a signal is given only by signal transmitter 4, whereas in an operating point within operating range II, a signal is given only by signal transmitter 5.

It is useful if in addition to this device, a display of the route-specific fuel consumption is provided in a vehicle. Such display devices are known per se; they generally utilize the induction manifold vacuum as a measure of the fuel consumption. A corresponding device is shown in DE-OS 27 31 065, for example. In this case, it is useful to integrate the signal transmitters denoted by 4 and 5 in Figure 2 into the instrument of the fuel consumption display, as sketched in Figure 3. During standard driving operation, pointer 30 of the fuel consumption display sweeps scale 31, while it is hidden behind cover 32 during an idling operation or at full-load accelerations. Incorporated in the scale is arrow 33, which constitutes part of a signal transmitter requesting upshifting, which therefore corresponds to signal transmitter 4 in Figure 2.

Up to this point, the use in a conventional transmission, in which all gears are shifted manually, has been the focus in the description of the present invention. By analogy, however, the present invention is able to be used to advantage in automatic transmissions as well, which, for example, feature positions denoted by "1" and "2" on their selection lever, in which higher gears are blocked. In transmissions of this type as well, it may be useful to employ the present invention in order to ask the driver to switch the selector lever to a different position.

-10-

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EXHIBIT 15

US005357438A

United States Patent [19]

Davidian

[11] **Patent Number: 5,357,438**

[45] **Date of Patent: Oct. 18, 1994**

[54] **ANTI-COLLISION SYSTEM FOR VEHICLES**

[76] Inventor: **Dan Davidian**, 16 Mania Shochat, Holon, Israel

[21] Appl. No.: **70,817**

[22] Filed: **Jun. 3, 1993**

[30] **Foreign Application Priority Data**

Jun. 4, 1992 [IL] Israel 102097

[51] **Int. Cl.**[5] **G06F 15/50**

[52] **U.S. Cl.** **364/461;** 364/426.04; 342/455; 340/436; 180/169

[58] **Field of Search** .... 364/460, 461, 424.01, 364/424.04, 426.04; 340/435, 436, 437, 438, 961; 342/29, 41, 455; 434/236, 238, 258; 273/440; 180/167–169; 73/517 A

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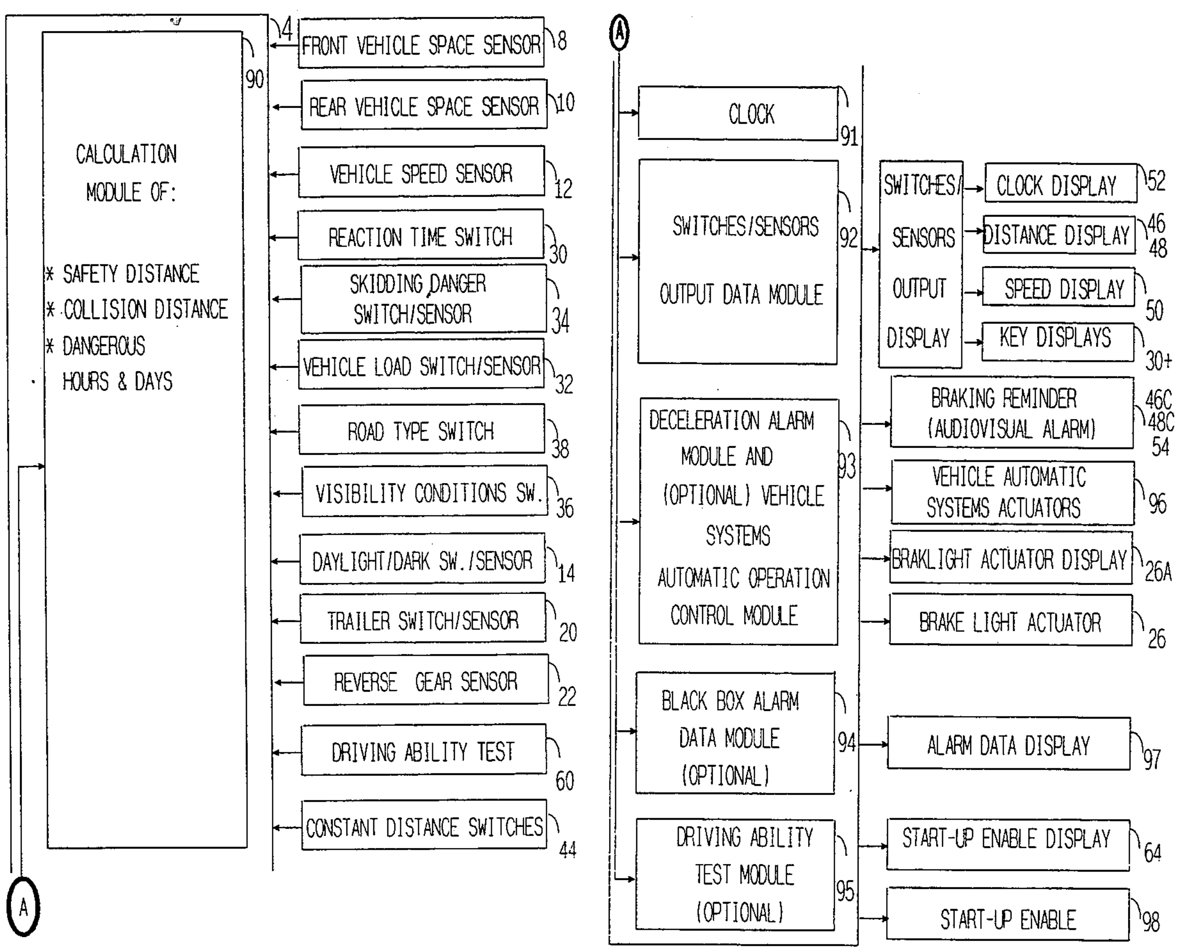
Primary Examiner—Gary Chin

Attorney, Agent, or Firm—Benjamin J. Barish

[57] **ABSTRACT**

An anti-collision system for vehicles includes a speed sensor for sensing the speed of the vehicle, a space sensor for measuring the distance of the vehicle from an object, a computer for computing a danger-of-collision distance to the object, an alarm actuated by the computer when the sensed distance of the object is equal to or less than the danger-of-collision distance compared by the computer, and a brake light actuated upon the actuation of said alarm. The system also includes a control panel having parameter presetting means for presetting preselected parameters concerning the vehicle, the vehicle driver, and the environment, which are utilized by the computer for computing the danger-of-collision distance to the object.

20 Claims, 30 Drawing Sheets



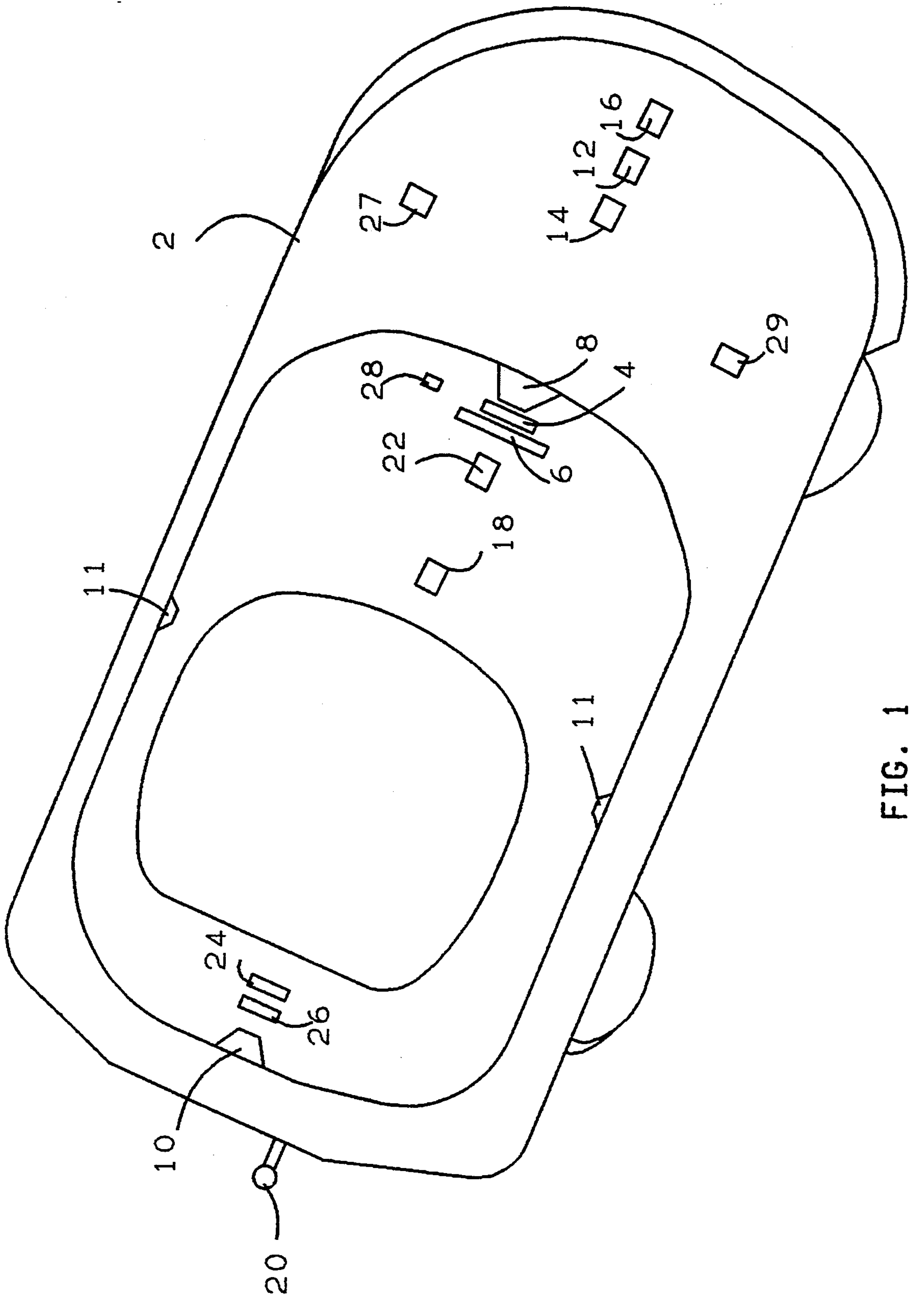


FIG. 1

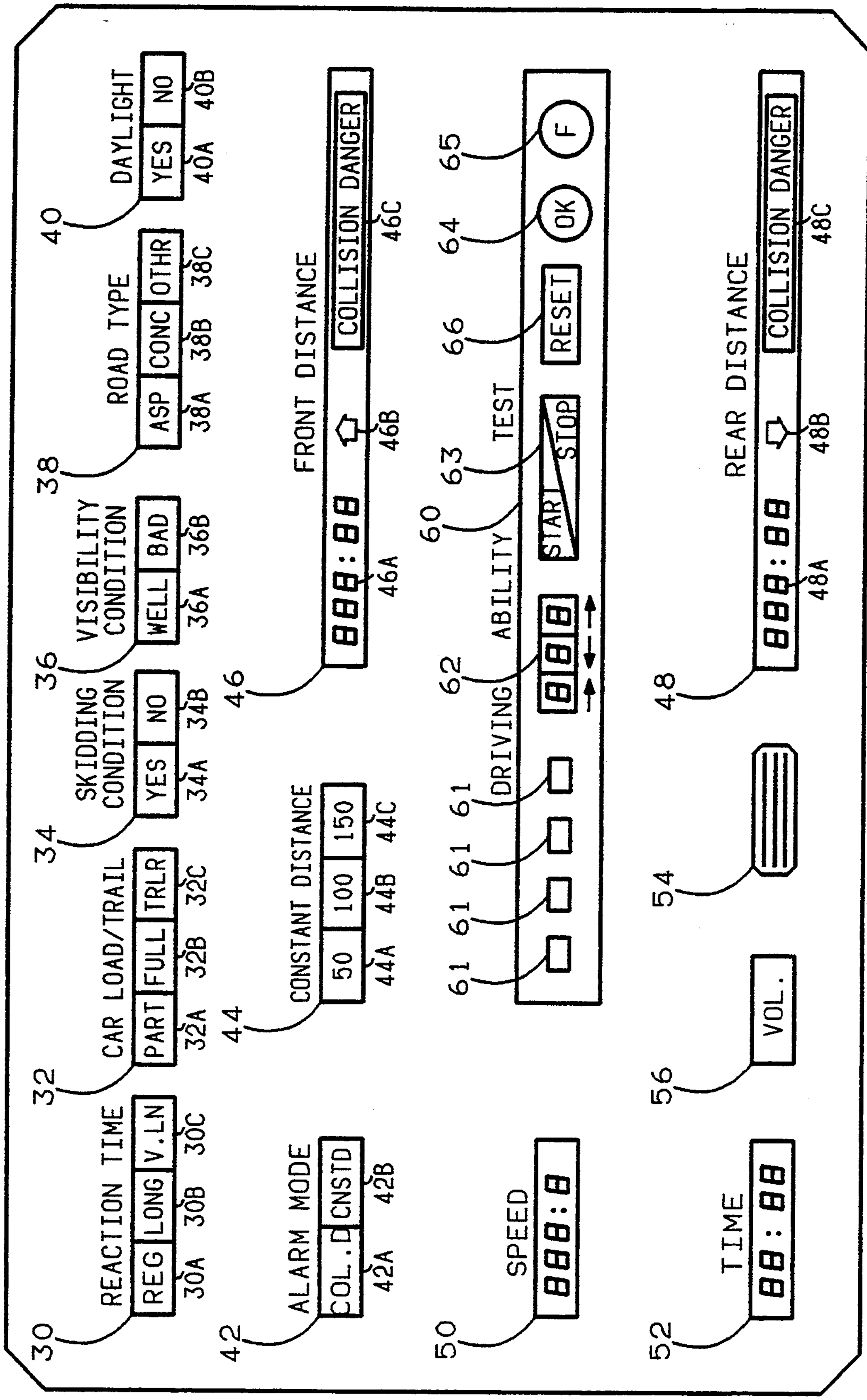

REACTION TIME
REG
LONG
V.LN
30
30A
30B
30C
CAR LOAD/TRAIL
PART
FULL
TRLR
32
32A
32B
32C
SKIDDING CONDITION
YES
NO
34
34A
34B
VISIBILITY CONDITION
WELL
BAD
36
36A
36B
ROAD TYPE
ASP
CONC
OTHR
38
38A
38B
38C
DAYLIGHT
YES
NO
40
40A
40B
ALARM MODE
COL.D
CNSTD
42
42A
42B
CONSTANT DISTANCE
50
100
150
44
44A
44B
44C
FRONT DISTANCE
888:88
COLLISION DANGER
46
46A
46B
46C
SPEED
888:8
50
DRIVING ABILITY TEST
START
STOP
RESET
OK
F
60
61
62
63
64
65
66
TIME
88:88
52
VOL.
56
54
REAR DISTANCE
888:88
COLLISION DANGER
48
48A
48B
48C
6

FIG. 2

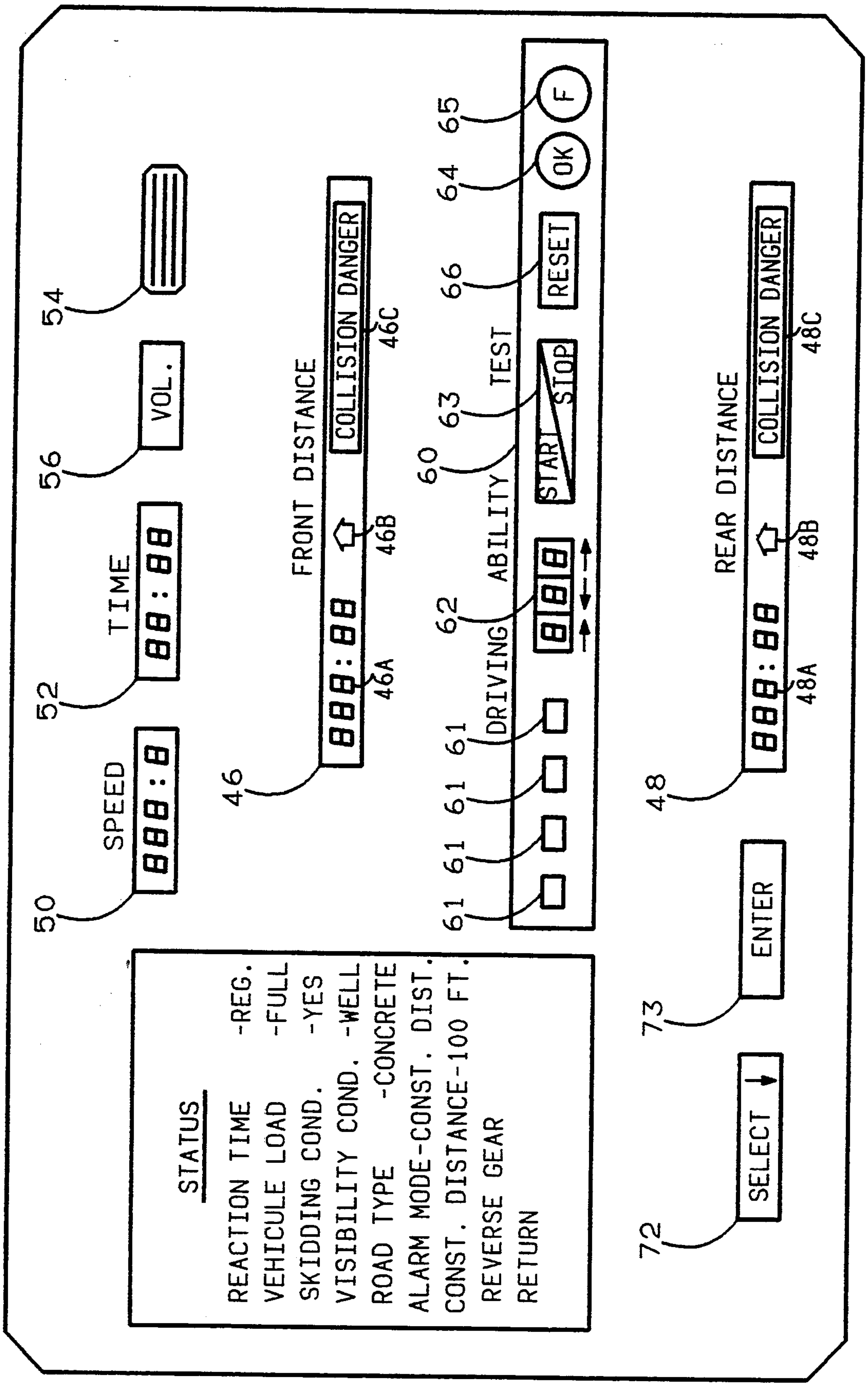

SPEED
888:8
TIME
88:88
VOL.
FRONT DISTANCE
888:88
COLLISION DANGER
DRIVING ABILITY TEST
888
START
STOP
RESET
OK
F
REAR DISTANCE
888:88
COLLISION DANGER
STATUS
REACTION TIME -REG.
VEHICULE LOAD -FULL
SKIDDING COND. -YES
VISIBILITY COND. -WELL
ROAD TYPE -CONCRETE
ALARM MODE-CONST. DIST.
CONST. DISTANCE-100 FT.
REVERSE GEAR
RETURN
ENTER
SELECT
50
52
56
54
46
46A
46B
46C
60
61
62
63
64
65
66
48
48A
48B
48C
72
73

FIG. 3

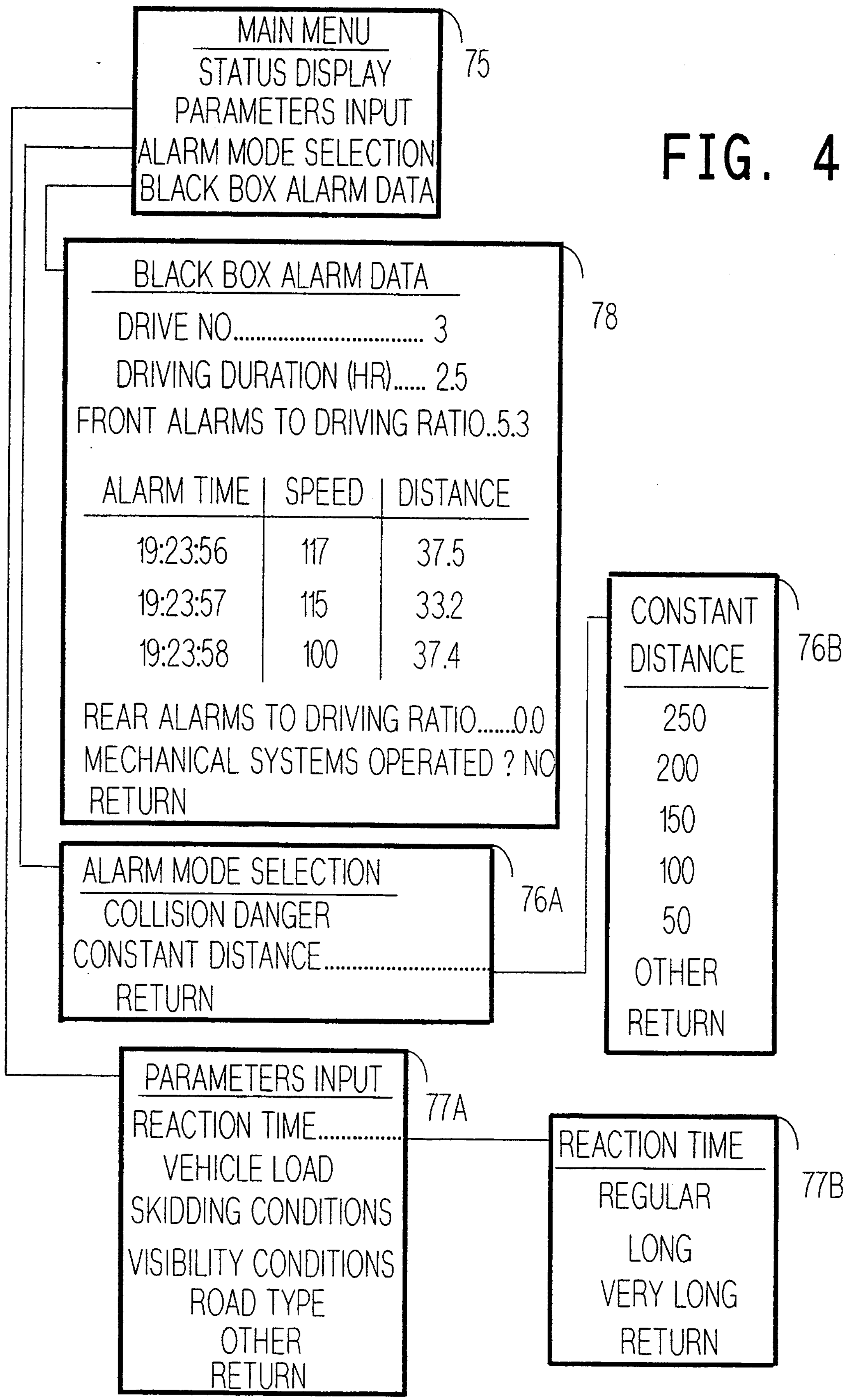

MAIN MENU
STATUS DISPLAY
PARAMETERS INPUT
ALARM MODE SELECTION
BLACK BOX ALARM DATA
75
BLACK BOX ALARM DATA
DRIVE NO.................................. 3
DRIVING DURATION (HR)...... 2.5
FRONT ALARMS TO DRIVING RATIO..5.3
ALARM TIME | SPEED | DISTANCE
19:23:56 | 117 | 37.5
19:23:57 | 115 | 33.2
19:23:58 | 100 | 37.4
REAR ALARMS TO DRIVING RATIO.......0.0
MECHANICAL SYSTEMS OPERATED ? NO
RETURN
78
CONSTANT DISTANCE
250
200
150
100
50
OTHER
RETURN
76B
ALARM MODE SELECTION
COLLISION DANGER
CONSTANT DISTANCE.............................
RETURN
76A
PARAMETERS INPUT
REACTION TIME..............
VEHICLE LOAD
SKIDDING CONDITIONS
VISIBILITY CONDITIONS
ROAD TYPE
OTHER
RETURN
77A
REACTION TIME
REGULAR
LONG
VERY LONG
RETURN
77B

FIG. 4

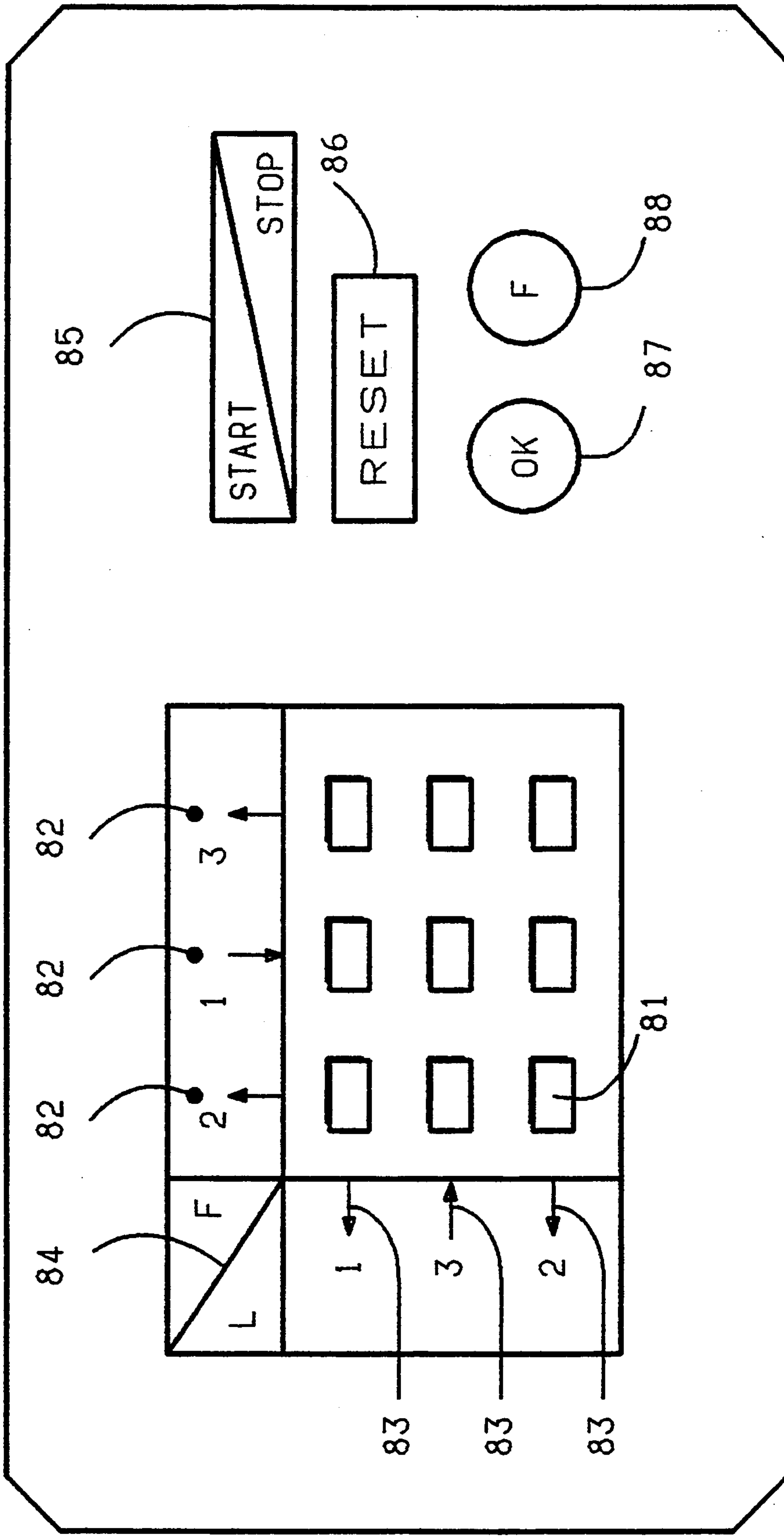
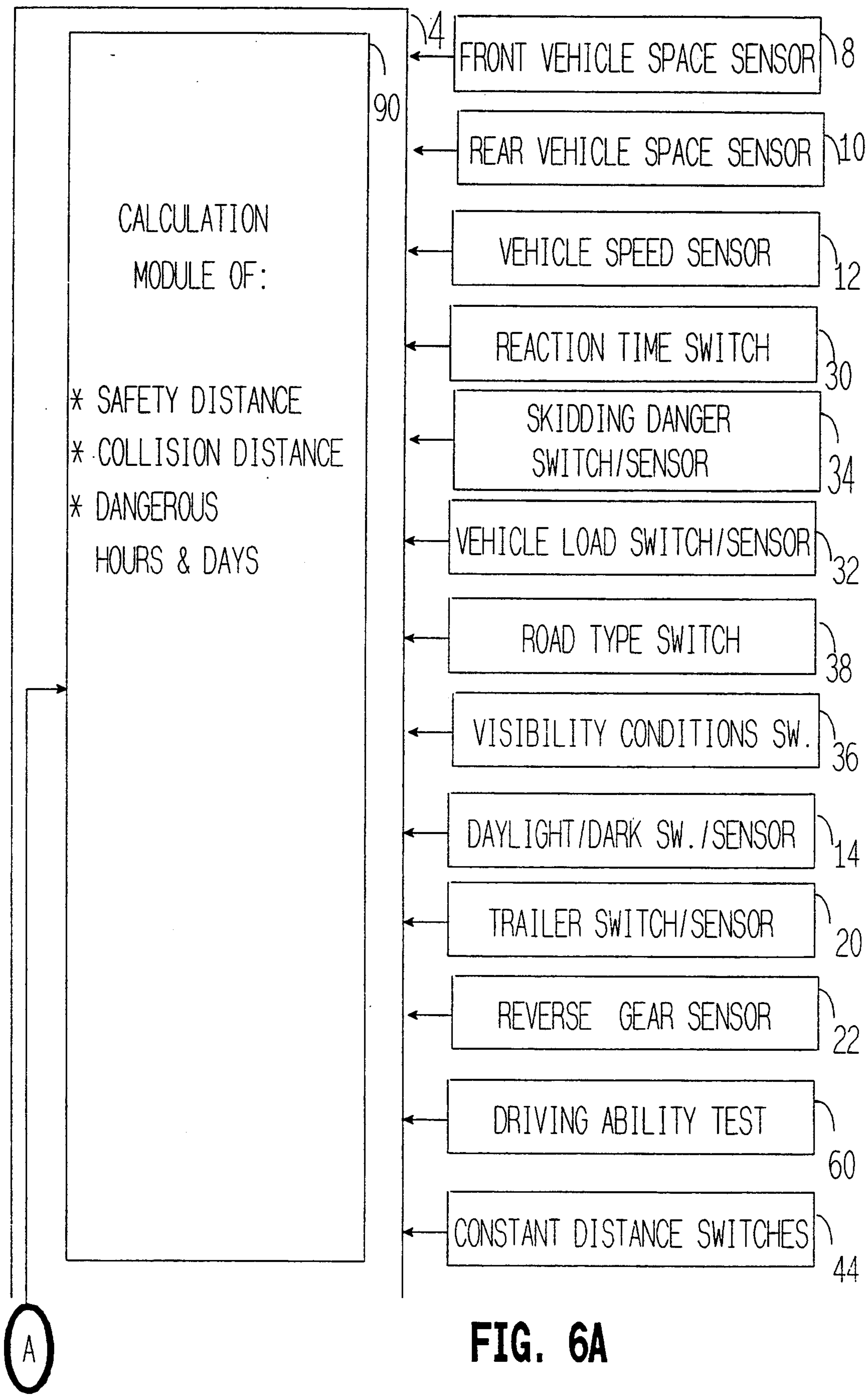


FIG. 5



CALCULATION MODULE OF:
* SAFETY DISTANCE
* COLLISION DISTANCE
* DANGEROUS HOURS & DAYS
90
4
FRONT VEHICLE SPACE SENSOR
8
REAR VEHICLE SPACE SENSOR
10
VEHICLE SPEED SENSOR
12
REACTION TIME SWITCH
30
SKIDDING DANGER SWITCH/SENSOR
34
VEHICLE LOAD SWITCH/SENSOR
32
ROAD TYPE SWITCH
38
VISIBILITY CONDITIONS SW.
36
DAYLIGHT/DARK SW./SENSOR
14
TRAILER SWITCH/SENSOR
20
REVERSE GEAR SENSOR
22
DRIVING ABILITY TEST
60
CONSTANT DISTANCE SWITCHES
44
A

FIG. 6A

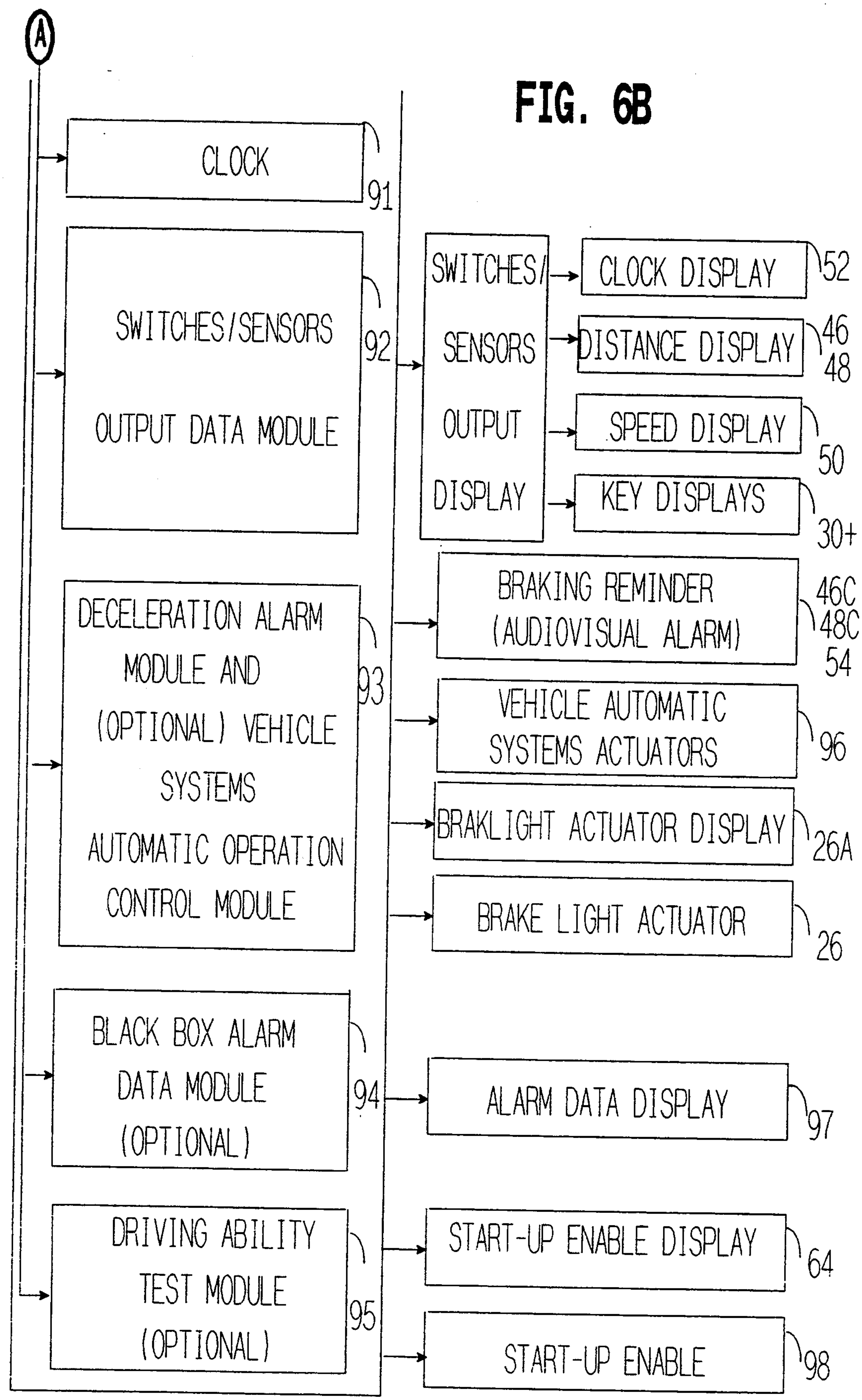

A
CLOCK
91
SWITCHES/SENSORS
OUTPUT DATA MODULE
92
SWITCHES/
SENSORS
OUTPUT
DISPLAY
CLOCK DISPLAY
52
DISTANCE DISPLAY
46
48
SPEED DISPLAY
50
KEY DISPLAYS
30+
DECELERATION ALARM
MODULE AND
(OPTIONAL) VEHICLE
SYSTEMS
AUTOMATIC OPERATION
CONTROL MODULE
93
BRAKING REMINDER
(AUDIOVISUAL ALARM)
46C
48C
54
VEHICLE AUTOMATIC
SYSTEMS ACTUATORS
96
BRAKLIGHT ACTUATOR DISPLAY
26A
BRAKE LIGHT ACTUATOR
26
BLACK BOX ALARM
DATA MODULE
(OPTIONAL)
94
ALARM DATA DISPLAY
97
DRIVING ABILITY
TEST MODULE
(OPTIONAL)
95
START-UP ENABLE DISPLAY
64
START-UP ENABLE
98

FIG. 6B

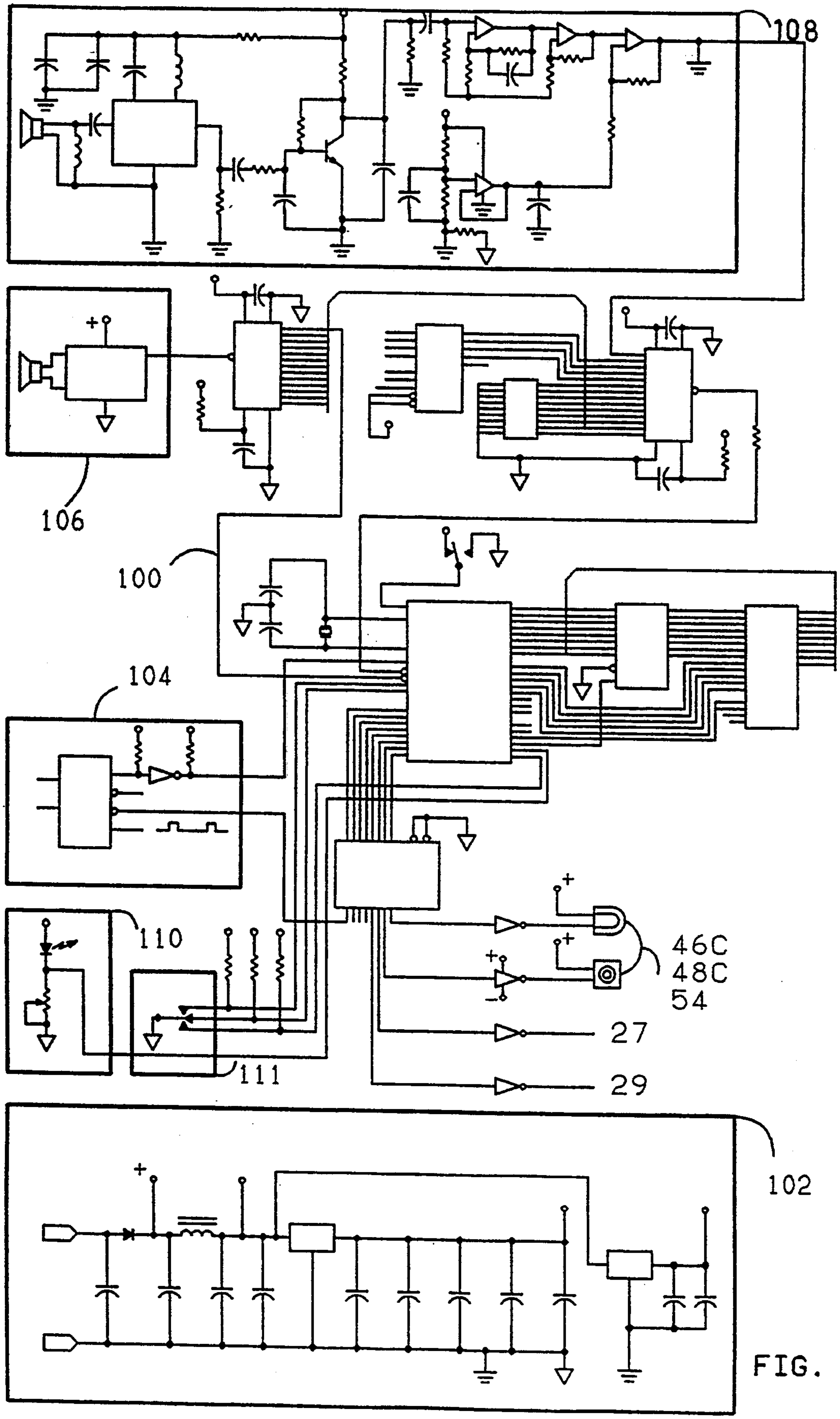


FIG. 7

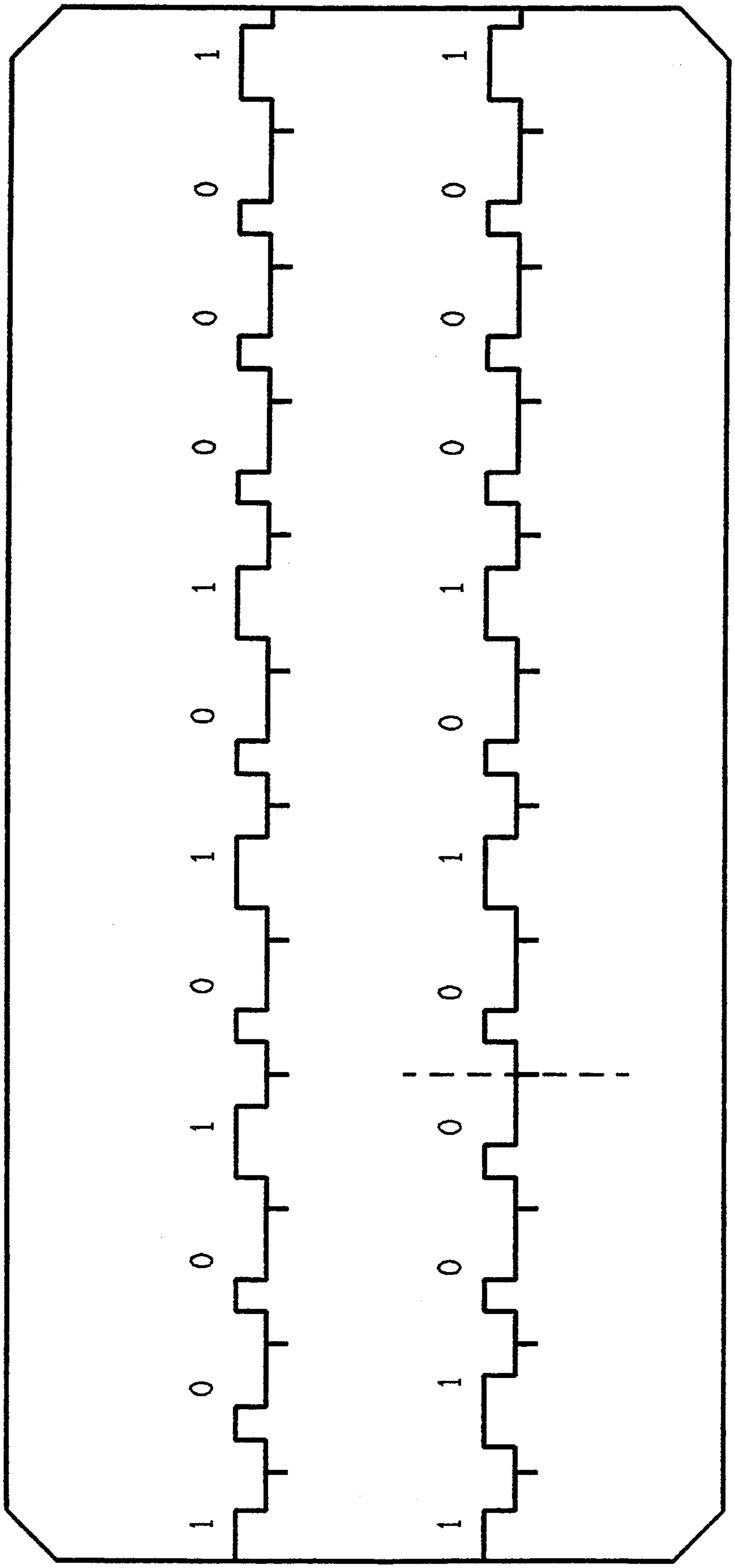
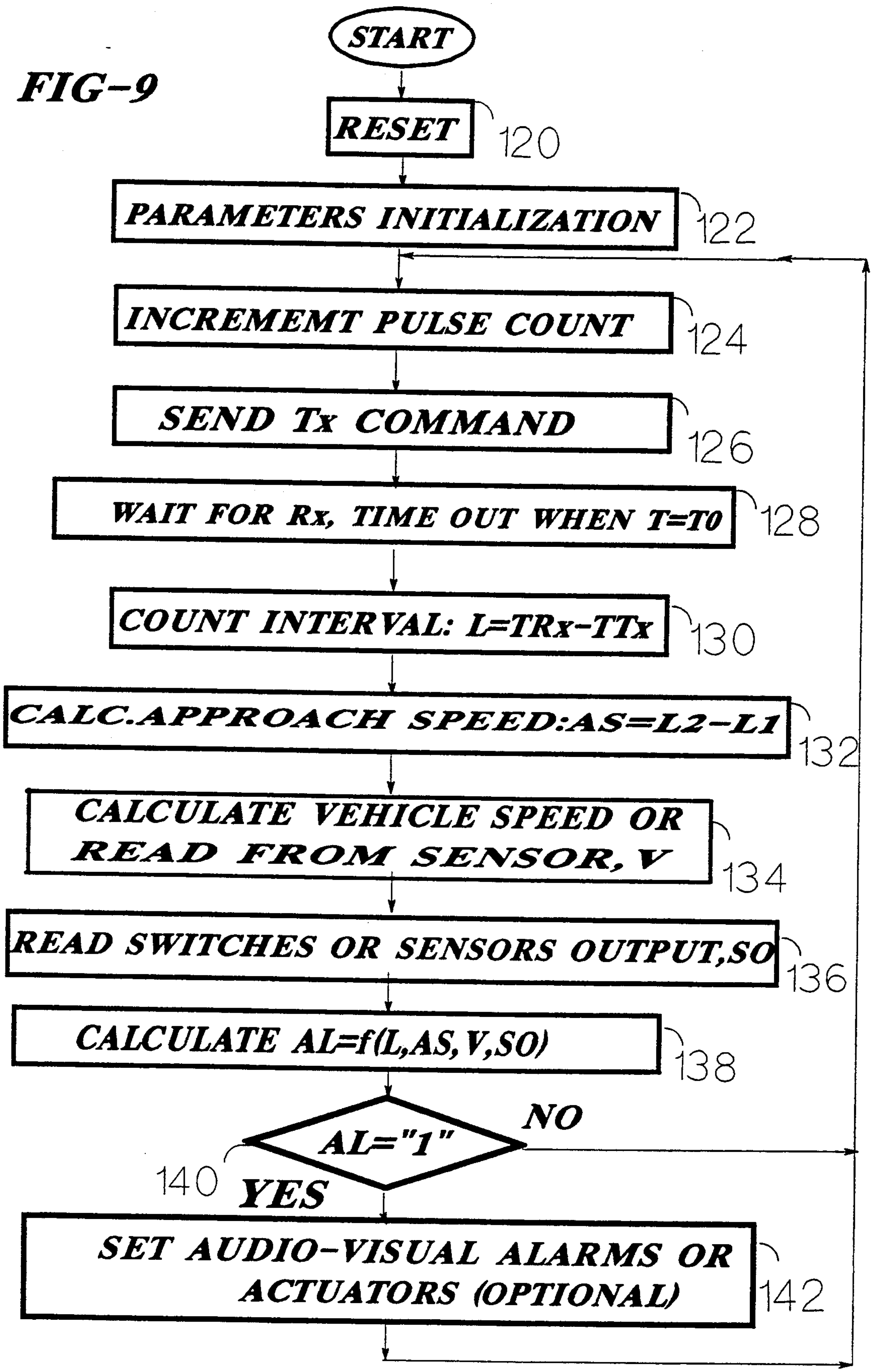


FIG. 8

FIG-9


START
RESET
120
PARAMETERS INITIALIZATION
122
INCREMEMT PULSE COUNT
124
SEND Tx COMMAND
126
WAIT FOR Rx, TIME OUT WHEN T=T0
128
COUNT INTERVAL: L=TRx-TTx
130
CALC.APPROACH SPEED:AS=L2-L1
132
CALCULATE VEHICLE SPEED OR READ FROM SENSOR, V
134
READ SWITCHES OR SENSORS OUTPUT,SO
136
CALCULATE AL=f(L,AS,V,SO)
138
AL="1"
NO
140
YES
SET AUDIO-VISUAL ALARMS OR ACTUATORS (OPTIONAL)
142

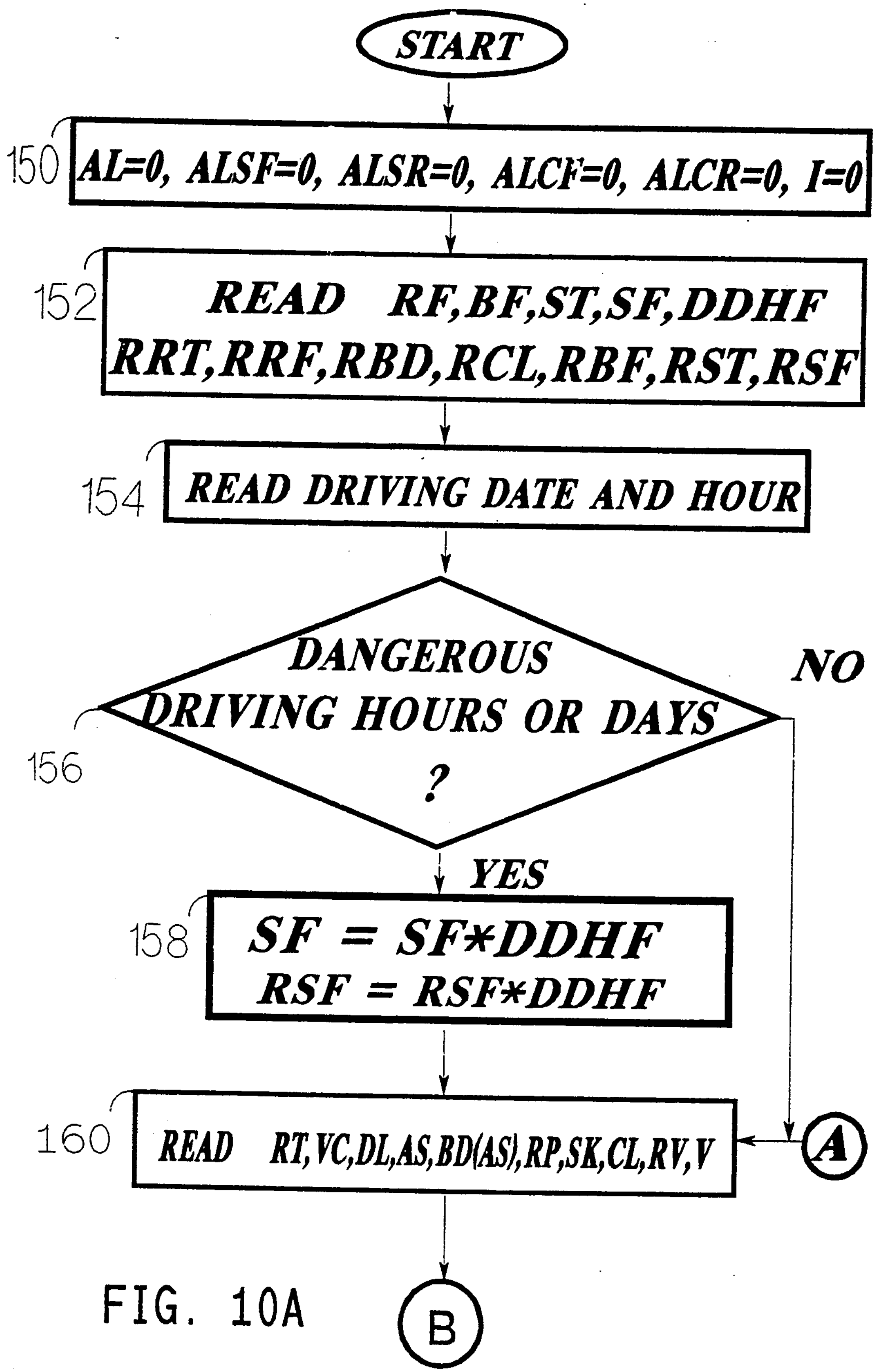
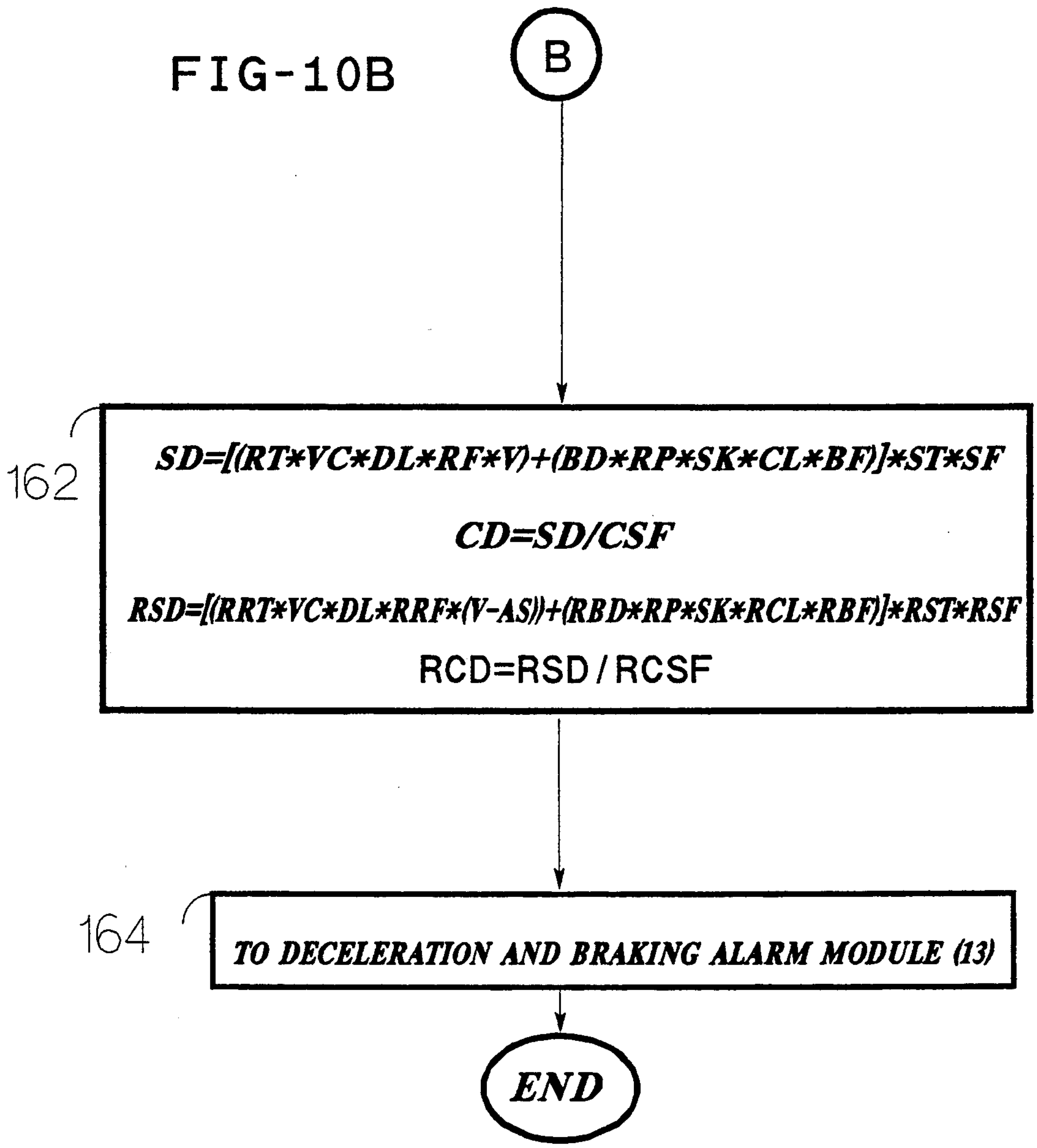

START
150
AL=0, ALSF=0, ALSR=0, ALCF=0, ALCR=0, I=0
152
READ RF,BF,ST,SF,DDHF
RRT,RRF,RBD,RCL,RBF,RST,RSF
154
READ DRIVING DATE AND HOUR
156
DANGEROUS
DRIVING HOURS OR DAYS
?
NO
YES
158
SF = SF*DDHF
RSF = RSF*DDHF
160
READ RT,VC,DL,AS,BD(AS),RP,SK,CL,RV,V
A
B

FIG. 10A

FIG-10B


B
162
SD=[(RT*VC*DL*RF*V)+(BD*RP*SK*CL*BF)]*ST*SF
CD=SD/CSF
RSD=[(RRT*VC*DL*RRF*(V-AS))+(RBD*RP*SK*RCL*RBF)]*RST*RSF
RCD=RSD / RCSF
164
TO DECELERATION AND BRAKING ALARM MODULE (13)
END

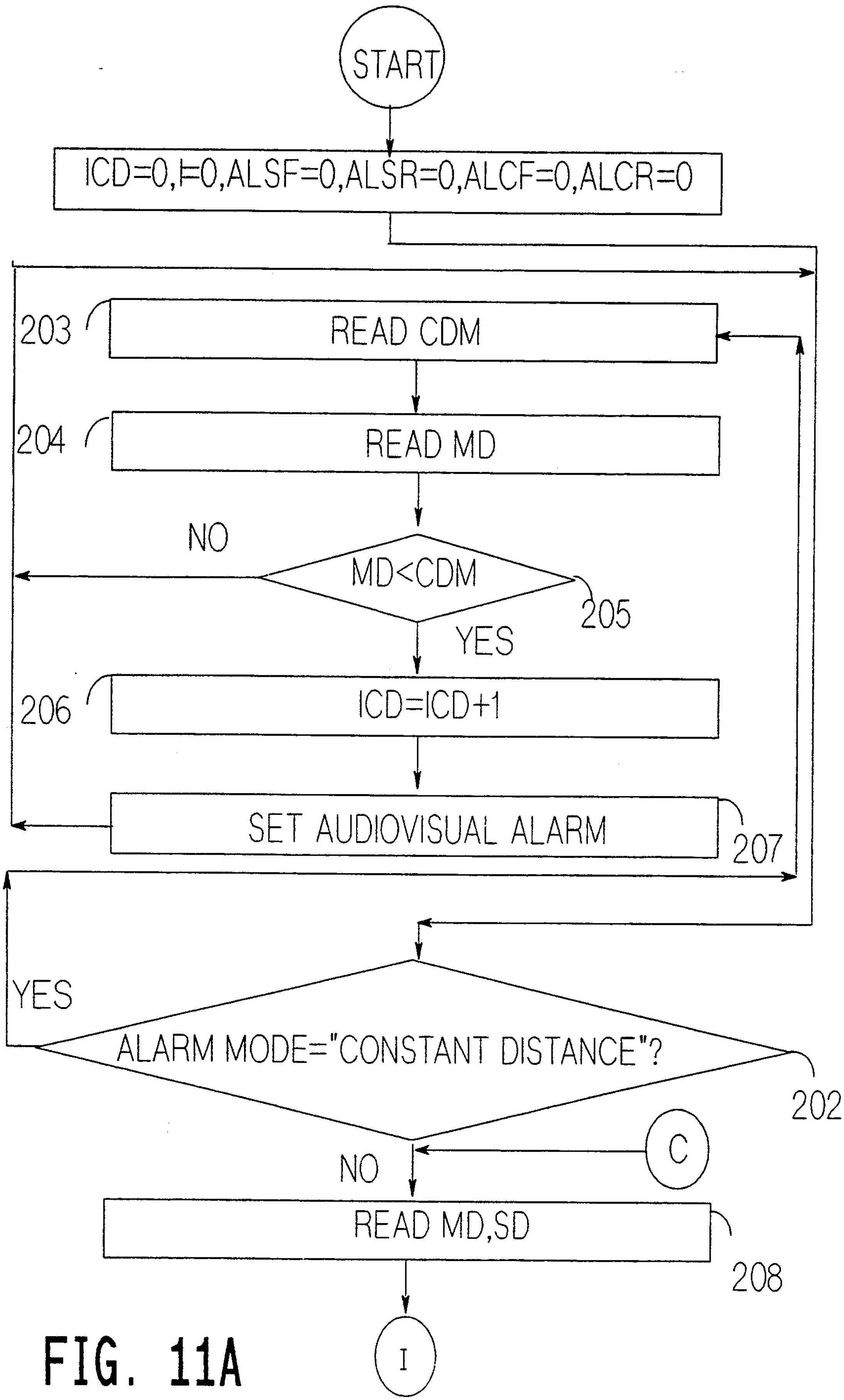

START
ICD=0,I=0,ALSF=0,ALSR=0,ALCF=0,ALCR=0
203
READ CDM
204
READ MD
NO
MD<CDM
205
YES
206
ICD=ICD+1
SET AUDIOVISUAL ALARM
207
YES
ALARM MODE="CONSTANT DISTANCE"?
202
C
NO
READ MD,SD
208
I

FIG. 11A

FIG. 11B

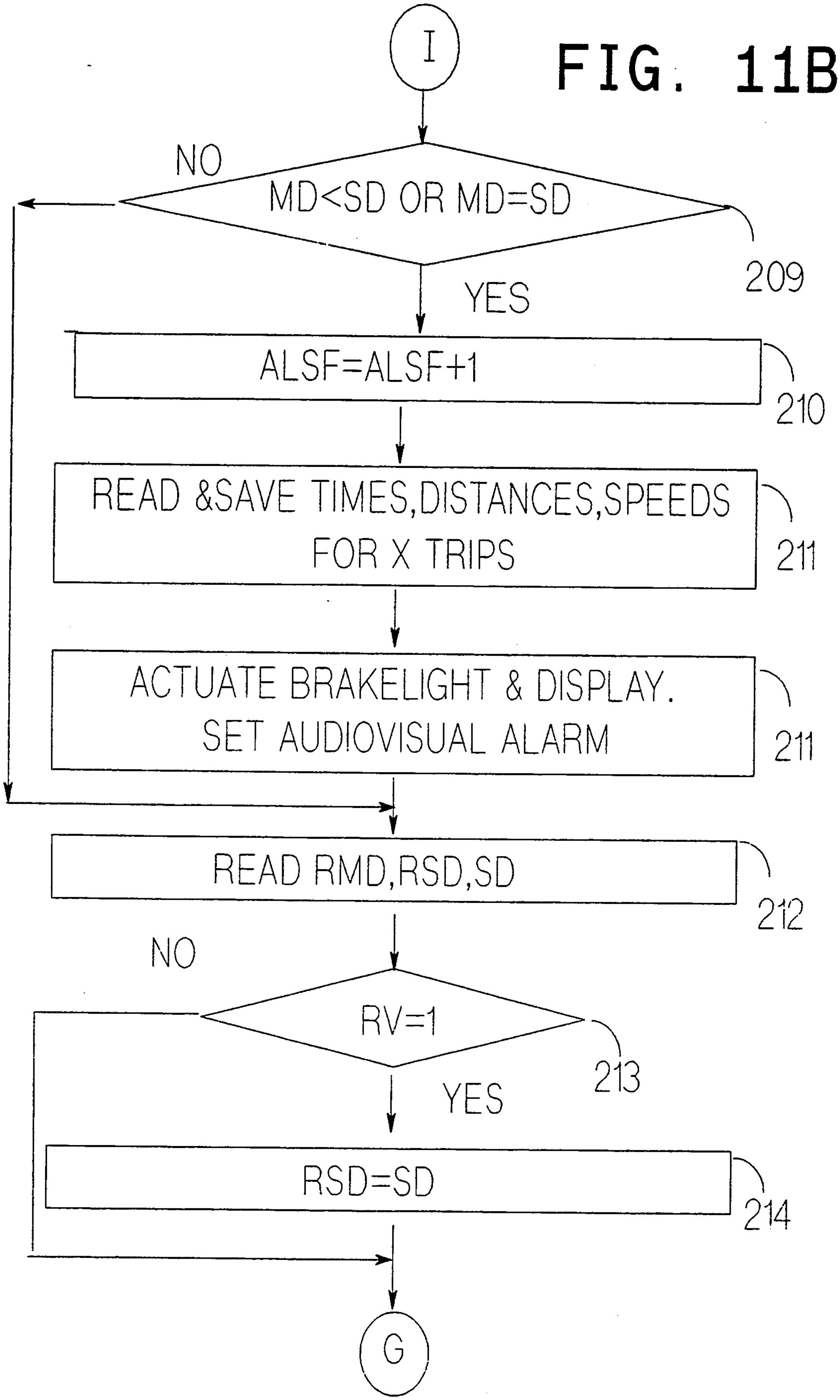
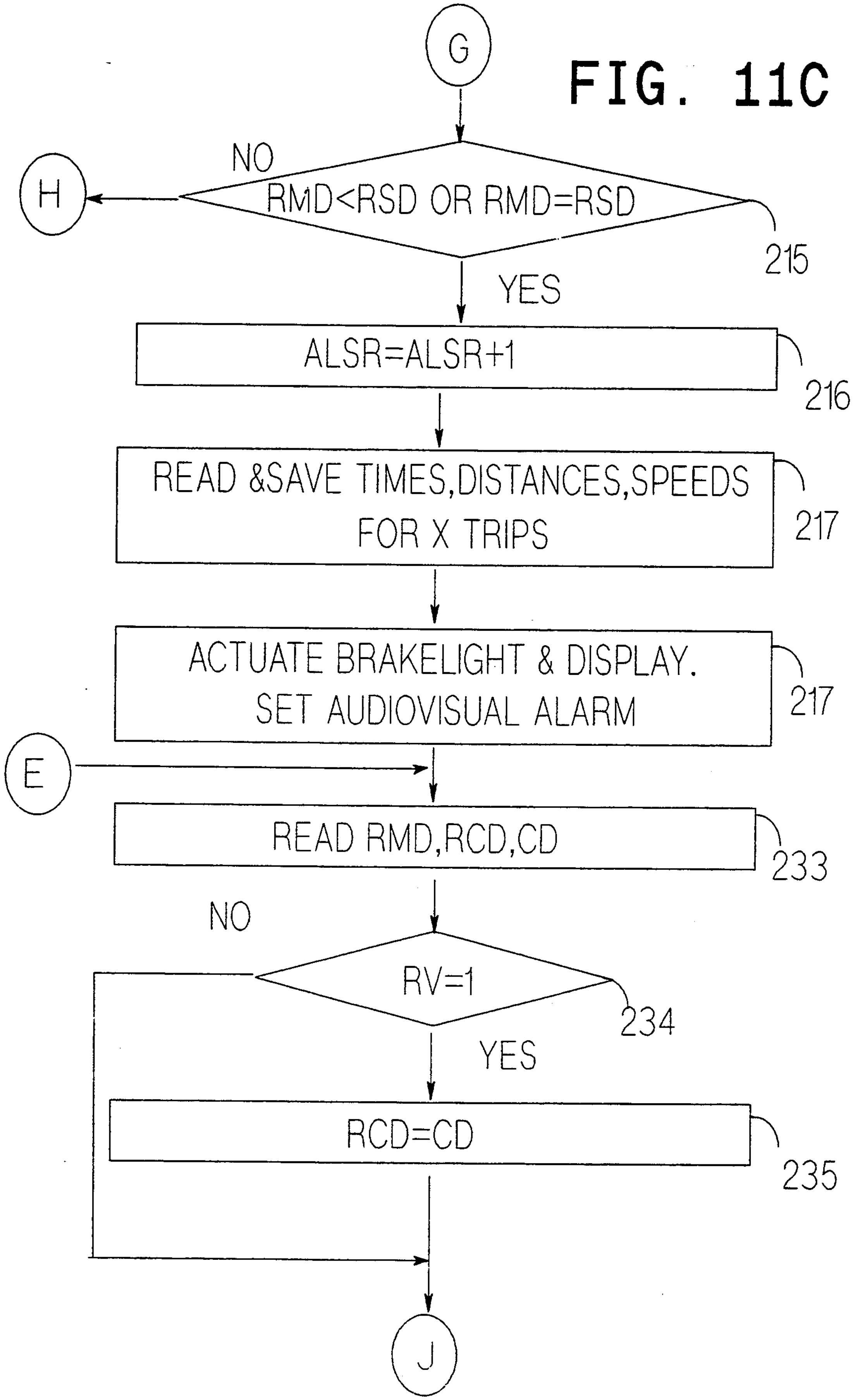

I
NO
MD<SD OR MD=SD
209
YES
ALSF=ALSF+1
210
READ &SAVE TIMES,DISTANCES,SPEEDS FOR X TRIPS
211
ACTUATE BRAKELIGHT & DISPLAY. SET AUDIOVISUAL ALARM
211
READ RMD,RSD,SD
212
NO
RV=1
213
YES
RSD=SD
214
G

FIG. 11C



G
NO
H
RMD<RSD OR RMD=RSD
215
YES
ALSR=ALSR+1
216
READ &SAVE TIMES,DISTANCES,SPEEDS FOR X TRIPS
217
ACTUATE BRAKELIGHT & DISPLAY. SET AUDIOVISUAL ALARM
217
E
READ RMD,RCD,CD
233
NO
RV=1
234
YES
RCD=CD
235
J

FIG. 11D

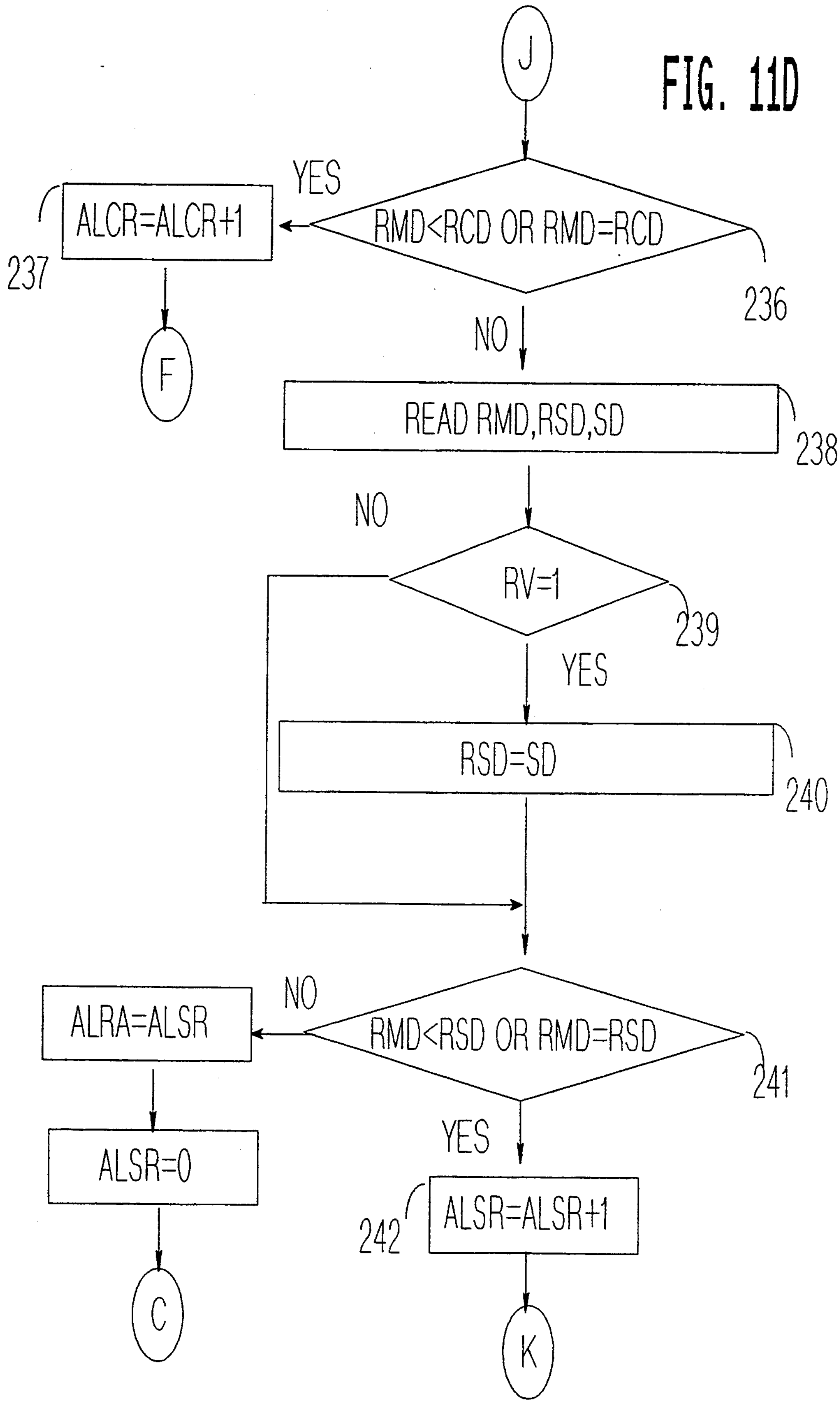

J
YES
ALCR=ALCR+1
RMD<RCD OR RMD=RCD
237
236
NO
F
READ RMD,RSD,SD
238
NO
RV=1
239
YES
RSD=SD
240
NO
ALRA=ALSR
RMD<RSD OR RMD=RSD
241
YES
ALSR=0
ALSR=ALSR+1
242
C
K

FIG. 11E

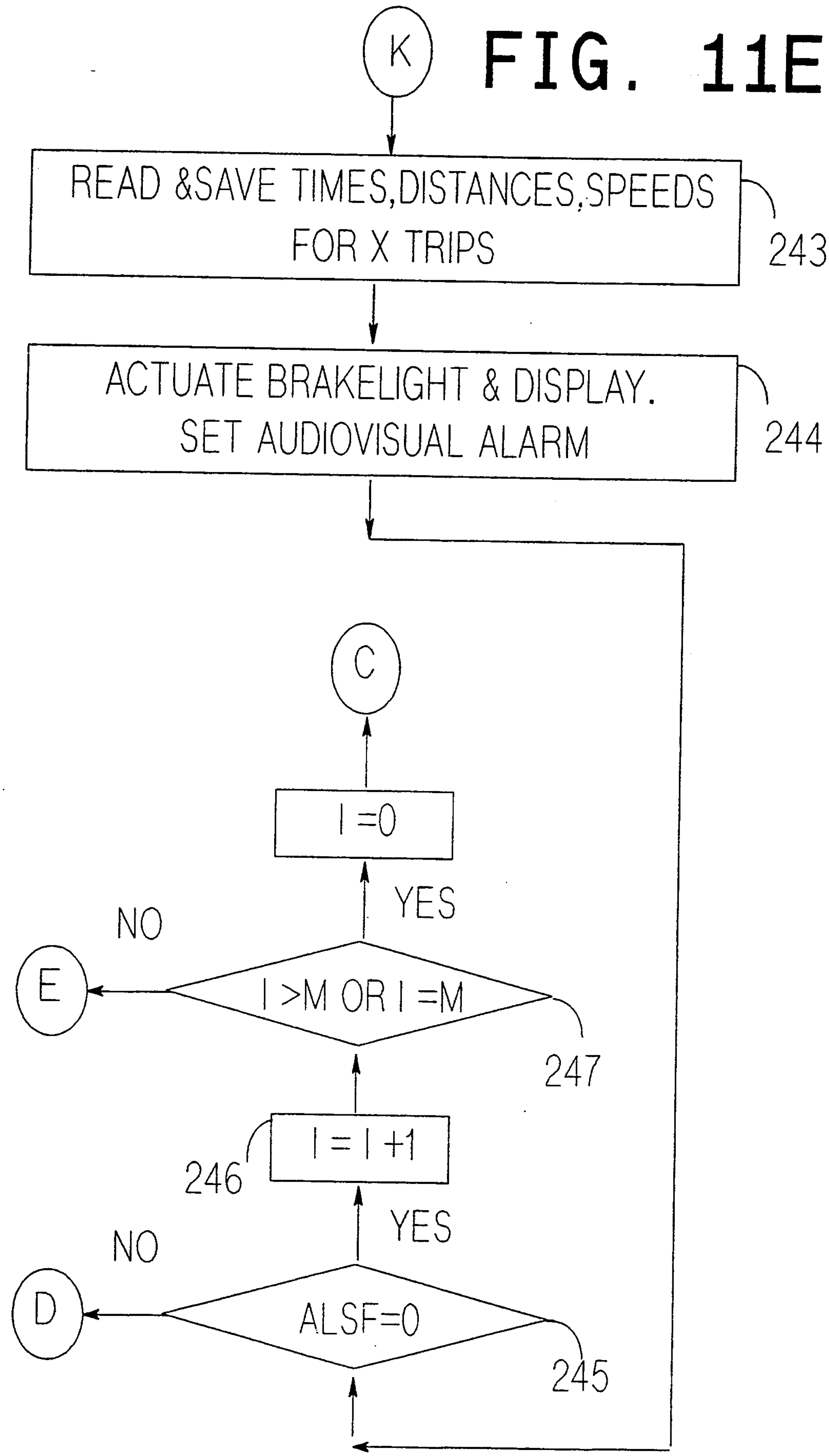

K
READ &SAVE TIMES,DISTANCES,SPEEDS FOR X TRIPS
243
ACTUATE BRAKELIGHT & DISPLAY. SET AUDIOVISUAL ALARM
244
C
I =0
YES
NO
E
I >M OR I =M
247
I = I +1
246
YES
NO
D
ALSF=0
245

FIG. 11F

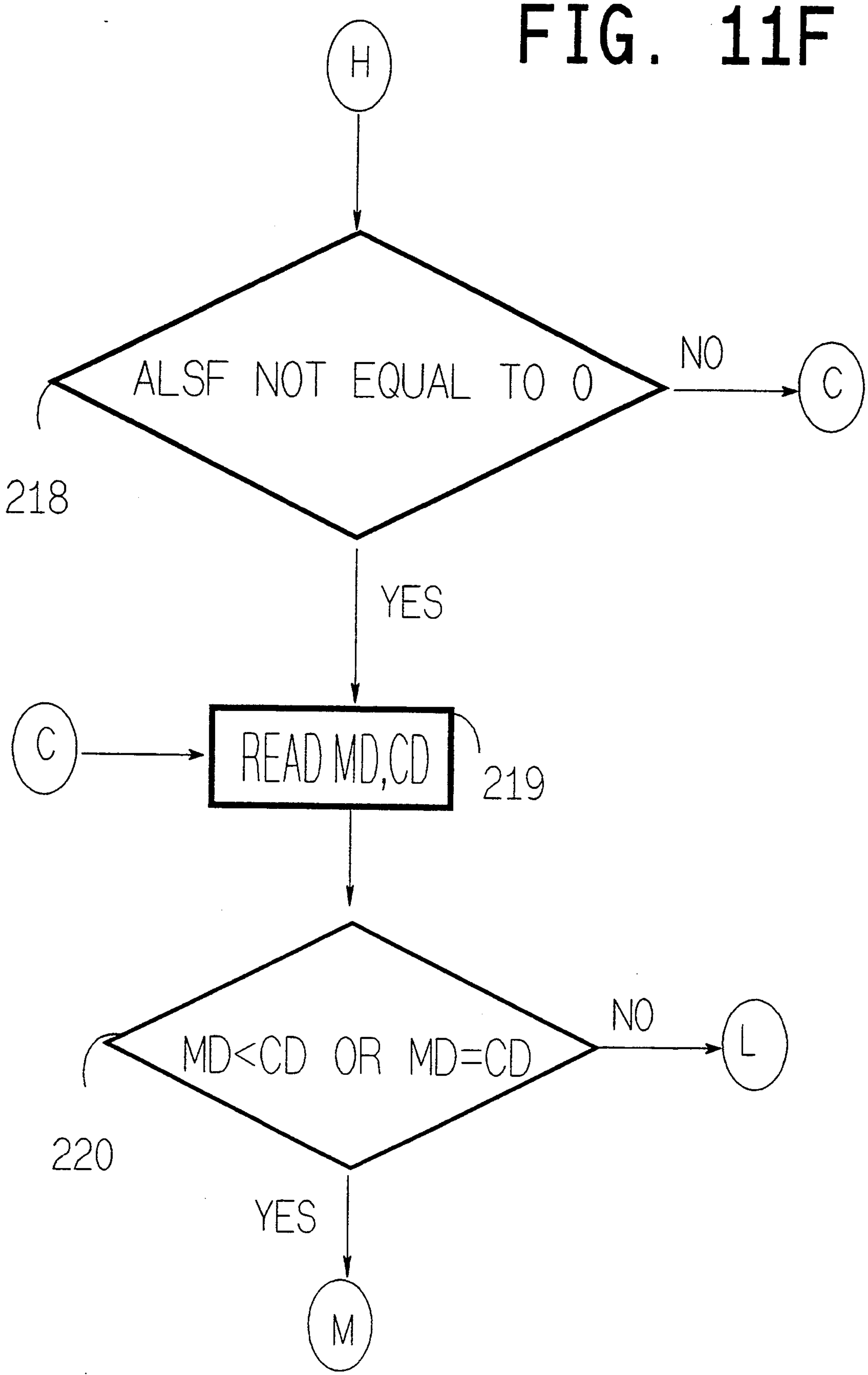

H
ALSF NOT EQUAL TO 0
NO
C
218
YES
C
READ MD,CD
219
MD<CD OR MD=CD
NO
L
220
YES
M

FIG. 11G

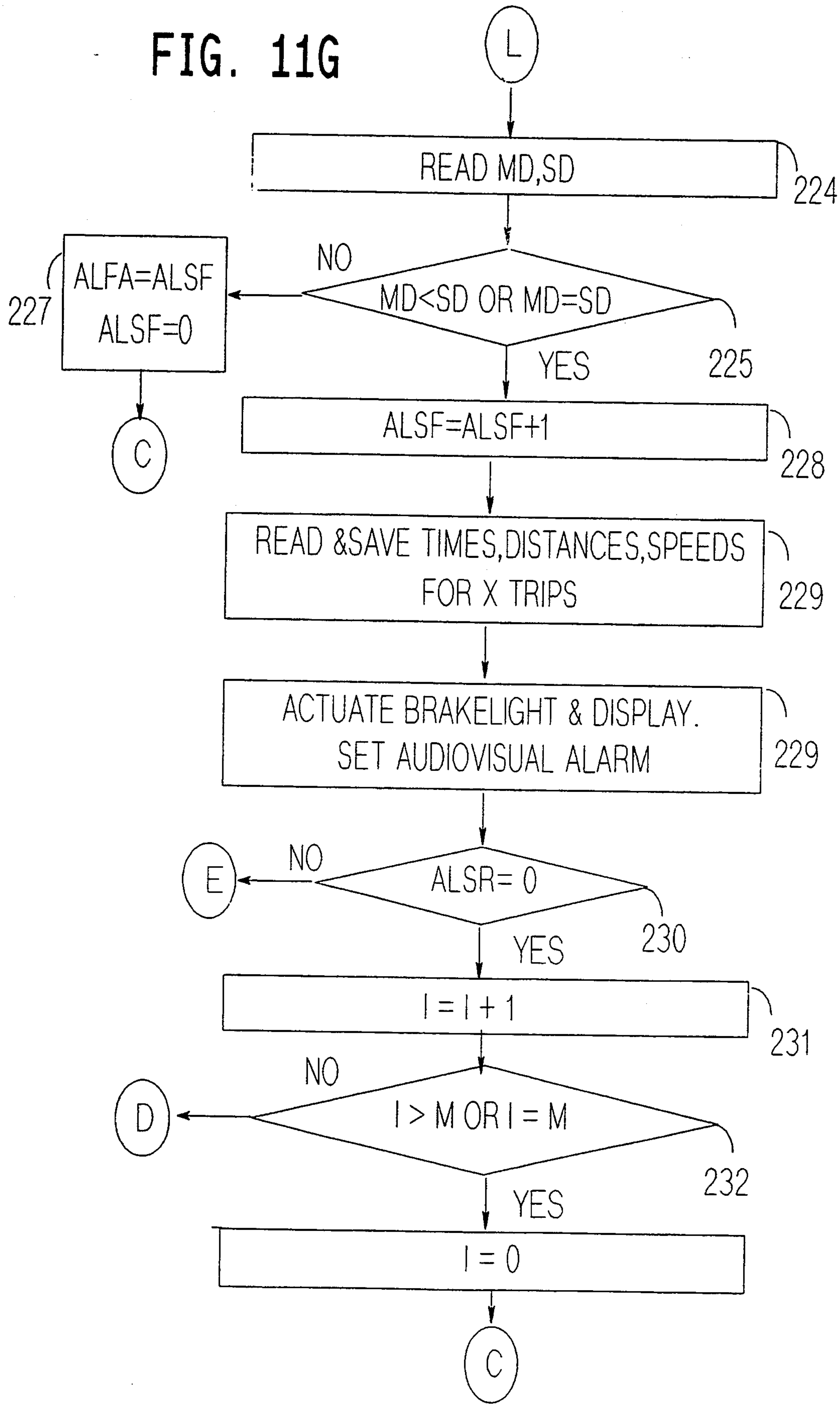
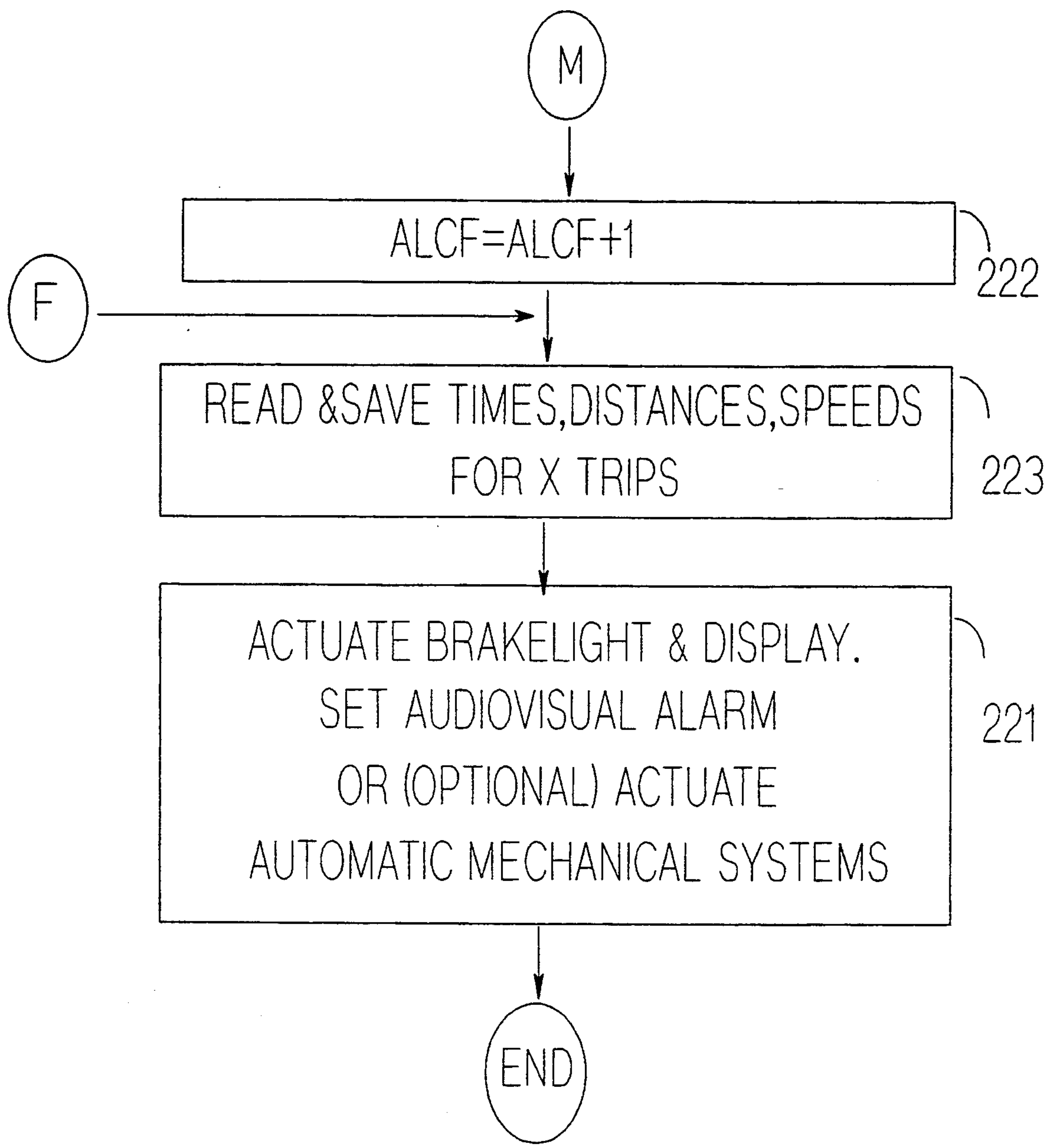

L
READ MD,SD
224
NO
MD<SD OR MD=SD
225
YES
ALFA=ALSF
ALSF=0
227
C
ALSF=ALSF+1
228
READ &SAVE TIMES,DISTANCES,SPEEDS
FOR X TRIPS
229
ACTUATE BRAKELIGHT & DISPLAY.
SET AUDIOVISUAL ALARM
229
NO
ALSR= 0
230
YES
E
I = I + 1
231
NO
I > M OR I = M
232
YES
D
I = 0
C

FIG. 11H


M
ALCF=ALCF+1
222
F
READ &SAVE TIMES,DISTANCES,SPEEDS FOR X TRIPS
223
ACTUATE BRAKELIGHT & DISPLAY. SET AUDIOVISUAL ALARM OR (OPTIONAL) ACTUATE AUTOMATIC MECHANICAL SYSTEMS
221
END

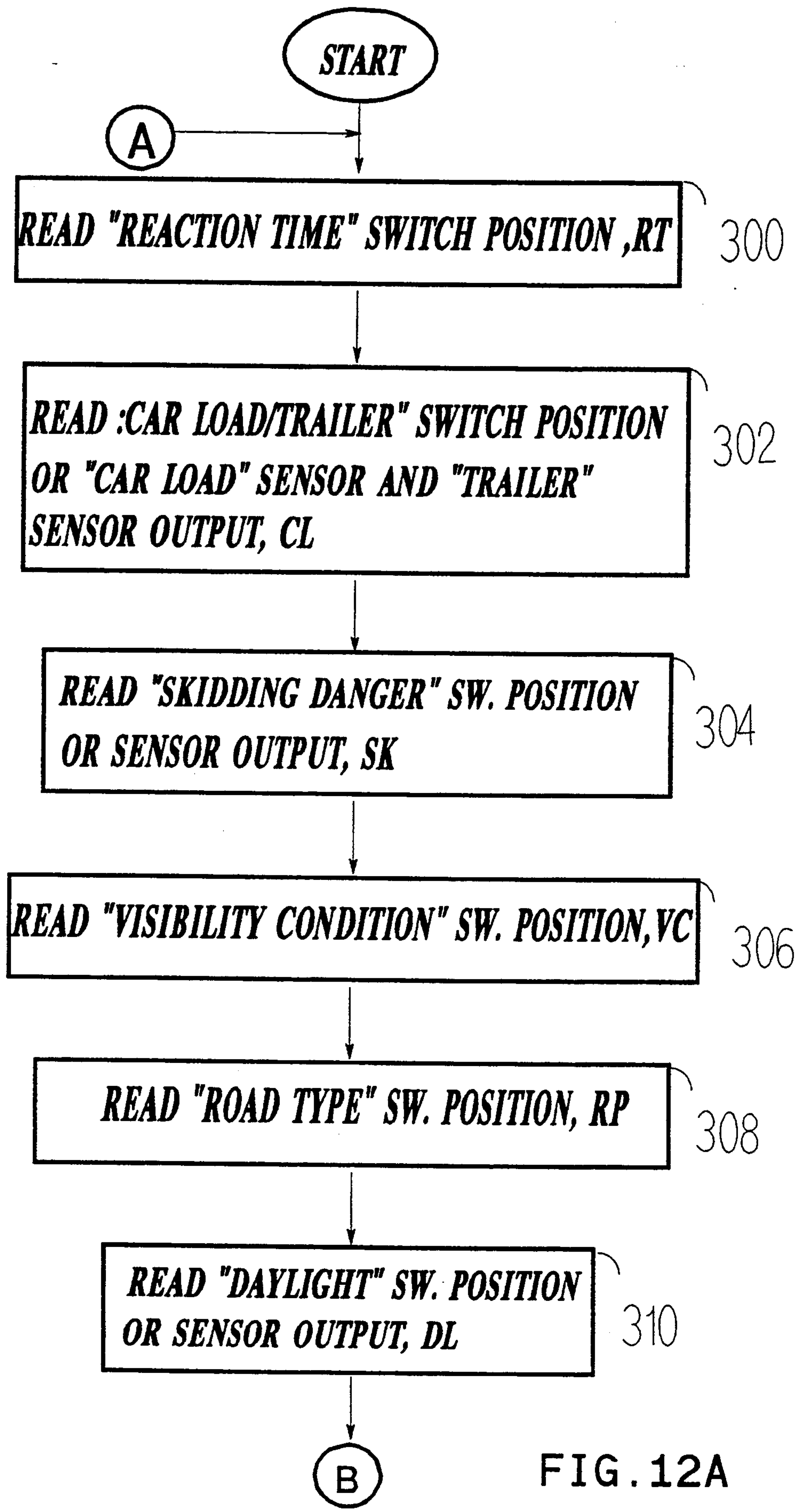
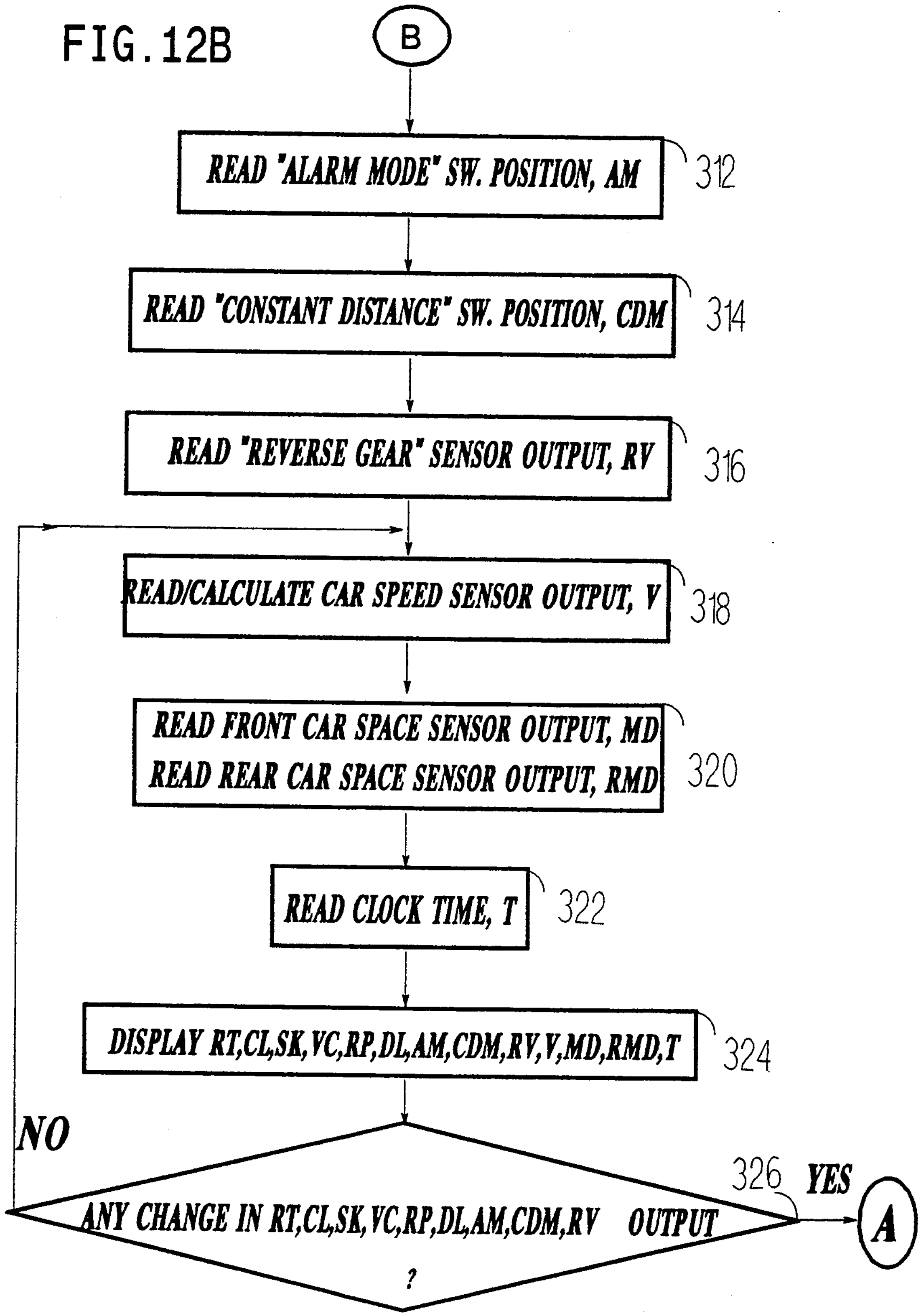

START
A
READ "REACTION TIME" SWITCH POSITION ,RT
300
READ :CAR LOAD/TRAILER" SWITCH POSITION OR "CAR LOAD" SENSOR AND "TRAILER" SENSOR OUTPUT, CL
302
READ "SKIDDING DANGER" SW. POSITION OR SENSOR OUTPUT, SK
304
READ "VISIBILITY CONDITION" SW. POSITION,VC
306
READ "ROAD TYPE" SW. POSITION, RP
308
READ "DAYLIGHT" SW. POSITION OR SENSOR OUTPUT, DL
310
B

FIG.12A

FIG. 12B


B
READ "ALARM MODE" SW. POSITION, AM
312
READ "CONSTANT DISTANCE" SW. POSITION, CDM
314
READ "REVERSE GEAR" SENSOR OUTPUT, RV
316
READ/CALCULATE CAR SPEED SENSOR OUTPUT, V
318
READ FRONT CAR SPACE SENSOR OUTPUT, MD
READ REAR CAR SPACE SENSOR OUTPUT, RMD
320
READ CLOCK TIME, T
322
DISPLAY RT,CL,SK,VC,RP,DL,AM,CDM,RV,V,MD,RMD,T
324
NO
ANY CHANGE IN RT,CL,SK,VC,RP,DL,AM,CDM,RV OUTPUT ?
326
YES
A

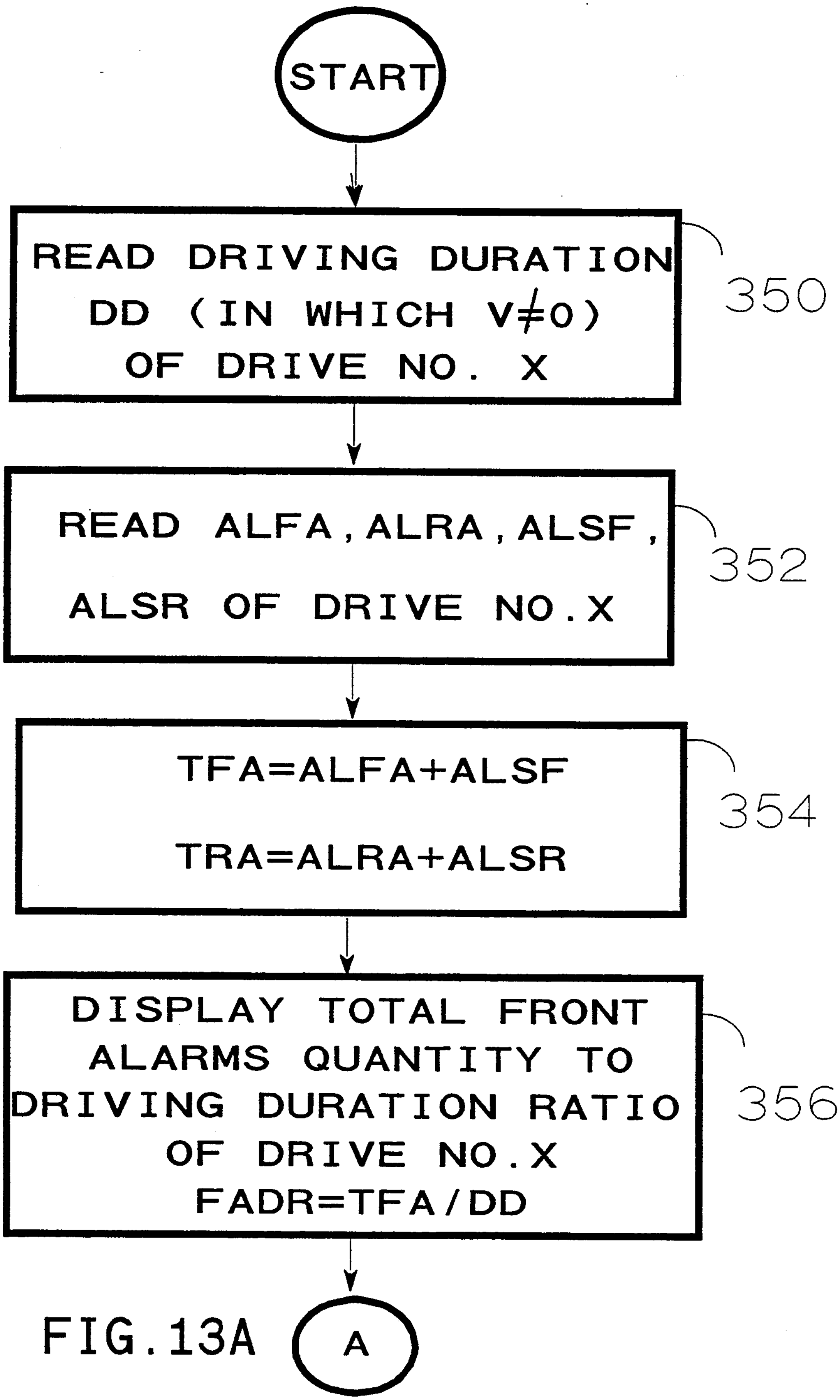

START
READ DRIVING DURATION DD (IN WHICH V≠0) OF DRIVE NO. X
350
READ ALFA, ALRA, ALSF, ALSR OF DRIVE NO. X
352
TFA=ALFA+ALSF
TRA=ALRA+ALSR
354
DISPLAY TOTAL FRONT ALARMS QUANTITY TO DRIVING DURATION RATIO OF DRIVE NO. X
FADR=TFA/DD
356
A

FIG. 13A

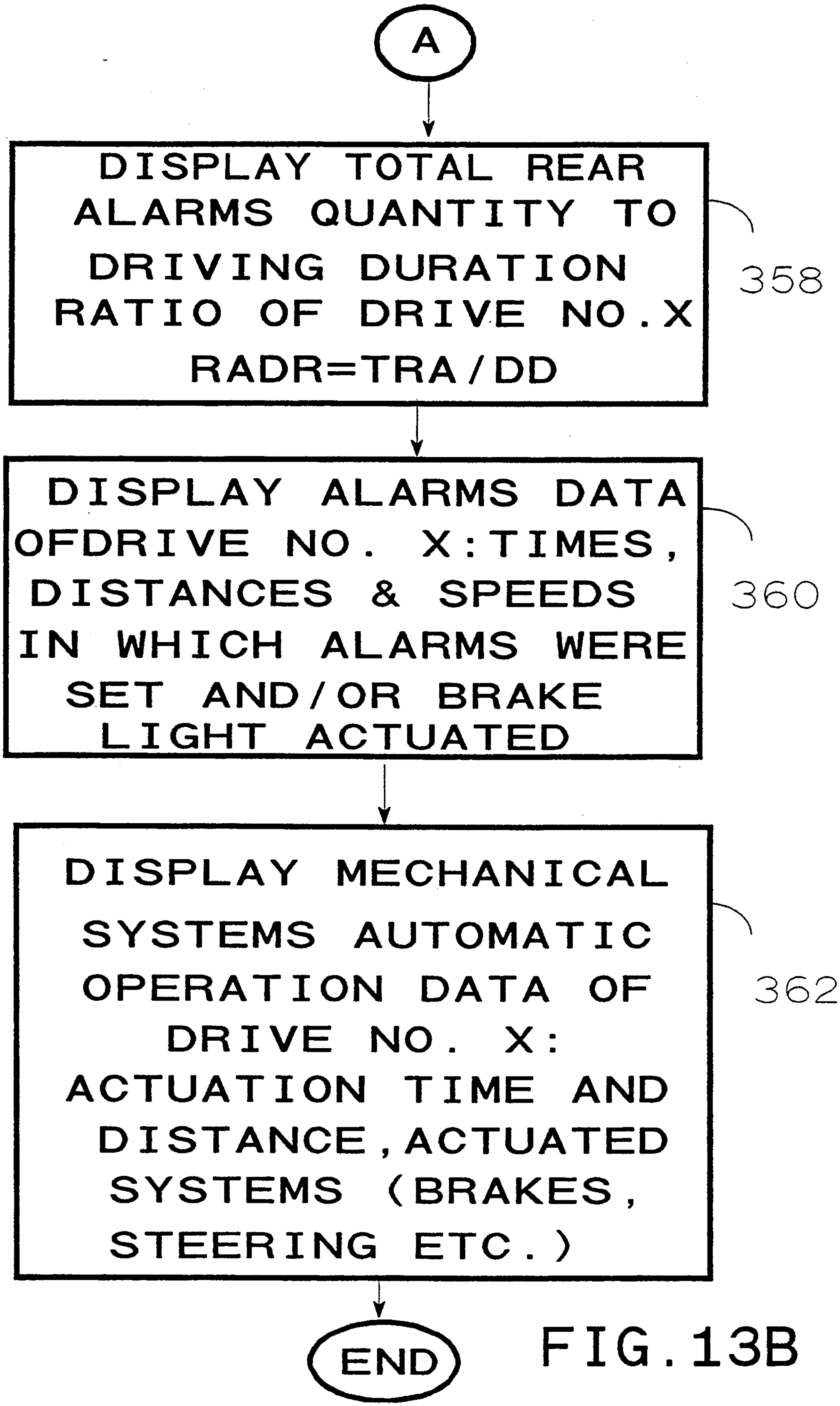

A
DISPLAY TOTAL REAR ALARMS QUANTITY TO DRIVING DURATION RATIO OF DRIVE NO.X RADR=TRA/DD
358
DISPLAY ALARMS DATA OFDRIVE NO. X:TIMES, DISTANCES & SPEEDS IN WHICH ALARMS WERE SET AND/OR BRAKE LIGHT ACTUATED
360
DISPLAY MECHANICAL SYSTEMS AUTOMATIC OPERATION DATA OF DRIVE NO. X: ACTUATION TIME AND DISTANCE,ACTUATED SYSTEMS (BRAKES, STEERING ETC.)
362
END

FIG.13B

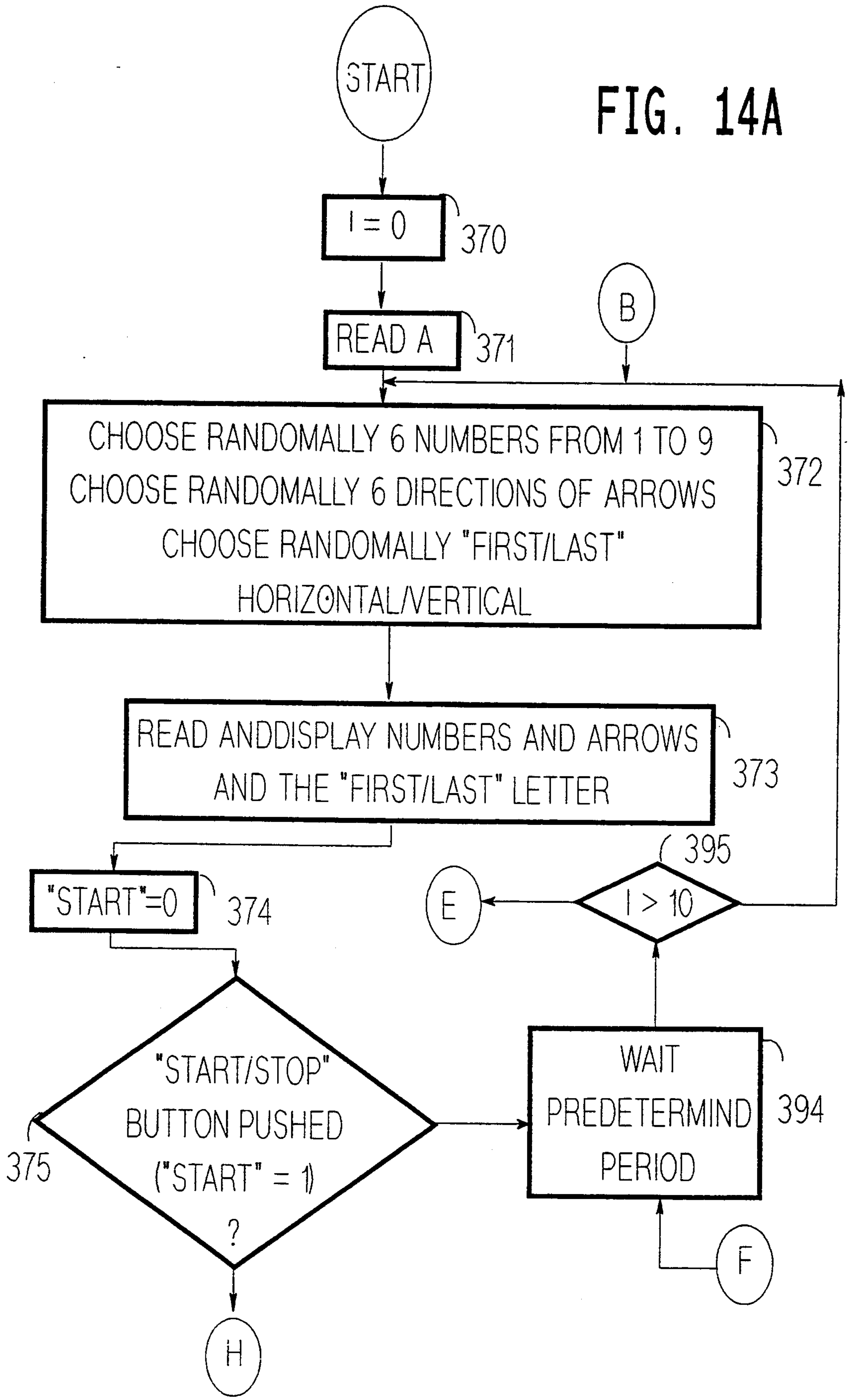

START
I = 0
370
READ A
371
B
CHOOSE RANDOMALLY 6 NUMBERS FROM 1 TO 9
CHOOSE RANDOMALLY 6 DIRECTIONS OF ARROWS
CHOOSE RANDOMALLY "FIRST/LAST"
HORIZONTAL/VERTICAL
372
READ ANDDISPLAY NUMBERS AND ARROWS
AND THE "FIRST/LAST" LETTER
373
395
"START"=0
374
E
I > 10
"START/STOP"
BUTTON PUSHED
("START" = 1)
?
375
WAIT
PREDETERMIND
PERIOD
394
F
H

FIG. 14A

FIG. 14B

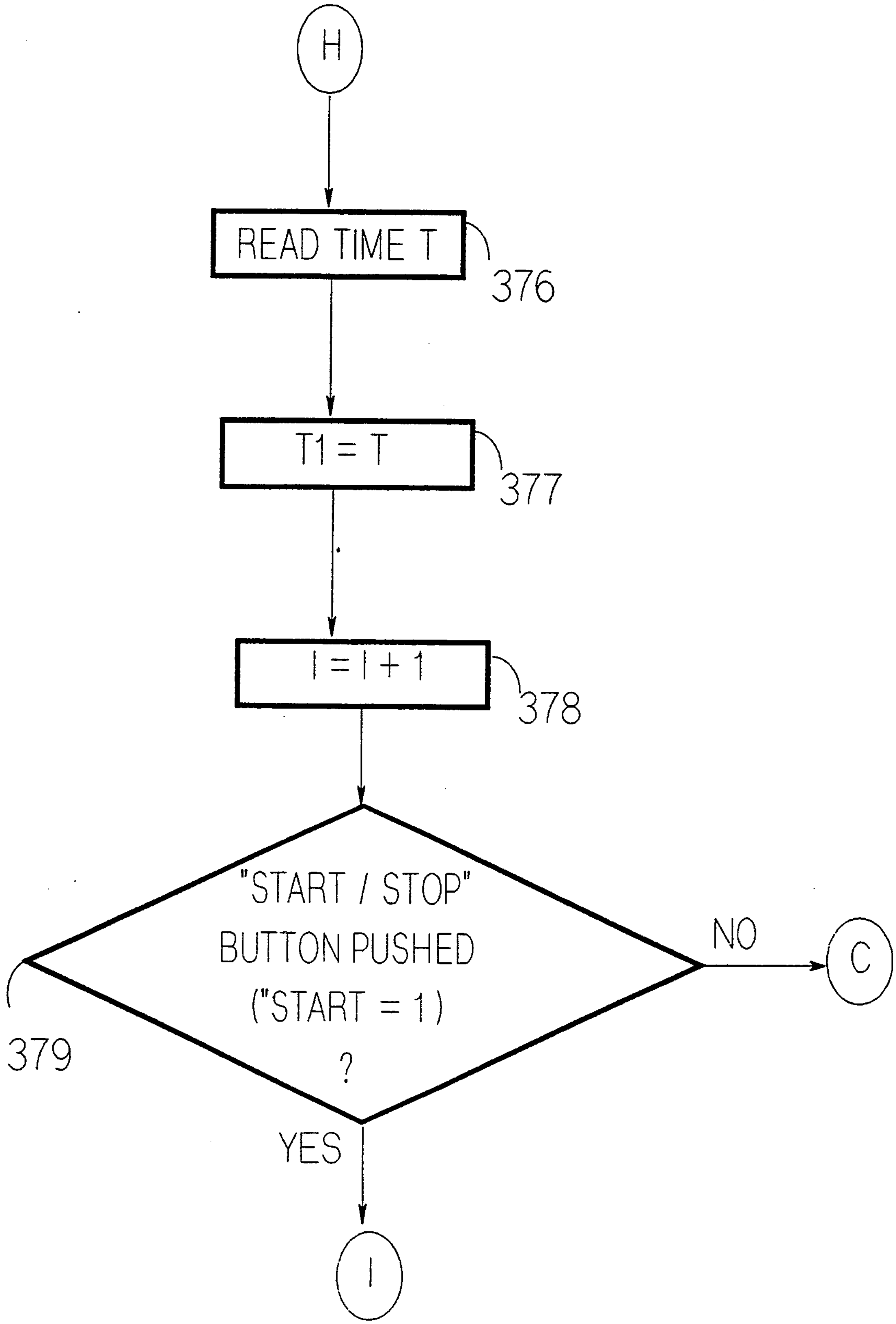

H
READ TIME T
376
T1 = T
377
I = I + 1
378
"START / STOP" BUTTON PUSHED ("START = 1) ?
379
NO
C
YES
I

FIG. 14C

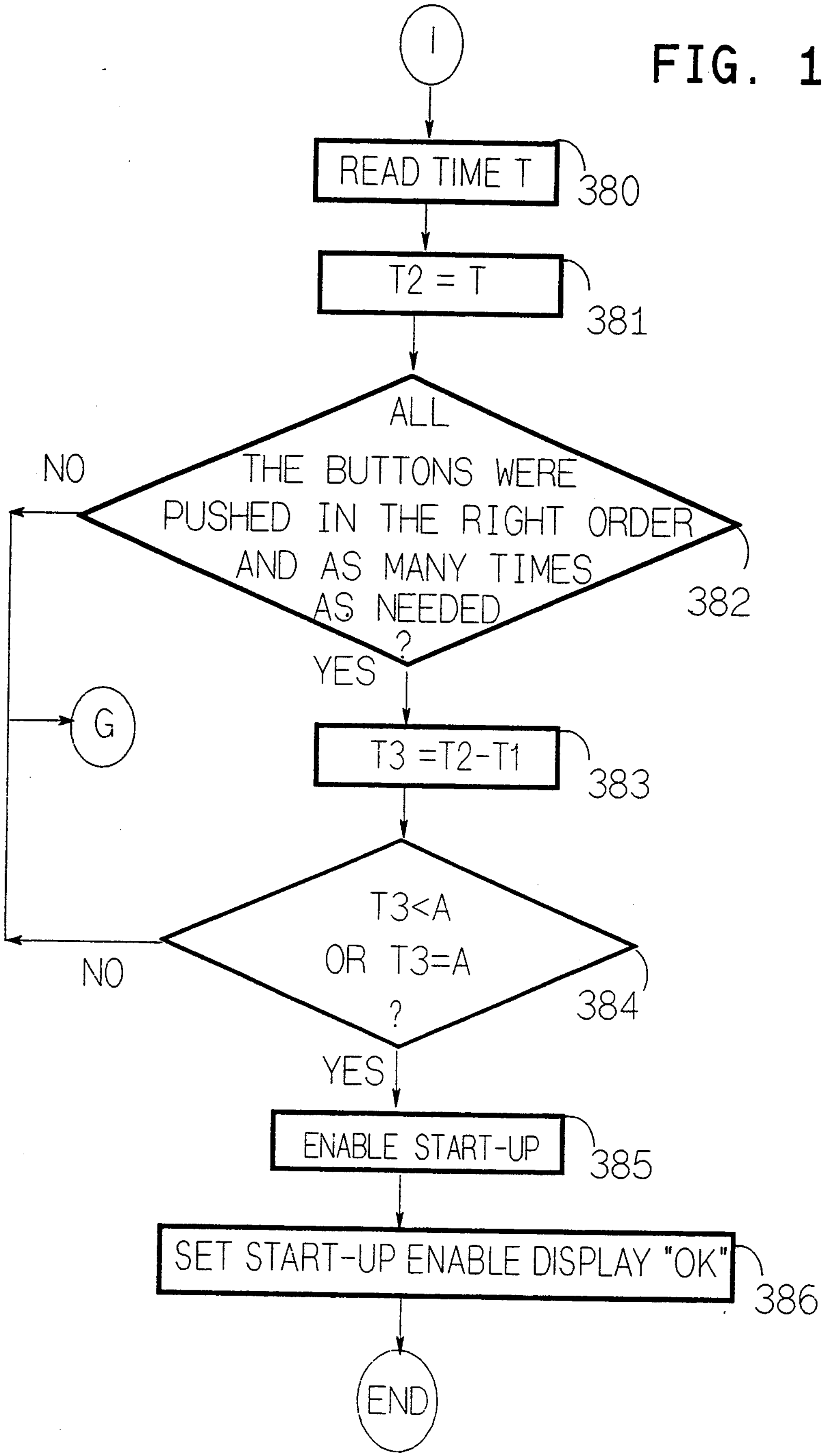
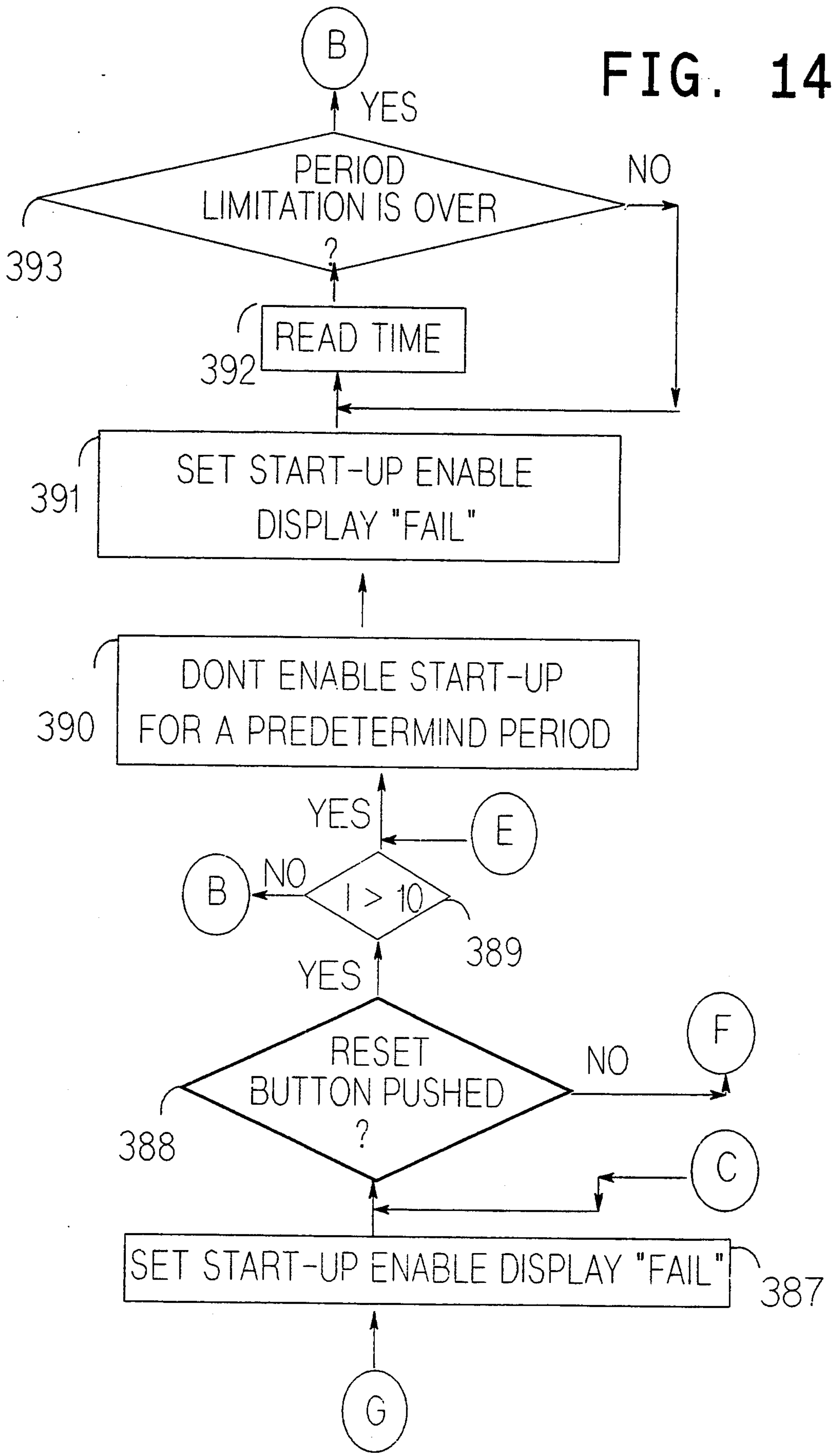

I
READ TIME T
380
T2 = T
381
ALL THE BUTTONS WERE PUSHED IN THE RIGHT ORDER AND AS MANY TIMES AS NEEDED ?
382
NO
YES
G
T3 =T2-T1
383
T3<A OR T3=A ?
384
NO
YES
ENABLE START-UP
385
SET START-UP ENABLE DISPLAY "OK"
386
END

FIG. 14D


B
YES
PERIOD LIMITATION IS OVER ?
NO
393
READ TIME
392
SET START-UP ENABLE DISPLAY "FAIL"
391
DONT ENABLE START-UP FOR A PREDETERMIND PERIOD
390
YES
E
B
NO
I > 10
389
YES
RESET BUTTON PUSHED ?
NO
F
388
C
SET START-UP ENABLE DISPLAY "FAIL"
387
G

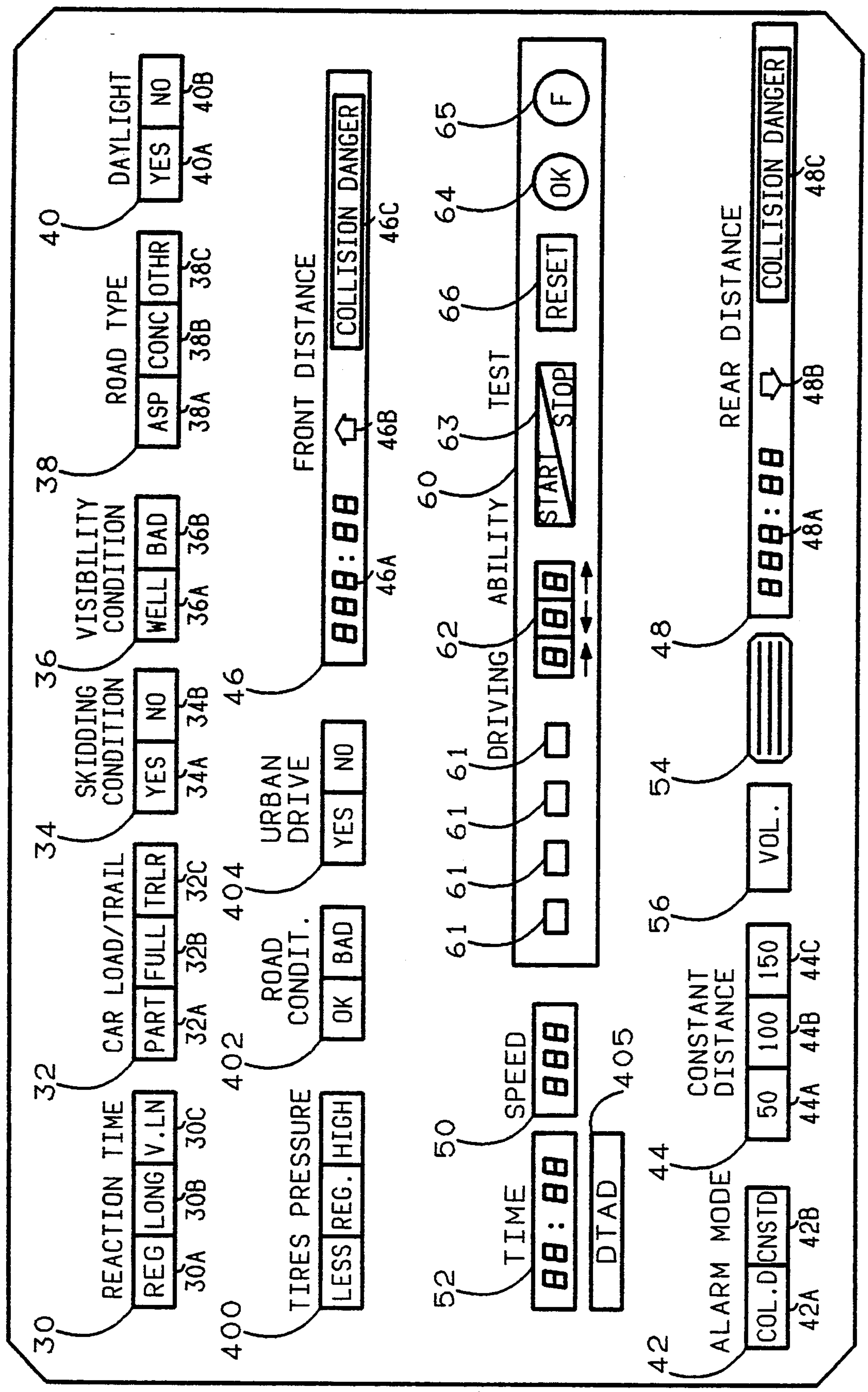

REACTION TIME
REG
LONG
V.LN
CAR LOAD/TRAIL
PART
FULL
TRLR
SKIDDING CONDITION
YES
NO
VISIBILITY CONDITION
WELL
BAD
ROAD TYPE
ASP
CONC
OTHR
DAYLIGHT
YES
NO
TIRES PRESSURE
LESS
REG.
HIGH
ROAD CONDIT.
OK
BAD
URBAN DRIVE
YES
NO
FRONT DISTANCE
888:88
COLLISION DANGER
TIME
88:88
SPEED
888
DTAD
DRIVING ABILITY
888
TEST
START
STOP
RESET
OK
F
ALARM MODE
COL.D
CNSTD
CONSTANT DISTANCE
50
100
150
VOL.
REAR DISTANCE
888:88
COLLISION DANGER
30
30A
30B
30C
32
32A
32B
32C
34
34A
34B
36
36A
36B
38
38A
38B
38C
40
40A
40B
400
402
404
405
46
46A
46B
46C
50
52
60
61
62
63
64
65
66
42
42A
42B
44
44A
44B
44C
56
54
48
48A
48B
48C

FIG. 15

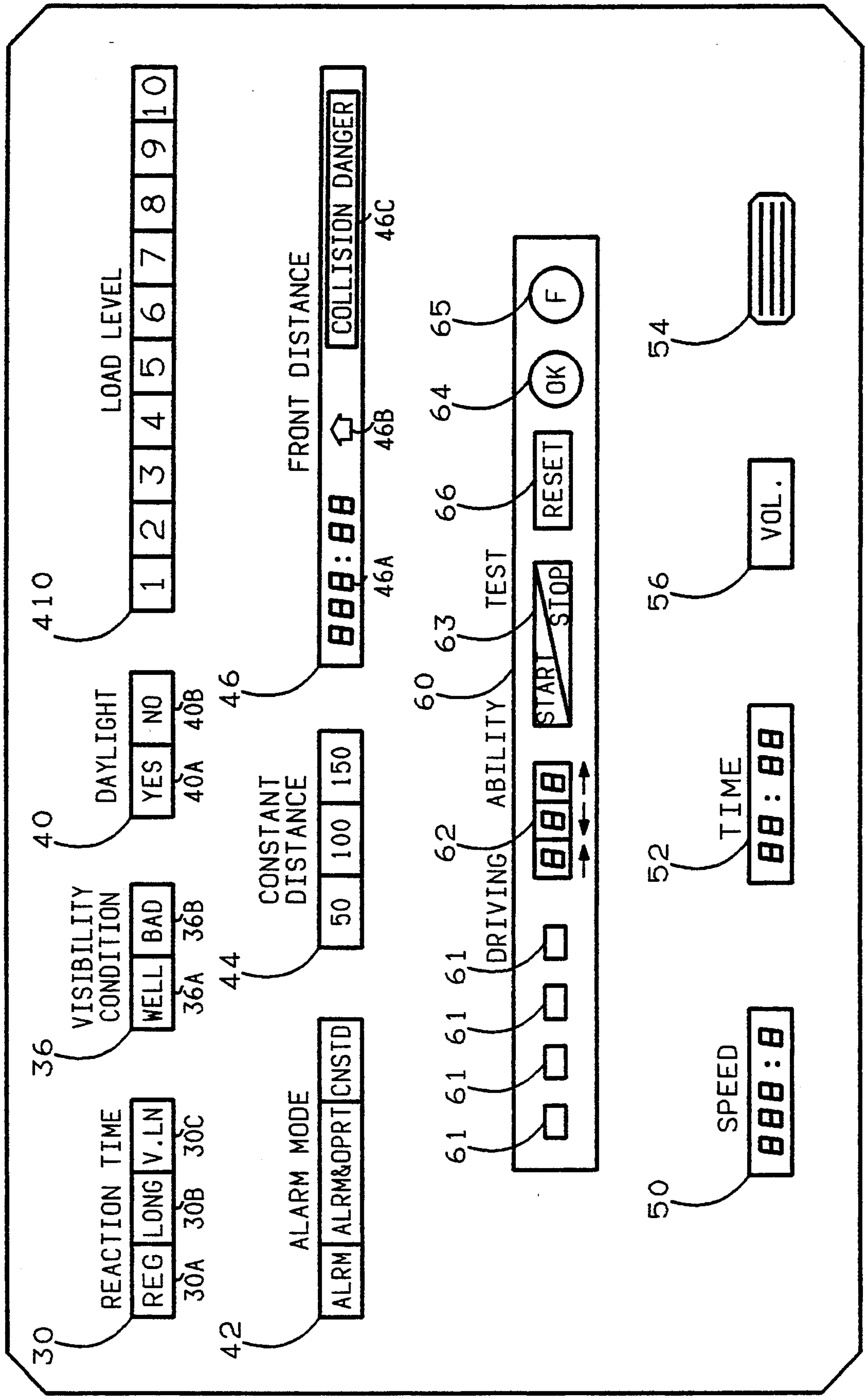

REACTION TIME
REG
LONG
V.LN
30
30A
30B
30C
VISIBILITY CONDITION
WELL
BAD
36
36A
36B
DAYLIGHT
YES
NO
40
40A
40B
LOAD LEVEL
1
2
3
4
5
6
7
8
9
10
410
ALARM MODE
ALRM
ALRM&OPRT
CNSTD
42
CONSTANT DISTANCE
50
100
150
44
FRONT DISTANCE
888:88
COLLISION DANGER
46
46A
46B
46C
DRIVING ABILITY TEST
888
START
STOP
RESET
OK
F
60
61
62
63
64
65
66
SPEED
888:8
50
TIME
88:88
52
54
VOL.
56

FIG. 16

ANTI-COLLISION SYSTEM FOR VEHICLES

FIELD AND BACKGROUND OF THE INVENTION

The present invention relates to an anti-collision system for vehicles. The invention is especially useful for passenger cars, taxis, trucks and buses, and is therefore described below particularly with respect to such vehicles, but the invention, or some aspects of the invention, could also advantageously be used for other types of vehicles, e.g., trains and aircraft.

One of the most frequent causes of vehicle accidents is the failure of a vehicle to maintain an assured safe distance behind another vehicle to prevent a rear end collision should the front vehicle suddenly stop. The assured safe distance required to prevent such a rear-end collision depends on the reaction time of the vehicle driver before the brake pedal is actually depressed, and the braking distance traversed by the vehicle before it comes to a complete stop after the braking pedal has been depressed. Both of these factors vary according to the surrounding circumstances at the time of driving.

In order to prevent collisions, many parameters, which are constantly changing during the year or even during a trip, may affect the stopping distance of the vehicle and therefore should be taken into account. These parameters include: the condition of the driver, such as the driver's reaction time; the condition of the vehicle, such as the vehicle load, the tires pressure; and environmental conditions, such as road type, visibility, skidding condition.

It is very important that the computer determines the danger-of-collision distance according to the specific conditions existing at the time the vehicle is being operated. Thus, if the determined danger-of-collision distance is too high for the specific operating conditions, there will be a high rate of "false alarms"; this will reduce the credibility of the system to the driver, which can result in a true collision condition being ignored. On the other hand, if the determined danger-of-collision distance is too low for the specific operating conditions, this could result in failure to actuate the alarm in time when there was truly a collision condition.

Many anti-collision systems have been proposed, but insofar as I am aware, none has yet gained any widespread use, probably because the proposed systems have not taken into consideration the variable nature of the many parameters which influence the reaction time and/or the braking distance involved at any particular time for determining the assured safe distance required to be maintained.

An object of the present invention is to provide an anti-collision system which is more closely responsive to the actual driving conditions for actuating an alarm.

BRIEF SUMMARY OF THE INVENTION

According to the present invention, there is provided an anti-collision system for vehicles, comprising: means for determining the speed of the vehicle; means for measuring the distance of the vehicle from an object; a computer for receiving a number of parameters, including the speed of the vehicle, and for computing from the parameters a danger-of-collision distance to the object; and a Collision alarm actuated by the computer when the measured distance of the object is equal to or less than the danger-of-collision distance computed by the computer; characterized in that the system also includes a control panel having parameter presetting means for presetting preselected parameters which are utilized by the computer for computing the danger-of-collision distance to the object.

According to further features in the preferred embodiment of the invention described below, the system also includes a Safety alarm actuated by the computer, before actuating the Collision alarm, when the measured distance is equal to or less than the danger-of-collision distance multiplied by a predetermined safety factor.

According to further features in the described preferred embodiment, below, the control panel also includes distance presetting means for presetting a selected fixed distance from an object, the computer being effective to actuate the Collision alarm also when the sensed distance to the object is equal to or less than the fixed distance.

According to still further features in the described preferred embodiment, the preselected parameters include: at least one vehicle parameter concerning a preselected condition of the vehicle; at least one driver parameter concerning a preselected condition of the vehicle driver; and at least one environmental parameter concerning a preselected condition of the environment. In the described preferred embodiment, the presetting is effected by a plurality of depressible keys on the control panel.

The system described below also includes a plurality of condition sensors for sensing any one of a plurality of selected conditions, and for automatically feeding to the computer information with respect to the sensed conditions, which information is also utilized by the computer for computing the danger-of-collision distance to the object. One of the described condition sensors includes a condition-of-driver sensor comprising a plurality of depressible keys, means for displaying a random sequence in which the latter keys are to be depressed, and means for comparing the actual sequence in which the keys are depressed with the displayed random sequence to provide a condition-of-driver parameter, which parameter is also utilized by the computer for enabling or disabling vehicle operation and/or for computing the danger-of-collision distance to the object.

According to another feature in the described preferred embodiment, the system further includes a sealed recording device which records all incidents in which the computer actuates the alarms.

As will be described more particularly below, an anti-collision system constructed in accordance with some or all of the foregoing features enables the system to be more closely responsive to the actual conditions at the time of driving the vehicle, including the condition of the vehicle, the driver, and the environment, in determining the danger-of-collision distance to avoid a rear-end collision. Such a system is useful not only for passenger vehicles, but also for other types of vehicles, such as trucks and buses. The condition-of-driver sensor referred to above, and also the sealed recording device, are particularly useful in buses, trucks, trains and aircraft, to test the condition of the driver, to assure that the driver is in proper condition for driving the vehicle, and/or to maintain a record which can be later checked as to all incidents in which an alarm was actuated by the computer.

According to a further feature, the system includes an actuator for actuating a mechanical system of the vehicle, e.g., the brakes of a train, or steering of an aircraft, at the time the collision alarm is actuated.

Further features and advantages of the invention will be apparent from the description below.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is herein described, by way of example only, with reference to the accompanying drawings, wherein:

FIG. **1** diagrammatically illustrates one form of vehicle equipped with an anti-collision system in accordance with the present invention;

FIG. **2** illustrates an example of the system control panel to be mounted in the driver's compartment to enable presetting various parameters and also to display various information;

FIG. **3** illustrates another type of control panel that may be used in the anti-collision system;

FIG. **4** illustrates examples of menu-type displays which may be included in the control panel of FIG. **3**;

FIG. **5** illustrates a driving ability test device used as a condition-of-driver sensor for sensing the condition of the driver and/or for enabling or disabling operation of the vehicle;

FIGS. **6**A and **6**B illustrates the microcomputer in the anti-collision system of FIG. **1** and all the inputs into and the outputs therefrom;

FIG. **7** is a circuit diagram illustrating one form of electrical circuit which may be used;

FIG. **8** illustrates one example of a pattern of pulses that may be used by the vehicle in determining its distance from an object;

FIG. **9** is a flow chart illustrating the overall operation of the system;

FIGS. **10**A–**10**B, together, constitute flow charts illustrating the overall operation of the Calculation module in the microcomputer of FIGS. **6**A and **6**B;

FIG. **11**A–**11**H, together, constitute flow charts illustrating the operation of the deceleration alarm module in the microcomputer of FIGS. **6**A and **6**B;

FIGS. **12**A–**12**B, together, constitute flow charts illustrating the operation of the output data module in the microcomputer of FIGS. **6**A and **6**B;

FIGS. **13**A–**13**B, together, constitute flow charts illustrating the operation of the black box module in the microcomputer of FIGS. **6**A and **7**B;

FIGS. **14**A–**14**D, together, constitute flow charts illustrating the operation of the driving ability test module in the microcomputer of FIGS. **6**A and **6**B;

FIG. **15** illustrates another control panel which may be used to include additional presettable parameters; and

FIG. **16** illustrates a control panel particularly useful with trains.

DESCRIPTION OF PREFERRED EMBODIMENTS

Overall System

The anti-collision system illustrated in FIGS. **1**–**14** is particularly useful for motor vehicles (passengers cars, buses, trucks) in order to actuate an alarm when the vehicle is travelling at a distance behind another vehicle or in front of another, which is equal to or less than a danger-of-collision distance computed by a computer such that if the front vehicle stops suddenly there is a danger of a rear-end collision. For this purpose, the system includes means for continuously determining the speed of the vehicle; means for measuring the distance and computing the relative speed between it and the other vehicle or object; presettable means for presetting various conditions of the vehicle, vehicle driver and/or environment; and sensors for automatically sensing other conditions. All of these are taken into consideration by the computer for determining the danger-of-collision distance. By thus taking into consideration all the foregoing parameters, which may vary widely under varying driving conditions, the system is more closely responsive to the actual conditions existing at the time the vehicle is operated, and therefore provides a more creditable alarm.

In the system described below, there are two alarms: a Collision alarm, which is actuated when the vehicle is determined to be within the danger-of-collision distance; and a Safety alarm, which is actuated before the Collision alarm, at a distance greater than the danger-of-collision distance by a predetermined safety factor, e.g., 1.25. For example, if the danger-of-collision distance is determined to be 100 feet for particular driving conditions, the Safety alarm will be actuated when the vehicle is within 125 feet, and if this distance continues to decrease, the Collision alarm will be actuated when the vehicle reaches 100 feet from the object. The Safety alarm alerts the driver and is preferably both an interrupted beep and a continuous visual indicator on the panel; whereas the Collision alarm is preferably a continuous, higher-intensity beep and a flashing visual indicator on the control panel.

The control panel also includes a distance presetting means for presetting a selected fixed distance from an object, so that when a constant distance alarm is made effective the driver can maintain a fixed distance behind another vehicle if he so desires. The computer is effective to actuate one of the alarms, e.g., the Safety alarm, when the distance to the object is equal to or less than the fixed distance.

Automatic sensors

FIG. **1** diagrammatically illustrates, for purposes of example, a plurality of automatic sensors and other electrical devices included in a vehicle equipped with an anti-collision system constructed in accordance with the present invention.

Thus, the vehicle, generally designated **2**, is equipped with a microcomputer **4** having a control panel **6** installed in the passenger compartment of the vehicle at a location conveniently accessible to the driver. FIGS. **2** and **3**, to be described below, illustrate two types of control panels that may be used for this purpose.

Vehicle **2** further includes a front space sensor **8** for sensing the space in front of the vehicle, such as the presence of another vehicle, a corresponding rear space sensor **10**, and a pair of side sensors **11**. All the space sensors are in the form of pulse (e.g., ultrasonic) transmitters and receivers, for determining the distance of the vehicle from an object, e.g., another vehicle, at front or rear. Space sensors may also be provided at the sides of the vehicle. Vehicle **2** is further equipped with a speed sensor **12** which may sense the speed of the vehicle in any known manner, for example using the speed measuring system of the vehicle itself, or a speed measuring system independent of the vehicle, e.g., an acceleration sensor, or by calculations based on the Doppler effect, etc.

The automatic sensors on vehicle **2** further include a daylight sensor **14**, a rain sensor **16**, a vehicle load sensor **18**, a trailer-hitch sensor **20**, and a reverse-gear sensor **22**.

In addition to the foregoing sensors, the vehicle **2** illustrated in FIG. **1** includes a brake light **24** at the rear of the vehicle controlled by a brake light actuator **26**. It also includes a start-up enable device **27** for starting the engine of the vehicle.

The illustrated vehicle further includes a black box shown at **28**. In this black box are reported every incident in which an alarm condition was experienced by the vehicle, including pertinent parameters with respect to the incident, particularly time, speed of the vehicle, and the distance from the object when the alarm was triggered. This information may be periodically read out of the black box and is particularly useful with respect to taxicabs, trucks, buses, trains, vehicles transporting dangerous cargo (e.g., explosives), ambulances, fire department vehicles, etc.

Further, the vehicle includes an automatic actuator **29**, e.g. for actuating the brakes in case of a train, or the steering in case of an aircraft.

Control Panel

FIG. **2** illustrates one form of control panel **6** for presetting various parameters into the system, for displaying the status of the presettable parameters, and for providing the alarms. The parameters are preset by depressing selected keys in the control panel, each key being illuminated by a light source when it is depressed to indicate its depressed condition. Control panel **6** illustrated in FIG. **2** also includes a number of displays, and also a driving ability testing device which will be described more particularly below.

With respect to the presettable parameters, control panel **6** illustrated in FIG. **2** includes a group of keys **30** for presetting the Reaction Time of the driver. Thus, key **30*a*** would be depressed to indicate a regular reaction time, key **30*b*** would be depressed to indicate a long reaction time, and key **30*c*** would be depressed to indicate a very long reaction time. The reaction time would be influenced primarily by the age of the driver, but could also be influenced by other factors, e.g., the alertness condition of the driver, etc.

Control panel **6** includes another group of presettable keys **32** to indicate the load condition of the vehicle. Thus, depressing key **32*a*** indicates a partial load, key **32b** indicates a full load, and key **32*c*** indicates a trailer is hitched to the vehicle. The foregoing presettable parameters concerning the load condition of the vehicle may be used in the absence of the sensors **18** and **20** for automatically sensing the load of the vehicle and the hitching of a trailer, respectively, as described earlier with respect to FIG. **1**.

Control panel **6** includes two keys **34** indicating the condition of the road with respect to the danger of skidding thereon by the vehicle. Thus, key **34*a*** would be depressed to indicate a slippery condition of the road and therefore a high danger of skidding, whereas key **34*b*** would be depressed to indicate an unslippery condition of the road (e.g., dry) and therefore a low danger of skidding.

Two keys **36** on the control panel **6** indicate the visibility condition of the road. Thus, key **36*a*** would be depressed where the visibility condition is high, whereas key **36*b*** would be depressed where it is low, e.g., because of fog, sandstorm, snow, etc.

Three keys **38** indicate the type of road over which the vehicle is travelling. Thus, the depression of key **38*a*** indicates an asphalt road, key **38*b*** a concrete road, and **38*c*** a dirt or gravel road.

Keys **40** indicate the daylight condition while driving. Thus, if it is daytime key **40*a*** would be depressed, and if it is nighttime key **40b** would be depressed.

The control panel **6** includes two keys **42** to select the mode of operation of the system. Thus, key **42*a*** selects the Collision Danger mode of operation, wherein the alarm would be actuated whenever a collision danger is present as will be described below. However, at times the driver would like to know whether or not his vehicle is within a predetermined fixed distance behind another vehicle. In such case, the fixed distance would be selected by keys **44**, and key **42*b*** would be depressed to select the Constant Distance mode, whereupon the system would actuate an alarm whenever the sensed distance is equal to or less than the selected constant distance. In the example illustrated in FIG. **2**, keys **44** enable the selection of any one of three distances, namely 50, 100 and 150 meters, by keys **44*a***, **44*b*** and **44*c***, respectively. It will be appreciated, however, that other parameters and distances, and other means of selecting such parameters and distances, could be provided in the control panel **4**.

Control panel **6** further includes a front distance display **46**, in which are displayed the distance to the front vehicle (in region **46*a***), in which direction (by arrow **46*b***), and whether or not there is a collision danger (region **46*c***). A similar display, shown at **48** and having regions **48*a***, **48*b*** and **48*c***, is provided with respect to the rear of the vehicle equipped with the system, whether a rear collision danger exists, and the status of the rear brake light.

The actual speed of the vehicle is shown in the speed display **50**. As indicated earlier, this speed may be taken from the conventional speed measuring system of the vehicle, or may be independently measured or calculated using the front space sensor, e.g., by the Doppler effect. Control panel **6** further includes a real time clock having a time display **52**.

Control panel **6** further includes a speaker **54** for producing an audio alarm in the event of a collision danger, in addition to the visually-indicated alarms of sections **46*c*** and **48*c*** of the displays **46** and **48**. A key **56** on the control panel enables presetting the volume of the audible alarm.

Control panel **4** further includes a driving ability test device, generally designated **60**, which enables the alertness condition of the driver to be tested. This device includes a line of depressible keys **61** and a display **62** controlled by the microcomputer **4** for randomly displaying sequences in which keys **61** are-to be depressed. In the example illustrated in FIG. **4**, display **62** indicates that keys **61** are to be depressed in a forward sequence (left to right) eight times, then depressed in the reverse sequence (right to left) another eight times, and then to be depressed in the forward sequence a further eight times. When the driving ability test is to be conducted, a Start/Stop key **63** is depressed whereupon a timer is started. When the driver completes the test, he again depresses key **63**. The time is measured between the two depressions of key **63** thereby providing an indication of the time required by the driver to depress the keys according to the required sequences.

This time is a measure of the "alertness" of the driver. It may thereby be used to provide a parameter of the driver condition and inputted into the microcomputer **4**. In the illustrated system, however, depressing the displayed sequences of the keys in the right order within a predetermined time period is a condition required to be met before the vehicle can be started, as will be described more particularly below with respect to the flow chart of FIG. **14**. Failure to meet the condition is indicated by display **65**, and passing the condition is indicated by display **64**. If one attempt fails, another attempt may be made by depressing Reset key **66**. Such a driving ability test device is particularly useful with respect to trucks, buses, vehicles carrying dangerous cargoes, aircraft, and trains, to make sure that the driver is fit to operate the vehicle before enabling the vehicle for operation.

FIG. **3** illustrates an alternative type of control panel, therein designated **70**, which may be used instead of the control panel **6** illustrated in FIG. **2**. Control panel **70** is of the "menu " type, in which a menu display **71** displays the various categories of information or options that may be selected or preset into the computer or displayed in the control panel. The menu display **71** is controlled by a Select key **72** which advances the display each time the key is depressed (or continuously until the key is permitted to return), and an Enter key **73** which enters the selection shown in the display **71** at the time that key is depressed. In this panel, the status of the driving conditions is displayed whenever selections or other displays are not made or shown.

FIG. **4** illustrates the examples of various types of menus which may be shown in the menu display **71**. Thus, one display is the Main Menu as shown at **75**, which lists the various modes of display that may be selected, namely the following: a Status display, as shown at **71** in FIG. **3**; an Alarm Mode Selection display, as shown at **76***a* (FIG. **4**), which enables the selection of the desired Alarm mode, namely Collision Danger, or Constant Distance; and if Constant Distance is selected, display **76***b* enables the selection of the distance; a Parameters Input mode **77***a*, which enables selection of the parameters input, each category of which includes a further display and enables the selection of one item within the respective category, as shown by the Reaction Time display **77***b*; and a Black Box alarm display **78**, which displays the printed data stored within the black box **28**.

By thus utilizing a menu display as shown in FIGS. **3** and **4**, it will be appreciated that a large number of operational modes may be provided, a large number of parameters may be preset with each parameter divided into a large number of classifications, and a large number of displays may be made, in a relatively compact control panel, as compared to the control panel **6** illustrated in FIG. **2**.

The control panel **70** illustrated in FIG. **3** includes the other displays and devices shown in FIG. **2**, and therefore have been identified by the same reference numbers to facilitate understanding.

FIG. **5** illustrates a more complicated driving ability test device that may be included in the control panel, or in a separate control panel.

Thus, the driving ability testing device **80** illustrated in FIG. **5** includes, instead of a single line of keys (keys **61** in FIGS. **2** and **3**), a matrix of keys **81** arranged in a plurality of horizontal rows and vertical columns. Device **80** further includes a horizontal display **82** and a vertical display **83**. The horizontal display **82** displays, for each vertical column, the random sequences and directions in which the keys are to be depressed and the random number of times such keys are to be sequentially depressed. The vertical display **83** also displays the random sequence, and a number of times, the keys in each of the three horizontal rows are to be depressed. A further display **84** indicates whether the sequencing of the vertical columns or the horizontal rows is to be effected first (F) or last (L).

Thus, in the example illustrated in FIG. **5**, display **84** indicates that the random display **82***a* is to be first executed, and then the random display **83** is to be executed. Random display **82** indicates that the first vertical column of keys are to be depressed consecutively in two sequences starting from the bottom, the middle column of keys are to be depressed in one sequence, starting from the top; and the rightmost column of keys are to be depressed consecutively in three sequences starting from the bottom. Display **83** indicates that the first horizontal line of keys are to be depressed once from right to left, the second horizontal line of keys are to be depressed three times, from left to right, and the third horizontal line of keys are to be depressed twice, from right to left.

The driving ability testing device **80** illustrated in FIG. **5** includes the other keys of device **60** shown in FIG. **2**, namely keys **85, 86, 87** and **88**, corresponding to keys **63, 64, 65** and **66**, respectively, in the device of FIG. **2**.

The Microcomputer

FIGS. **6***a*, **6***b*, are a block diagram illustrating the microcomputer **4** and its inputs and outputs described earlier which enable it to continuously monitor the operation of the vehicle and to actuate first a Safety alarm, and then a Collision alarm whenever the vehicle may enter a danger-of-collision situation according to the various preset parameters and automatic parameters introduced into the computer.

The microcomputer **4** as illustrated in FIGS. **6***a*, **6***b* is divided into various functional modules, as follows: a calculation module **90**, which receives data concerning the various parameters briefly described above and as will be described more particularly below to enable it to make the necessary computations for actuating the Safety alarm and the Collision alarm; a real time clock **91** which keeps track of time in a real time manner; a switches/sensors output data module **92** which controls the various displays on the control panel; a deceleration alarm module **93**, which controls the Safety alarm and Collision alarm on the control panel, the brake light actuator **26** and (e.g., in the case of a train) the vehicle brakes automatically; a black box module **94**, which controls the information recorded into and read out of the black box **28**; and a driving ability test module **95**, involved in the driving ability test **60** in the control panel of FIG. **2**, or **80** in the control panel of FIG. **5**. The operation of each of these modules (except the clock **91**) is described more particularly below with reference to the flow charts of FIGS. **9–14**.

Thus, module **90** receives inputs from the front space sensor **8**, the rear space sensor **10**, and the vehicle speed sensor **12**. Module **90** also receives inputs from the sensors in case there is no depressible key, e.g., the daylight sensor **14**, the trailer sensor **20**, the reverse gear sensor **22**, the rain sensor **16**, and the vehicle load sensor **18**.

With respect to the preset parameters, the module **90** receives as inputs the reaction time as preselected by keys **30**, the vehicle load condition as preset by keys **32**, the skidding danger condition of the road as preset by keys **34**, the visibility condition as preset by keys **36**, the road-type condition as preset by keys **38**, the daylight condition as preset by keys **40**, as preset by key **32***c*.

Computer module **90** also receives an input from the mode selector **42** and the constant distance selector **44**, to indicate whether the system is to operate according to the Collision Danger mode as preselected by key **42***a* to actuate the Safety alarm or Collision alarm whenever the vehicle approaches or is within the computed danger-of-collision distance, or the Constant Distance mode as selected by depression of key **42b**. In the latter case, the alarm would be actuated whenever the vehicle is within a fixed distance as preset by depressing keys **44**.

Computer module **90** also receives an input from the driving ability testing device **60** of FIG. **2** (or **80** of FIG. **5**), which introduces the driver alertness condition as a parameter in the computation to be made by the computer, and/or as a condition to enable the vehicle for operation.

Computer module **90** also includes information about the vehicle braking distances as a function of speed. This is preferably in the form of a look-up table, for example, provided by the manufacturer for predetermined defined conditions concerning road type, skidding danger, vehicle load and tires pressure, and is stored in a ROM (read-only memory) of the microcomputer so that it can be changed periodically if necessary.

Computer module **90** also includes information concerning specific days during the year, or specific hours during the day, which are defined as dangerous driving days or hours. Examples of the latter include Saturday nights, Christmas Eve, New Year's Eve, dusk hours, etc., statistically known as dangerous driving times. This information could be introduced into the calculations by the computer in one of the safety factors or coefficients used by the computer in its calculations.

Computer module **92** controls the various displays, including the clock display **52**, the distance display **46**, **48**, the speed display **50** and other displays such as the key displays, namely the indicator lights which illuminate each of the keys (**30**, etc.) on the control panel whenever the key is depressed, as described earlier.

The deceleration alarm module **93** controls the Safety and Collision alarms. As indicated earlier, the Safety alarm is first actuated to alert the driver that the vehicle is approaching the danger-of-collision distance from an object, or another rear vehicle is approaching the danger-of-collision distance. This alarm may be in the form of an Interrupted Audio alarm from speaker **54** and a Continuous Visual alarm from the collision danger display **46***c* or **48***c*. The Collision alarm, which is actuated when the vehicle is within the danger-of-collision distance, may be in the form of an Continuous, Higher-Intensity Audio alarm from speaker **54**, and a Flashing Visual alarm from display region **46***c* or **48***c*.

The deceleration alarm module **93** further controls the brake light actuator **26** to alert drivers that may be trailing the vehicle involved, and also a brake light actuator display, shown at **26***a* in FIG. **6**, to indicate this to the driver of the vehicle equipped with the safety system.

In some vehicles, such as a train or aircraft, the described system may also be provided with an actuator for automatically effecting a control of the vehicle, e.g., for automatically actuating the brakes in a train, or a steering control in an aircraft, in response to a danger-of-collision condition. This is schematically indicated by block **96** in FIG. **6** as controlled by the deceleration alarm module **93**.

The black box module **94** controls various displays, generally indicated by block **97** in FIG. **6***b*, carried by the black box itself to read out the information recorded in the black box concerning alarm incidents which occurred, including the time, speed of the vehicle, and distance from he object, for each alarm incident.

The driving ability test module **95** controls a start-up enable device, generally designed **98**, which enables the vehicle to be operated only when the test has been satisfactorily passed, and a display, such as display **64** in FIG. **2**, indicating that the driver has satisfactorily passed the test and therefore the vehicle is enabled for operation.

FIG. **7** is a circuit diagram of the microcomputer **4** and the other components of the electrical system. The microprocessor is indicated by block **100**, its power supply by block **102**, and its watchdog circuit by block **104**. It includes a transmitter **106** and a receiver **108** for transmitting and receiving the pulses (e.g., RF, ultrasound, laser, IR, etc.) in the front space sensor **8** and the rear space sensor **10** for measuring the distance of the vehicle from objects in front of, and to the rear, of the vehicle, respectively. The microprocessor **100** includes inputs from all the automatic sensors, and from the presettable keys on the control panel, as described above. For purposes of example, only one of the sensors, indicated schematically at **110**, and only one of the presettable keys indicated schematically at **111**, are shown as inputs into the microprocessor. Since the circuit illustrated in FIG. **7** is well known and commercially available, further details of its structure and mode of operation are not set forth herein.

Distance Determination

As indicated earlier, the distance of the vehicle from an object is determined by the front space sensor **8** with respect to objects in front of the vehicle, and by the rear space sensor **10** with respect to objects at the rear of the vehicle. Each of these space sensors may be of known construction, including a transmitter as indicated at **106** in FIG. **7**, and a receiver as indicated at **108**. Thus, pulses are continuously transmitted by each transmitter, and the echoes from the objects in front of or to the rear of the vehicle are received by the respective receiver. The computer then measures the round-trip time from the pulse transmission to the echo reception in order to determine the distance of the vehicle from the object.

FIG. **8** illustrates an example of the pattern of pulses transmitted by the transmitters. Each pulse is identified by a twelve-bit code. As shown in FIG. **8**, the first eight bits do not change and identify the vehicle transmitting the pulses, whereas the next four bits change with each transmission and thereby identify the pulse then being transmitted, such that the computer can compare the return pulse with the transmitted pulse and thereby determine the round-trip time of the respective pulse. The receiver is "opened" to receive echoes for a predetermined "window time" so as to eliminate echoes from distances which are defined as too long.

OPERATION

General

The operation of the described anti-collision system is illustrated in the flow charts of FIGS. **9–14**. The abbreviations included in the flow chart are identified by the following table:

TABLE

AS	Approach speed
A	Maximum permissible time for performing driving ability test
AL	Alarm
ALSF	Alarm stopping front counter
ALSR	Alarm stopping rear counter
ALCF	Alarm collision front counter
ALCR	Alarm collision rear counter
ALFA	Alarm stopping front accumulator
ALRA	Alarm stopping rear accumulator
AM	Alarm mode
BD(AS)	Braking distance as a function of approaching speed
BF	Braking factor
CL	Carload or vehicle load
CD	Collision distance
CDM	"Constant Distance" mode distance
CSF	Collision safety factor
DL	Daylight/darkness
DD	Driving duration
DDHF	Dangerous driving hours factor
FADR	Front alarms to driving duration ratio
I	Counter
ICD	Constant Distance Alarm Counter
M	Maximum permissible time for checking collision danger existance in front when at rear there was no danger last time checked.
MD	Measured distance
RMD	Rear MD (measured distance)
RADR	Rear alarms to driving duration ratio
RV	Reverse gear (RV = '1' when reverse)
RT	Reaction time
RF	Reaction factor
RP	Road type
RRT	Rear RT (e.g., RRT=RT+3 Standard deviations)
RRF	Rear RF (RRF ≧1)
RBD	Rear BD
RCL	Rear CL
RBF	Rear BF (RBF ≧1)
RST	Rear ST (RST ≧1)
RSF	Rear SF (RSF ≧1)
Rx	Receiving echo
RSD	Rear stopping distance
RCSF	Rear CSF
SD	Stopping distance
SO	Sensors output
SK	Skidding danger
ST	Stopping factor
SF	Safety factor
T	Time
TFA	Total front stopping alarms
TRA	Total rear stopping alarms
TO	Time over (for the receiver "window-time")
Tx	Transmission command
TRx	Time of Rx
TTx	Time of Tx
V	Vehicle speed
VC	Visibility conditions
X	Trip number

As shown in the foregoing table, many factors are to be included in making the various computations. These factors may be determined for each case in order to make the appropriate computation for actuating the collision alarm, and before it the safety alarm, as close as possible to the actual conditions at the time of driving, including the driver conditions, vehicle conditions, and the environmental conditions as described above. The ALSF and ALSR counters, the ALCF and ALCR counters, and the ALFA and ALRA accumulators in the above table, and referred to in the flow charts below, would be provided in the black box **28** which records all the incidents in which the safety alarm and collision alarm were actuated, including the time, vehicle speed and vehicle distance for each alarm incident.

Overall Operation

The overall operation is illustrated in the flow chart of FIG. **9**. Thus, after the system is reset (block **120**), all the parameters are initialized (block **122**), and the pulse transmitters in the front and rear space sensors **8** and **10** are incremented one pulse count (block **124**), by incrementing the last four bits of the twelve-bit pulse, as described above with respect to FIG. **8**. The pulse is then transmitted (block **12,5**), and the time is measured until its echo is received within a limited duration (blocks **128**, **130**). This time is used for calculating the approach speed of the vehicle with respect to an object (block **132**). The vehicle speed is then determined, e.g., as read from a speed sensor on the vehicle,, or as determined independently, e.g., by the Doppler effect (block **134**). All the parameters as preset by the presettable keys on the control panel **6**, as well as the outputs from the various sensors as illustrated in FIG. **1**, are then read (block **136**), and the computer then determines whether there is a collision danger, i.e., whether the measured distance is within the collision-of-danger distance (block **138**). If so, it actuates the alarms; and if not, it returns to increment and transmit the next pulse (blocks **140** and **142**).

Operation of the Calculation Module **90**

As indicated earlier, the illustrated system includes two alarms, namely a Collision alarm which is actuated whenever the measured distance of the vehicle from an object is within the danger-of-collision distance as computed by the computer; but before that alarm is actuated, a Safety alarm is first actuated to alert the driver that the vehicle is approaching the above collision alarm distance. For example, the safety alarm may be actuated when the vehicle is determined to be within a distance which is increased by 25% as compared to the collision distance, in which case the collision distance is multiplied by a safety factor of 1.25 to determine the distance for energizing the safety alarm.

The foregoing is more clearly illustrated in the flow chart of FIGS. **10***a*, **10***b* which illustrates the operation of the calculation module **90**.

Thus, the system is first initialized as shown by block **150**, and then the various factors concerning the reaction, braking and stopping distances, and other parameters (representing the rear vehicle and driver parameters), that are not presettable from the keyboard, and are read into the computer as indicated by block **152**. The driving date and hour are then read (block **154**), and a determination is made whether that time is a dangerous time (e.g., a high-accident rate time, block **156**). If so, safety factors (SF and RSF) are introduced to compensate for this danger time (block **158**), before the reaction time (RT), as well as the other presettable parameters, including approach speed, braking distance as a function of approach speed, etc., as shown in box **160**, are introduced.

The system then makes the computations illustrated (as an example) in block **162** to determine the stopping distance SD, which is equal to the reaction distance plus the braking distance multiplied by a stopping factor ST and a safety factor SF. In the illustrated example, the stopping distance is the sum of the reaction distance and the braking distance. The reaction distance is the product of the reaction time, visibility condition, daylight condition, reaction factor and speed; and the braking distance is the product of the braking distance (as supplied by the manufacturer), road type, skidding danger, vehicle load and braking factor. The stopping distance (SD) includes further safety factors, and determines when the safety alarm will be actuated to first alert the driver of an approaching collision danger.

A determination is also made of the collision distance CD which is equal to the stopping distance SD divided by the collision safety factor CSF, e.g., 1.25 in the example illustrated above, such that should the distance between the vehicle and the object come within the collision distance CD, the collision alarm is then actuated.

The foregoing calculations of stopping distance SD and collision distance CD with respect to objects at the front of the vehicle are also made with respect to objects at the rear of the vehicle, these calculations being RSD and RCD, respectively, also shown in block **162**.

Whenever the distance between the vehicle and an object to the front of the vehicle or to the rear of the vehicle comes within the stopping distance SD and the collision distance CD, the system operates according to the deceleration alarm module **93**, as indicated by block **164**.

Operation of Deceleration Alarm Module 93

The function of this module is to actuate the safety alarm or collision alarm, and also the brake light, at the proper time, and also to record the events within the black box **128**. The operation of this module is more particularly illustrated in FIG.**11**a–**11**h.

After the system initializes (block **200**), it checks to see whether the Alarm mode or the Constant Distance mode has been preset (block **202**). If the Constant Distance mode has been preset, it continuously checks to determine whether the measured distance is less than the preset constant distance, and if so, it actuates the alarm (blocks **203–207**); at the same time, it also increments the constant distance alarm counter (block **206**) in the black box **28**.

If the system is in the Collision Danger mode, it continuously compares the measured distance with the computed stopping distance, and whenever the measured distance is equal to or less than the computed stopping distance, it actuates the alarm; at the same time, it increments an alarm counter (ALSF) and also records the time, distance and speed in the black box (blocks **208–211**).

The above operations are repeated with respect to the rear measured distance (blocks **212–217**). During these operations, the system also checks to determine whether the vehicle is driving in reverse, and if so, the reverse stopping distance (RSD) is considered to be the stopping distance (SD), as shown by blocks **213, 214**.

This information is also recorded in the black box (block **217**). During this operation, the system also checks to see whether there was a problem with the front (block **218**); if not, it repeats the foregoing operations (starting with block **208**). If, however, there was a problem at the front, the system compares the measured distance with the collision distance (blocks **219, 220**). If there is a collision danger, the Collision alarm is actuated (block **221**); at the same time, the Collision alarm counter in the black box is incremented (block **222**), and the time, distance and speed of the vehicle are recorded in the black box (block **223**). If the system is included in an anti-collision system for trains, then the actuation of the collision alarm would also be accompanied by the actuation of the braking system of the train (block **221**).

Where the measured distance was greater than the collision distance, the system monitors the measured distance now with the stopping distance and if it is greater than the stopping distance, the value in counter ALSF is accumulated in accumulator ALFA, and then the counter is reset to zero (blocks **224–227**). The system then returns to the beginning of the loop, point C.

Whenever the measured distance is equal to or less than the stopping distance (block **225**), the system increments the alarm stopping front counter (block **228**), records the time, distance and speed in the black box, and also actuates the safety alarm (block **229**).

The system also checks to see whether there had been a problem with the rear the last time this had been checked; if so (i.e., ALSR not equal to zero), the system proceeds to point E. As will be described more particularly below, point E checks to determine whether there is a rear collision danger.

If there had not been a problem with the rear the last time it was checked, and the last time it was checked is less than a predetermined maximum time (blocks **231,232**), the system again checks to determine whether there is a collision danger in the front (point D); but if the maximum time was exceeded, it then returns to the beginning of the loop (point C).

When it was determined that there is a problem with the stopping distance which actuated the Safety alarm (block **215**) or that there was a problem with the stopping distance at the rear (block **230**), the system checks whether there is a Collision danger at the rear (block **233**). If the vehicle is being driven in reverse (block **234**) it considers the computed rear collision distance to be the same as the front collision distance (block **235**), and then checks to determine whether the measured rear distance is equal to or less than the computed rear collision distance (block **236**). If there is a danger of collision (block **237**), the Collision alarm is actuated, etc. (as described above with respect to point F).

If there is no danger of a rear collision, a check is again made to determine whether the vehicle is in reverse, and if so, the computed Rear stopping distance is considered to be the same as the front stopping distance (blocks **239, 240**). The system then checks to determine whether the rear measured distance is equal to or less than the computed rear stopping distance (block **241**). If the rear measured distance is greater than the computed rear stopping distance (block **241**), the value in counter ALSR is introduced into accumulator ALRA, counter ALSR is reset to zero, and the system then returns to the beginning of the loop, point C.

If, however, the rear measured distance is equal to or less than the computed stopping distance, the Safety alarm and the brake light are actuated, and the same operations are repeated with respect to the information stored in the black box as described above (blocks **242–244**). The system then checks to determine whether there had not been a previous problem with the front stopping distance, and whether the last check had been within a previous time interval. If so, it returns to check the collision danger from the rear; but if not, it returns to the beginning of the loop at point C, or continues to check the front collision danger (point D) if there was a problem at the front (i.e., ALSF is not equal to "0").

Operation of the Switches/Sensors Module 92

FIGS. **12**a, **12**b, are a flow chart illustrating the operation of the switches/sensors output data module **92**.

During this operation, the system first reads the presettable parameters according to the settings of the reaction time key **30** (block **300**), the carload-trailer key **32** (block **302**), the skidding danger key **324** (block **304**), the visibility condition key **36** (block **306**), the road type key **38** (block **308**), the daylight key **40** (block **310**), the Alarm mode key **42** (block **312**), and the constant distance key **44** (block **314**). The system also reads the position of the reverse gear sensor output schematically shown at **22** in FIG. **1** (block **316**), reads or calculates the car speed (block **318**), reads the front and rear car distances (block **320**), and reads the clock time (block **322**). The foregoing parameters are displayed by actuating the clock display **52**, the distance displays **46**, **48**, the speed display **50**, and the key display **30**, etc. (block **324**). If no change is made in these settings, the system continues to read or calculate the car speed, etc., until a change occurs, at which time the system begins the loop at point A.

Operation of the Black Box Module 94

As indicated earlier, the black box (**28**, FIG. **1**) maintains a record of all incidents during which the safety alarm and collision alarm were actuated, recording the time, speed and relative distance between the vehicle and object for each such occurrence. This record is accumulated within the black box and may be read out at any desired time, e.g., by operators of taxicabs, buses, trucks, trains or aircraft, to provide a record of what occurred during the vehicle trip. This information can be recorded for a predetermined number of trips.

The flow chart of FIGS. **13*a***, **13*b*** more particularly illustrates the operation of the black box module **94**, wherein it will be seen that a record is made with the driving duration at all times in which the vehicle is moving during the current trip (block **350**), during which the various accumulators (ALFA and ALRA), and counters (ALSF and ALSR) are recorded (block **352**) and accumulated (block **354**). These are used to calculate the total number of front stopping alarms and the ratio thereof to the driving duration, and may be displayed at any time when requested (e.g., by using the blackbox alarm data menu **78** illustrated in FIG. **4**, blocks **356**, **358** and **360**). In the same way, the total collision alarms may be calculated and the ratio thereof to the driving duration.

In the case of trains or aircraft where the vehicle itself was automatically controlled, e.g., automatic actuation of the brakes in a train, this is also displayed (block **362**).

Operation of Driving Ability Test Module 95

FIG. **2** illustrates one form of driving ability test, at **60**, and FIG. **5** illustrates a more complicated driving ability test that may be used to determine the fitness of the driver to operate the vehicle. The result of this test may be used as one of the parameters indicating the condition of a driver to be used in calculating the collision distance before either the collision alarm or the safety alarm is actuated. The results of this test may also be used to disable the operation of the vehicle unless and until the driver has successfully passed the test. The latter operation is more particularly illustrated in the flow chart of FIGS. **14*a*–14*d***.

Thus, as shown in FIG. **14*a***, a counter I, which accumulates the number of attempts by the driver to pass the test, is first initialized (block **370**), and then a predetermined number A, representing the maximum permissible time to perform the test, is read (block **371**). With respect to the more complicated device illustrated in FIG. **5**, the random values in the horizontal display **82**, vertical display **83**, and first/last (F/L) display **84**, are then read into the system (block **373**); these set forth the sequences and directions in which keys **81** are to be depressed and the number of times in each sequence they are to be depressed.

The driver then depresses the Start/Stop key **85**, and then executes the test depressing the keys **81** according to the random displays **82**, **83** and **84**, and as soon as this has been completed, the Start/Stop key **85** is again depressed. These operations are indicated by blocks **374–381** in FIG. **14**. Following this, a determination is made whether the keys were depressed in the right order and in the correct number of times as displayed (block **382**), and within the maximum permissible time allowed (blocks **383**, **384**). If so, the test was satisfactorily passed, and the operation of the vehicle is enabled (blocks **385** and **386**).

On the other hand, if the test was not satisfactorily passed, either because the keys were not properly depressed or the specified time limit was exceeded, the FAIL display **88** is energized. The system permits the operator to make another attempt by depressing the reset key **86** provided the maximum number of attempts had not been exceeded, e.g., ten attempts (blocks **388–393**). If the driver failed the test a prescribed number of times, the vehicle is disabled for a prescribed period (e.g., thirty minutes) before the driver can again attempt to pass the test.

Some Variations

FIGS. **15** and **16** illustrate two further variations that may be made in the control panel.

FIG. **15** illustrates a control panel which is the same as in FIG. **2**, except for the following changes.

One change is that three further parameters may be preset into the system, to be taken into consideration in computing the collision distance and safety distance. Thus, in addition to the other presettable parameters as illustrated in FIG. **2**, the control panel shown in FIG. **15** includes an additional group of keys **400** for presetting the tire pressure (which parameter could also be automatically sensed by a sensor), keys **402** for presetting the road condition, and keys **404** for presetting whether the vehicle is being driven in an urban area or on a high speed highway (e.g., a freeway or toll road).

Another change included in the control panel illustrated in FIG. **15** is that it includes a depressible key **405** marked DTAD, standing for Dense Traffic Alarm Disable. Thus, this key may be depressed by the driver when driving in a dense area and, if depressed, would be effective to disable the alarm whenever the distance to another object is less than a predetermined minimum distance, or whenever the speed of the vehicle is less than a predetermined minimum speed, or whenever the product of the above two factors is less than a predetermined minimum value.

The control panel illustrated in FIG. **16** is particularly useful for trains, since it also includes a set of keys **410** indicating many different load levels, e.g., corresponding to the number of cars in the train.

In all other respects, the control panels illustrated in FIGS. **15** and **16** may be substantially the same as described above.

While the invention has been described with respect to several preferred embodiments, it will be appreciated that these are set forth merely for purposes of example, and that the invention, or various aspects of the invention, may be advantageously used with other modifications or in other applications.

What is claimed is:

1. An anti-collision system for moving vehicles, comprising:

means for determining the speed of a moving vehicle;

means for measuring the distance of the moving vehicle from an object;

a computer for receiving a number of parameters, including the speed of the vehicle, and for computing from said parameters a danger-of-collision distance to said object;

and a collision alarm actuated by said computer when the measured distance of said object is equal to or less than said danger-of-collision distance computed by the computer;

characterized in that said system also includes a control panel having parameter presetting means for presetting preselected parameters which are utilized by said computer for computing said danger-of-collision distance to said object;

said preselected parameters including at least one vehicle parameter concerning a preselected condition of the vehicle, and at least one environmental parameter concerning a preselected condition of the environment.

2. The system according to claim 1, wherein the system also includes a safety alarm actuated by said computer, before actuating said collision alarm, when said measured distance is equal to or less than said danger-of-collision distance multiplied by a predetermined safety factor.

3. The system according to claim 2, wherein said control panel also includes distance presetting means for presetting a selected fixed distance from said object, said computer being effective to actuate one of said alarms when the distance to said object is equal to or less than said fixed distance.

4. The system according to claim 1, wherein said preselected parameters further include:

at least one driver parameter concerning a preselected condition of the vehicle driver.

5. The system according to claim 4, wherein said driver parameter includes a selected one of a plurality of relative reaction times of the vehicle driver.

6. The system according to claim 1, wherein said vehicle parameter includes a selected one of a plurality of relative load conditions of the vehicle.

7. The system according to claim 1, wherein said environmental parameter includes a selected parameter indicative of the danger of the road to skidding.

8. The system according to claim 1, wherein said environmental parameter includes a selected parameter indicative of the visibility condition at the time of driving.

9. The system according to claim 1, wherein said environmental parameter includes a selected parameter indicative of the type of road over which the vehicle is travelling.

10. The system according to claim 1, wherein said environmental parameter includes a selected parameter indicative of whether or not it is daylight at the time of driving.

11. The system according to claims 1, wherein said presetting means includes a plurality of depressible keys on said control panel.

12. The system according to claim 1, wherein said vehicle includes a brake light indicator which is automatically actuated when said collision alarm is actuated.

13. The system according to claim 2, wherein said vehicle includes a brake light indicator which is automatically actuated when said safety alarm is actuated.

14. The system according to claim 1, wherein said control panel includes presettable means for disabling said collision alarm when said measure distance, said determined speed, or the product of said measured distance and said determined speed is less than a predetermined minimum.

15. The system according to claim 1, further including a plurality of condition sensors for sensing any one of a plurality of, said selected conditions, and for automatically feeding to said computer information with respect to said sensed conditions, said information also being utilized by the computer for computing said danger-of-collision distance to said object.

16. The system according to claim 15, wherein said condition sensors include a condition-of-driver sensor, comprising:

a plurality of depressible keys including a start key and further keys;

means effective upon depressing the start key for displaying a random sequence in which said further keys are to be depressed;

and means for comparing the actual sequence in which said further keys are depressed with said displayed random sequence to provide a condition-of-driver parameter, which said condition-of-driver parameter is also utilized by the computer for enabling or disabling vehicle operation or for computing said danger-of-collision distance to said object.

17. The system according to claim 1, wherein said system further includes a sealed recording device which records all incidents in which said computer actuated said alarm including the time, speed and relative distance between the vehicle and said object for each incident.

18. The system according to claim 1, wherein said system further includes an actuator for automatically actuating a mechanical system of the vehicle at the time said collision alarm is actuated.

19. An anti-collision system for moving vehicles, comprising:

means for determining the speed of a moving vehicle;

means for measuring the distance of the moving vehicle from an object;

a computer for receiving a number of parameters, including the speed of the vehicle, and for computing from said parameters a danger-of-collision distance to said object;

and a collision alarm actuated by said computer when the measured distance of said object is equal to or less than said danger-of-collision distance computed by the computer;

characterized in that said system also includes a control panel having parameter presetting means for presetting preselected parameters which are utilized by said computer for computing said danger-of-collision distance to said object;

said preselected parameters including at least one vehicle parameter concerning the load carried by the vehicle, and at least one driver parameter concerning a preselected condition of the vehicle driver.

20. An anti-collision system for moving vehicles, comprising:

means for determining the speed of a moving vehicle;

means for measuring the distance of the moving vehicle from an object;

a computer for receiving a number of parameters, including the speed of the vehicle, and for computing from said parameters a danger-of-collision distance to said object;

and a collision alarm actuated by said computer when the measured distance of said object is equal to or less than said danger-of-collision distance computed by the computer;

characterized in that said system also includes a control panel having parameter presetting means for presetting preselected parameters which are utilized by said computer for computing said danger-of-collision distance to said object;

said preselected parameters including at least one driver parameter concerning a preselected condition of the vehicle driver, and at least one environmental parameter concerning a preselected condition of the environment.

* * * * *

EXHIBIT 16

United States Patent [19]

Iizuka et al.

[11] **4,061,055**

[45] **Dec. 6, 1977**

[54] **FUEL INJECTION CONTROL SYSTEM FOR AN INTERNAL COMBUSTION ENGINE OF A VEHICLE**

[75] Inventors: **Haruhiko Iizuka; Junichiro Matsumoto,** both of Yokosuka; **Fumiaki Kato,** Yokohama, all of Japan

[73] Assignee: **Nissan Motor Co., Ltd.,** Yokohama, Japan

[21] Appl. No.: **718,189**

[22] Filed: **Aug. 27, 1976**

[30] **Foreign Application Priority Data**

Aug. 28, 1975 Japan 50-103474

[51] **Int. Cl.**[2] **B60K 41/18;** F02B 3/00; F02B 77/00

[52] **U.S. Cl.** .... **74/866;** 123/198 F; 123/32 EA; 74/859

[58] **Field of Search** .... 123/198 F, 32 EA; 74/857, 858, 859, 860, 866

[56] **References Cited**

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4,008,567	2/1977	Hirsch	74/866 X

Primary Examiner—Samuel Scott
Assistant Examiner—Lance W. Chandler

[57] **ABSTRACT**

A control system which controls the number of fuel-injected cylinders is used with an electronic type of automatic transmission system and includes compensating means or an engine operating parameter changing unit for changing a parameter fed to the transmission system to properly operate the same, thus increasing fuel economy or reducing fuel consumption.

10 Claims, 2 Drawing Figures

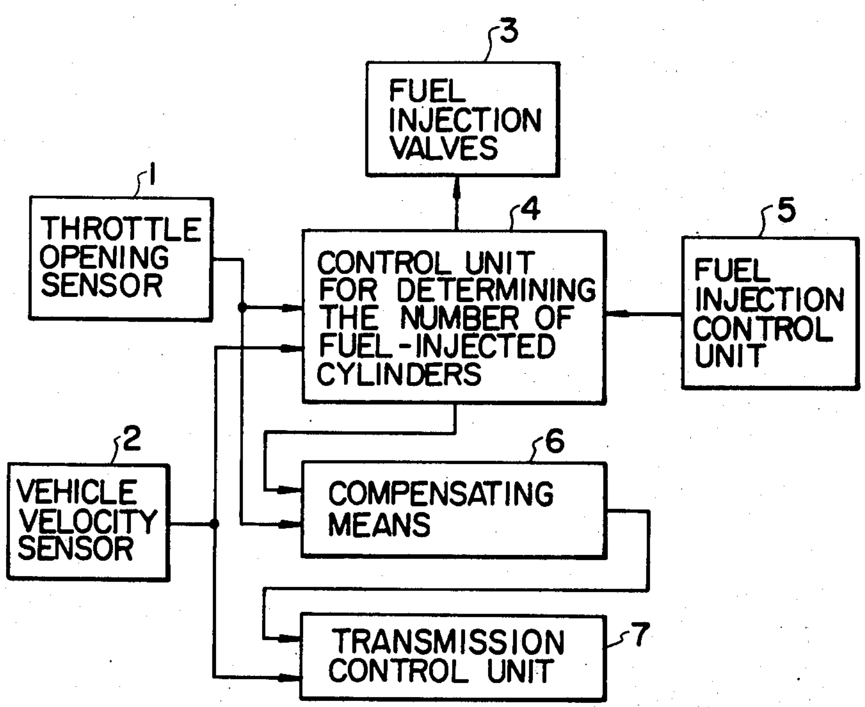


FIG. 1

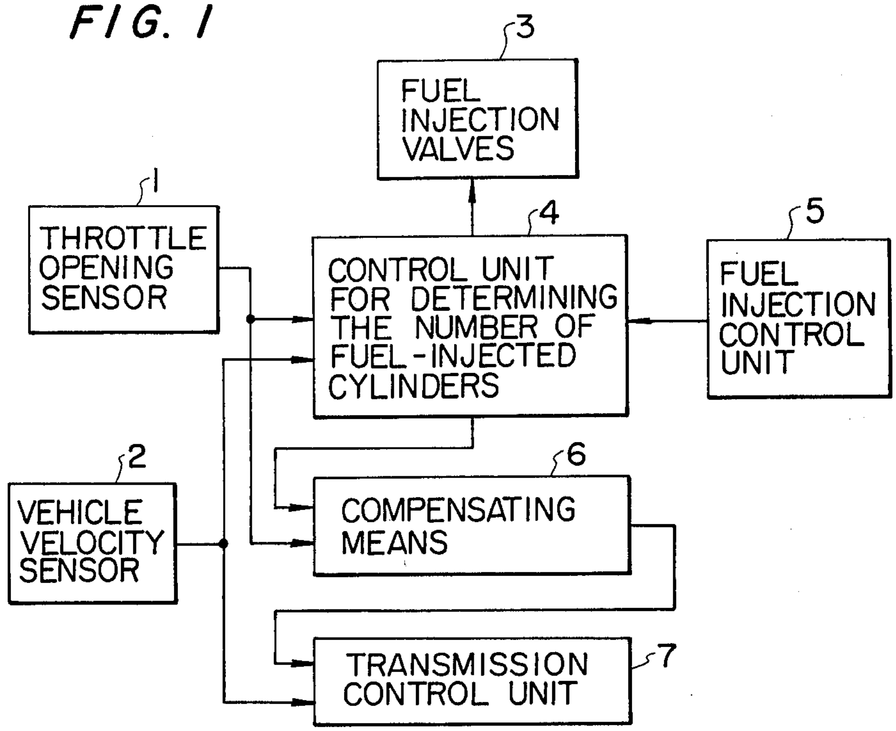
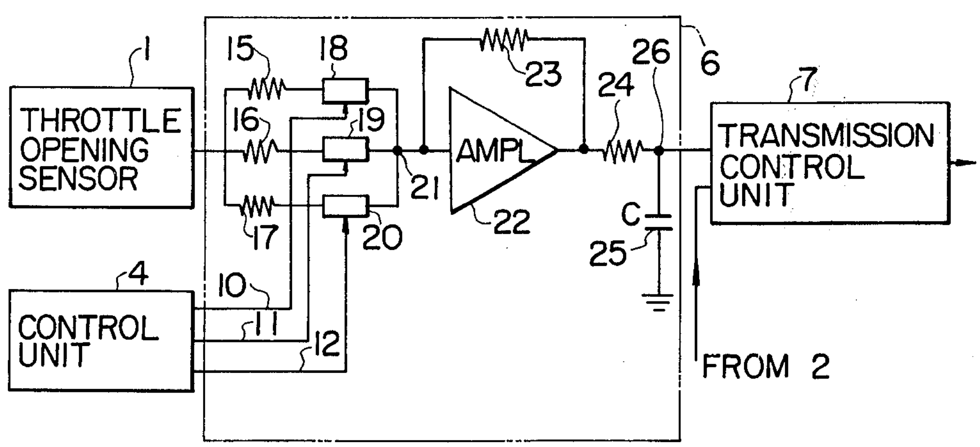

3
FUEL INJECTION VALVES
1
THROTTLE OPENING SENSOR
4
CONTROL UNIT FOR DETERMINING THE NUMBER OF FUEL-INJECTED CYLINDERS
5
FUEL INJECTION CONTROL UNIT
2
VEHICLE VELOCITY SENSOR
6
COMPENSATING MEANS
TRANSMISSION CONTROL UNIT
7

FIG. 2


1
THROTTLE OPENING SENSOR
15
16
17
18
19
20
21
AMPL
22
23
24
26
6
7
TRANSMISSION CONTROL UNIT
C
25
4
CONTROL UNIT
10
11
12
FROM 2

FUEL INJECTION CONTROL SYSTEM FOR AN INTERNAL COMBUSTION ENGINE OF A VEHICLE

This invention relates in general to a fuel injection control system for an internal combustion engine of a vehicle, and particularly to a fuel injection control system controlling the number of cylinders to which fuel is injected, and more particularly to such a fuel injection control system for use with a conventional electronic type of automatic transmission system.

Certain electronic types of automatic transmission systems have been proposed which are disclosed for example in U.S. Pat. Nos. 2,995,949 and 3,052,134. However, when these conventional automatic transmission systems are employed together with a fuel injection control system for controlling the number of cylinders to which fuel is injected, the following disadvantage can be pointed out. That is, when employing such a fuel injection control system, the number of the cylinders to which fuel is injected is determined such that manifold absolute pressure becomes generally within the range from 100 to 150 mmHg in order to attain fuel economy or decrease fuel consumption. Therefore, the opening degree of a throttle is adjusted to maintain the above described manifold absolute pressure. On the other hand, the shifting of gear ratios in the automatic transmission system is determined depending upon vehicle velocity and also a suitable engine operating parameter. However, when the fuel injection control system is employed together with the automatic transmission system, the opening degree of the throttle or the manifold absolute pressure is used as the engine operating parameter. In this instance, however, the opening degree of the throttle or the manifold absolute pressure is not preferable because it is no longer a proper parameter for controlling the shifting of gear ratios. This is because the opening degree of the throttle is always controlled to maintain the manifold absolute pressure within the above described range. Therefore, if the opening degree of the throttle or the manifold absolute pressure is used as a parameter without any compensation, a gear ratio change is liable to take a lower position than intended. For example, even if a second gear ratio is desirable from a viewpoint of fuel economy, gears are shifted into the first gear ratio for reducing engine torque. This contravenes the concept of the aforementioned fuel injection control system, reducing the fuel conomy.

The present invention therefore contemplates an improved fuel injection control system, which controls the number of cylinders to which fuel is injected, in order to remove the above described defect.

In accordance with the present invention, an improved fuel injection control system for use with an electronic type of automatic transmission system for an internal combustion engine of a vehicle comprises in combination: a plurality of injection means respectively provided at corresponding cylinders of the engine; a first sensor for sensing the opening degree of a throttle or a manifold absolute pressure to generate a signal representative thereof; a second sensor for sensing vehicle velocity to generate a signal representative thereof, which second sensor is connected to a transmission control unit of the automatic transmission system to supply the same with the signal; a control unit connected to said first and said second sensor receiving the signals therefrom for determining the number of cylinders to which fuel is injected, and controlling the plurality of injection means connected thereto; and compensating means connected to the first sensor for receiving the signal therefrom and also connected to the control unit of the fuel injection control system for receiving a signal representative of the number of the cylinders to which fuel is injected, and generating a signal representative of the opening degree of the throttle under the condition that fuel is injected to all of the cylinders, regardless of the cylinders to which fuel is actually injected, said compensating means being connected to the transmission control unit for supplying the same with the signal therefrom, whereby the transmission control unit determines a proper shifting of gear ratios based on the signals from both the compensating means and from the second sensor.

It is therefore an object of the present invention to remove the above described defect by providing an improved compensating means in order to properly control a control unit of an automatic transmission system of an electronic type, which transmission system is used with a fuel injection control system for controlling the number of cylinders to which fuel is injected.

This and other objects, features and many of the attendant advantages of this invention will be appreciated more readily as it becomes better understood by reference to the following detailed description, when considered in connection with the accompanying drawings, wherein like parts in each of the several figures are identified by the same reference characters, and wherein:

FIG. **1** is a schematic diagram of the present invention; and

FIG. **2** is a detailed illustration of a unit in FIG. **1** in conjunction with its pheripheral units for better understanding of the present invention.

Reference is now made to the accompanying drawings, first to FIG. **1**, which illustrates a schematic block diagram of a preferred embodiment of the present invention. A fuel injection control unit **5** feeds a control signal to a control unit **4**, which control signal represents an optimum quantity of fuel to effectively operate an internal combustion engine (not shown) of a vehicle. In the followings, detailed description of the fuel injection control unit **5** will be omitted because the present invention is not concerned therewith. The control unit **4** determines the number of cylinders to which fuel is injected, and controls fuel injection through a plurality of fuel injection valves **3** which are respectively positioned on the cylinders. The determination of the number of the cylinders to which fuel is injected is performed based on signals from a throttle opening sensor **1** and a vehicle velocity sensor **2**. The throttle opening sensor **1** is connected to the control unit **4** and converts the opening degree of the throttle into a proportional electrical signal. As to the vehicle velocity sensor **2**, which is also connected to the control unit **4**, a conventional speedometer is available. With this arrangement, when the signal from the vehicle velocity sensor **2** exceeds a predetermined level and at the same time the signal from the throttle opening sensor **1** falls below another predetermined level, the control unit **4** determines the number of cylinders to which fuel is actually injected based on the two signals applied and stops injection of fuel to specified one or more cylinders. Under this circumstance, in order to maintain the original engine operating condition, the vehicle driver should depress the accelerator pedal (not shown) more to open the throttle more. Therefore, the opening degree of the throttle is changed to a desirable value where fuel consumption is desirably decreased and the engine is running efficiently.

An engine operating parameter changing unit or compensating means 6 receives the signal from the throttle opening sensor 1 and also the signal from the control unit 4. The signal from the control unit 4 represents the number of the cylinders to which fuel is not injected. Then, the compensating means 6 feeds an electrical signal to a transmission control unit 7. The signal from the compensating means 6 represents the opening degree of the throttle when fuel is injected to all of the cylinders, regardless of the number of the cylinders to which fuel is actually injected. This means that the transmission control unit 7 is not affected by the provision of the control unit 4 which controls the number of fuel-injected cylinders for maintaining the manifold absolute pressure within the range from 100 to 150 mmHg as previously referred to. Thus, the transmission control unit 7 can properly cntrol the automatic shifting of gear ratios in the transmission.

In the above, the signal from the control unit 4 can be changed to represent the number of the cylinders to which fuel is actually injected, and the throttle opening sensor 1 can be replaced by a sensor for sensing a manifold absolute pressure.

FIG. 2 illustrates a detailed circuit of the engine operating parameter changing unit or the compensating means 6 together with its peripheral units 1, 4 and 7. Suitable resistors 15, 16 and 17 are respectively connected in series with suitable electronic switches 18, 19 and 20, and these three series circuits are then connected in parallel with one another as shown. The switches 18, 19 and 20 are connected to the control unit 4 and controlled by the signal therefrom such that one of the switches is energized or closed in order that the compensating means 6 generates a signal which represents the condition where fuel is injected to all of the cylinders. An operational amplifier 22 is connected at its input terminal to a junction 21 and at its output terminal to a resistor 24. A feedback resistor 23 is connected across the operational amplifier 22. A capacitor 25 is connected between one terminal of the resistor 24 and the ground forming a smoothing circuit together with the resistor 24. A junction 26 between the resistor 24 and the capacitor 25 is connected to the transmission control unit 7.

In operation, when fuel is actually injected to all of the cylinders, a signal is fed to the switch 18 from the control unit 4 through a conducting line 10 to close the same with the switches 19 and 20 open, so that the signal from the throttle opening sensor 1 is applied through the resistor 15 and the switch 18 to the operational amplifier 22. As is well known, the amplification degree of the amplifier 22 is determined by the resistance ratio of the resistor 23 to resistor 15. Therefore, when the resistances of the resistors 15 and 23 are made equal to each other, the signal from the sensor 1 is tranferred unchanged in its magnitude to the transmission control unit 7.

On the other hand, when fuel is not injected to one of the cylinders, the signal from the control unit 4 is fed through line 11 to the switch 19 closing the same with the other switches 18 and 20 open. Therefore, the signal from the sensor 1 is fed to the operational amplifier 22 through the resistor 16 and the switch 19. In this case, the resistance ratio of the resistor 23 to resistor 16 is determined such that the magnitude of the signal fed to the unit 7 represents the condition where fuel is injected to all of the cylinders. Therefore, the transmission control unit 7 receives the signal the magnitude of which is equal to that of the first mentioned signal.

Whilst, when fuel is not injected to two cylinders, the signal from the control unit 4 is fed through line 12 to the switch 20 closing the same with the other switches 18 and 19 opened. As a result, the signal from the sensor 1 is fed to the operational amplifier 22 through the resistor 16 and the switch 20. In this case, like in the second mentioned one, the resistance ratio of the resistor 23 to resistor 17 is determined such that the magnitude of the signal fed to the unit 7 represents the condition where fuel is injected to all of the cylinders. Therefore, the transmission control unit 7 receives the signal the magnitude of which is equal to that of the first mentioned signal.

The integration circuit consisting of the resistor 24 and the capacitor 25 serves to smooth an abrupt change of the output signal from the amplifier 22 when the number of the fuel-injected cylinders changes. The provision of the integration circuit is preferable to precisely determine a proper shifting of gear ratios.

In the above, as aforementioned, the signal fed from the control unit 4 to the switches 18, 19 and 20 can be changed to represent the number of the cylinders to which fuel is actually injected.

It is apparent from the foregoing that, in accordance with the present invention, the fuel injection control system, which controls the number of the cylinders to which fuel is injected, properly operates together with a conventional electronic control type of automatic transmission system by merely providing the engine operating parameter changing unit or the compensating means 6. Thus, fuel economy can be achieved in comparison with the absence of the compensating means 6.

What is claimed is:

1. A fuel injection control system for use with an electronic type of automatic transmission system for an internal combustion engine of a vehicle, said electronic automatic transmission system including a transmission control unit for generating a signal representative of a proper shifting of gears,

said fuel injection control system comprising in combination:

a plurality of injection means respectively provided at corresponding cylinders of the engine;

a first sensor for sensing the opening degree of a throttle to generate a signal representative thereof;

a second sensor for sensing vehicle velocity to generate a signal representative thereof, which second sensor is connected to said transmission control unit supplying the same with the signal;

a control unit connected to said first and said second sensor receiving the signals therefrom for determining the number of cylinders to which fuel is injected, and controlling said plurality of injection means connected thereto; and

compensating means connected to said first sensor for receiving the signal therefrom and also connected to said control unit for receiving a signal representative of the number of the cylinders to which fuel is injected, and generating a signal representative of the opening degree of the throttle under the condition that fuel is injected to all of the cylinders, regardless of the number of the cylinders to which fuel is actually injected, said compensating means connected to said transmission control unit for supplying the same with the signal therefrom, whereby said transmission control unit determines the proper shifting of gear ratios based on the signals from said compensating means and said second sensor.

2. A fuel injection control system claimed in claim **1**, in which said compensating means comprises:

an amplifier;

an input circuit connected between the input terminal of said amplifier and said first sensor and also connected to said control unit of said fuel injection control system, said input circuit changing the amplification degree of said amplifier in accordance with the signal from said control unit so that said amplifier generates the signal representative of the opening degree of the throttle under the condition that fuel is injected to all of the cylinders.

3. A fuel injection control system claimed in claim **2**, in which said input circuit includes a plurality of series circuits which are connected in parallel with one another and each of which consists of an electronic switch and a resistor, the resistance of each of the resistors being different from one another and determined to properly change the amplification degree of said amplifier, and each of the electronic switches being controlled by the signal from said control unit to electrically connect one of the series circuits between the input terminal of said amplifier and said first sensor.

4. A fuel injection control system claimed in claim **2**, in which said amplifier is an operational amplifier across of which a feedback resistor is connected.

5. A fuel injection control system claimed in claim **3**, in which said compensating means further comprises a smoothing circuit including a resistor and a capacitor.

6. A fuel injection control system for use with an electronic type of automatic transmission system for an internal combustion engine of a vehicle, said electronic automatic transmission system including a transmission control unit for generating a signal repesentative of a proper shifting of gear ratios,

said fuel injection control system comprising in combination:

a plurality of injection means respectively provided at corresponding cylinders of the engine;

a first sensor for sensing manifold absolute pressure to generate a signal representative thereof;

a second sensor for sensing vehicle velocity to generate a signal representative thereof, which second sensor is connected to said transmission control unit supplying the same with the signal;

a control unit connected to said first and said second sensor receiving the signals therefrom for determining the number of cylinders to which fuel is injected, and controlling said plurality of injection means connected thereto; and

compensating means connected to said first sensor for receiving the signal therefrom and also connected to said control unit for receiving a signal representative of the number of the cylinders to which fuel is injected, and generating a signal representative of manifold absolute pressure under the condition that fuel is injected to all of the cylinders, regardless of the number of the cylinders to which fuel is actually injected, said compensating means connected to said transmission control unit for supplying the same with the signal therefrom, whereby said transmission control unit determines the proper shifting of gear ratios based on the signals from said compensating means and said second sensor.

7. A fuel injection control system claimed in claim **6**, in which said compensating means comprises:

an amplifier;

an input circuit connected between the input terminal of said amplifier and said first sensor and also connected to said control unit of said fuel injection control system, said input circuit changing the amplification degree of said amplifier in accordance with the signal from said control unit so that said amplifier generates the signal representative of the manifold absolute pressure under the condition that fuel is injected to all of the cylinders.

8. A fuel injection control system claimed in claim **7**, in which said input circuit includes a plurality of series circuits which are connected in parallel with one another and each of which consists of an electronic switch and a resistor, the resistance of each of the resistors being different from one another and determined to properly change the amplification degree of said amplifier, and each of the electronic switches being controlled by the signal from said control unit to electrically connect one of the series circuits etween the input terminal of said amplifier and said first sensor.

9. A fuel injection control system claimed in claim **7**, in which said amplifier is an operational amplifier across of which a feedback resistor is connected.

10. A fuel injection control system claimed in claim **8**, in which said compensating means further comprises a smoothing circuit including a resistor and a capacitor.

* * * * *

EXHIBIT 17

US005121324A

United States Patent [19]

Rini et al.

[11] Patent Number: 5,121,324

[45] Date of Patent: Jun. 9, 1992

[54] MOTOR VEHICLE MAGAGEMENT AND CONTROL SYSTEM INCLUDING SOLENOID ACTUATED FUEL INJECTION TIMING CONTROL

[75] Inventors: **Guy T. Rini; Oldrich S. Kolarik; James E. Marsden**, all of Hagerstown, Md.; **June M. Warner**, Lovettsville, Va.; **Ramin Younessi; Dolyn P. Ruffner**, both of Hagerstown, Md.; **Stephen W. Heffner**, Chambersburg, Pa.

[73] Assignee: **Mack Trucks, Inc.**, Allentown, Pa.

[21] Appl. No.: **454,269**

[22] Filed: **Dec. 21, 1989**

[51] **Int. Cl.**[5] **G06G 15/50;** F02D 31/00; F02M 59/20

[52] **U.S. Cl.** **364/431.05;** 123/500; 123/349; 123/351; 364/426.04; 364/431.07

[58] **Field of Search** 364/431.01, 431.03, 364/431.04, 431.05, 431.07, 424.1, 424.01, 426.04; 123/500-503, 357, 349, 350, 351

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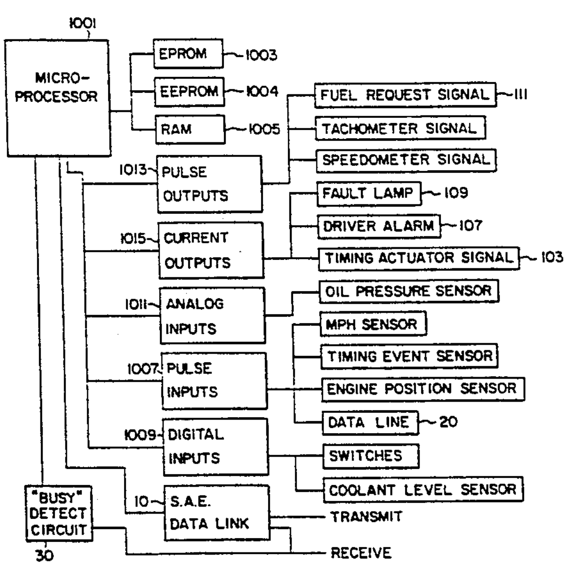
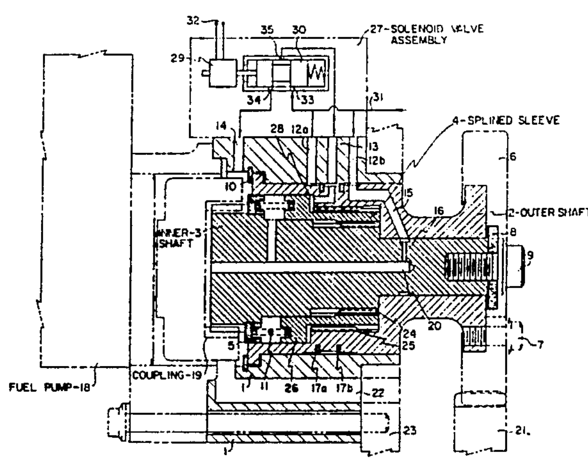
Primary Examiner—Parshotam S. Lall
Assistant Examiner—E. J. Pipala
Attorney, Agent, or Firm—Rothwell, Figg Ernst & Kurz

[57] **ABSTRACT**

An electronic integrated engine and vehicle management and control system includes an electronic vehicle control module and a fuel injection control module, in communication with each other, which together control the total vehicle and engine operation functions of a heavy duty vehicle. A novel fuel injection timing device is utilized with the control module to allow precise and sophisticated control of engine timing based on a number of engine and vehicle operating parameters as determined by the control modules. Functions such as engine speed control, vehicle road speed control, engine protection shutdown, fuel economy, braking control and diagnostics are performed by the system.

8 Claims, 8 Drawing Sheets





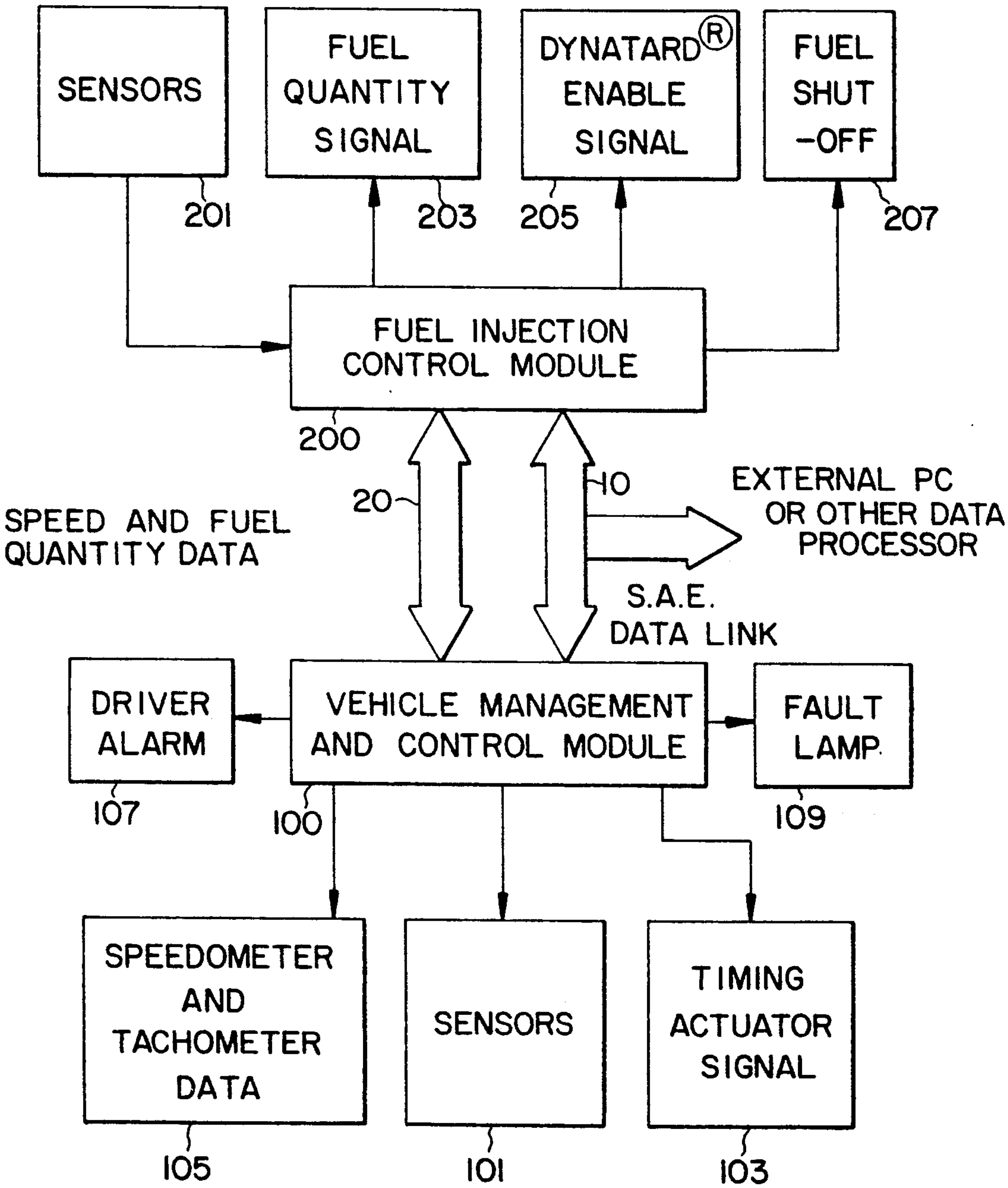
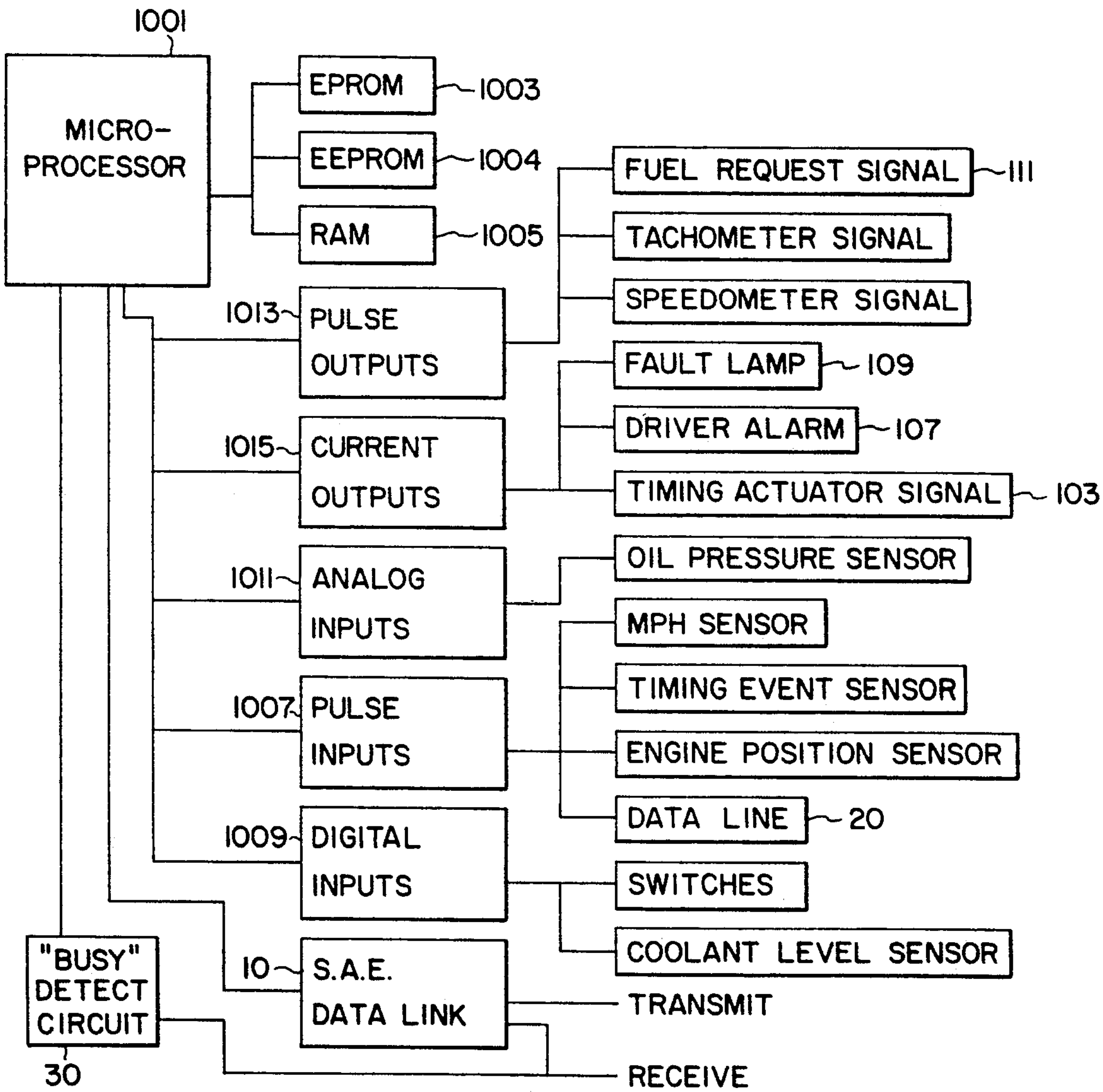

SENSORS
201
FUEL QUANTITY SIGNAL
203
DYNATARD® ENABLE SIGNAL
205
FUEL SHUT -OFF
207
FUEL INJECTION CONTROL MODULE
200
20
10
SPEED AND FUEL QUANTITY DATA
EXTERNAL PC OR OTHER DATA PROCESSOR
S.A.E. DATA LINK
DRIVER ALARM
107
VEHICLE MANAGEMENT AND CONTROL MODULE
100
FAULT LAMP
109
SPEEDOMETER AND TACHOMETER DATA
105
SENSORS
101
TIMING ACTUATOR SIGNAL
103

FIG.1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MICRO-
PROCESSOR
EPROM
1003
EEPROM
1004
RAM
1005
1013
PULSE
OUTPUTS
1015
CURRENT
OUTPUTS
1011
ANALOG
INPUTS
1007
PULSE
INPUTS
1009
DIGITAL
INPUTS
10
S.A.E.
DATA LINK
"BUSY"
DETECT
CIRCUIT
30
FUEL REQUEST SIGNAL
111
TACHOMETER SIGNAL
SPEEDOMETER SIGNAL
FAULT LAMP
109
DRIVER ALARM
107
TIMING ACTUATOR SIGNAL
103
OIL PRESSURE SENSOR
MPH SENSOR
TIMING EVENT SENSOR
ENGINE POSITION SENSOR
DATA LINE
20
SWITCHES
COOLANT LEVEL SENSOR
TRANSMIT
RECEIVE

FIG. 2

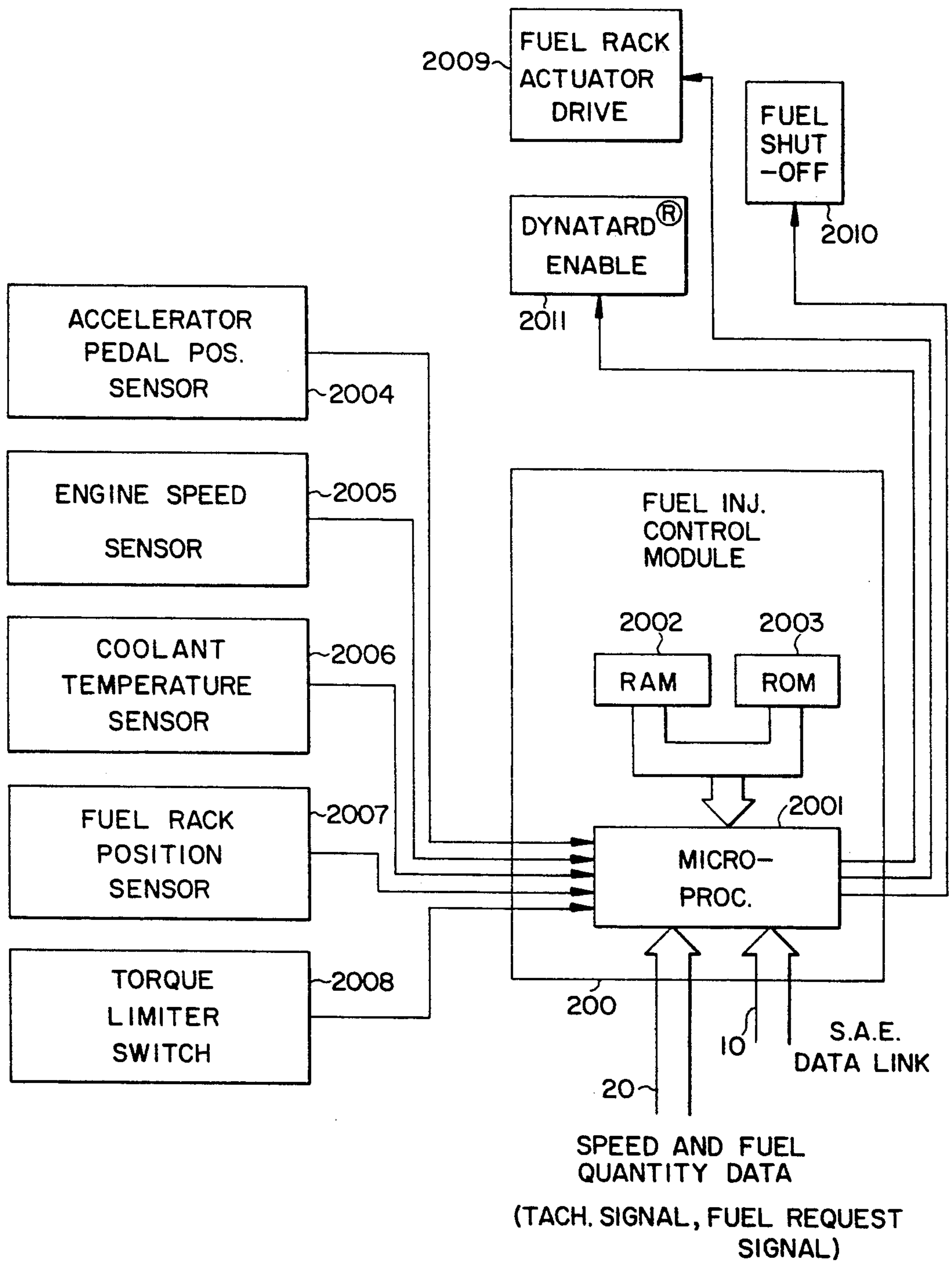
FUEL RACK ACTUATOR DRIVE
2009
FUEL SHUT -OFF
2010
DYNATARD® ENABLE
2011
ACCELERATOR PEDAL POS. SENSOR
2004
ENGINE SPEED SENSOR
2005
COOLANT TEMPERATURE SENSOR
2006
FUEL RACK POSITION SENSOR
2007
TORQUE LIMITER SWITCH
2008
FUEL INJ. CONTROL MODULE
2002
2003
RAM
ROM
2001
MICRO-PROC.
200
10
S.A.E. DATA LINK
20
SPEED AND FUEL QUANTITY DATA
(TACH. SIGNAL, FUEL REQUEST SIGNAL)

FIG.3

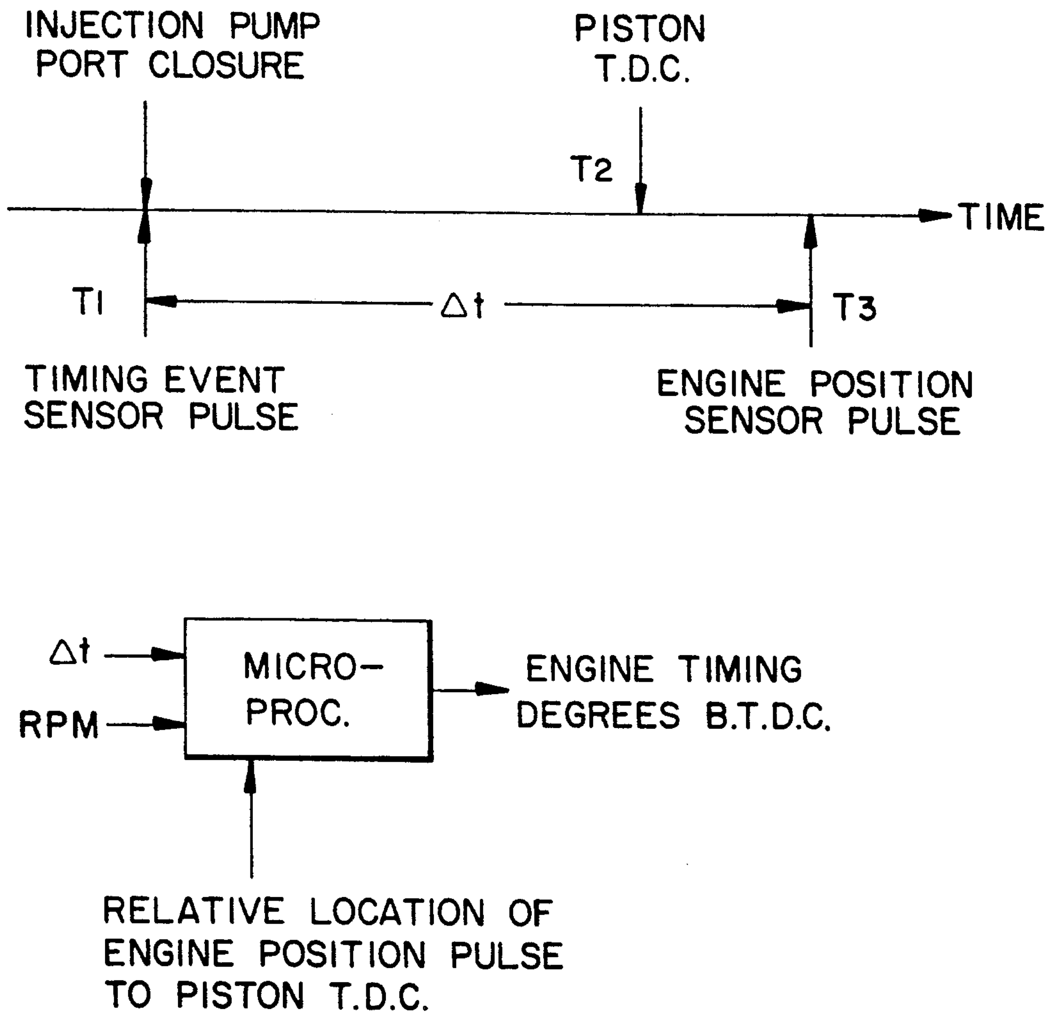
INJECTION PUMP
PORT CLOSURE
PISTON
T.D.C.
T2
TIME
T1
Δt
T3
TIMING EVENT
SENSOR PULSE
ENGINE POSITION
SENSOR PULSE
Δt
RPM
MICRO-
PROC.
ENGINE TIMING
DEGREES B.T.D.C.
RELATIVE LOCATION OF
ENGINE POSITION PULSE
TO PISTON T.D.C.

FIG.4

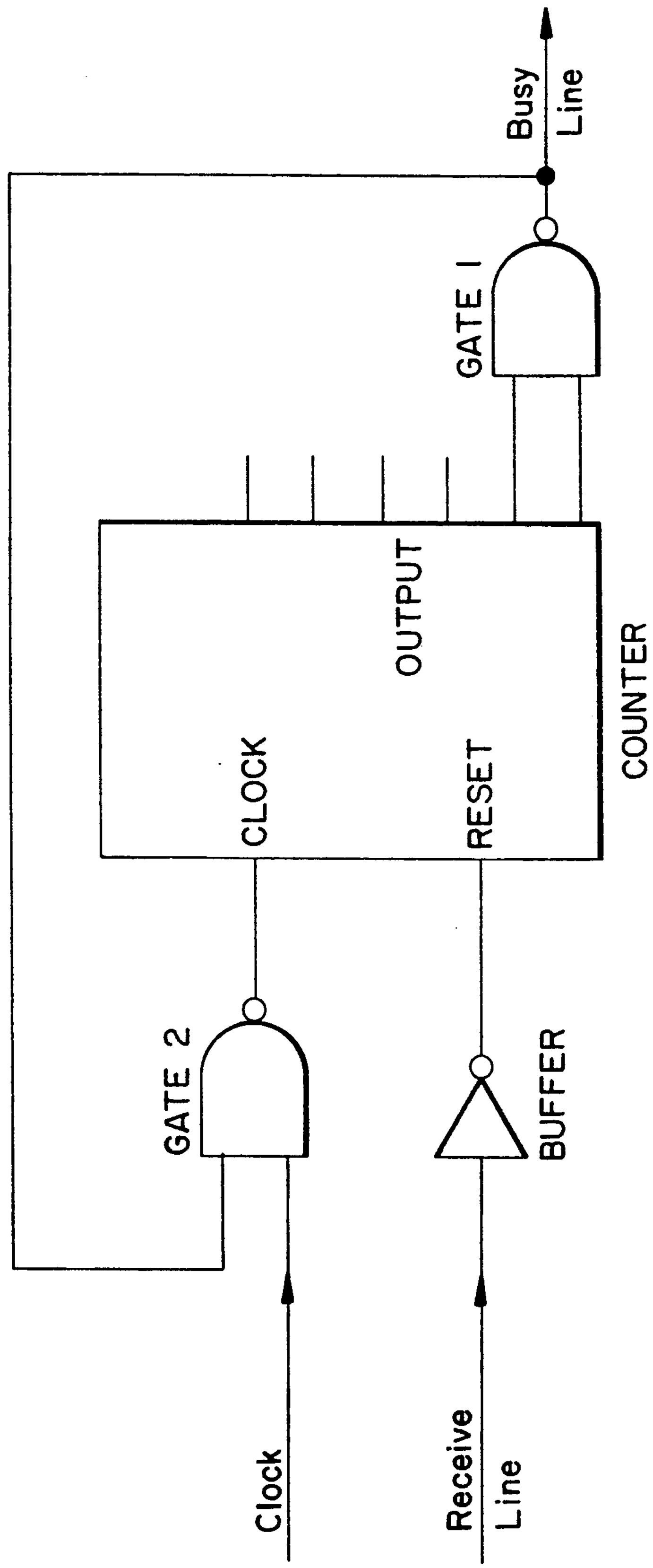
Busy
Line
GATE 1
OUTPUT
COUNTER
CLOCK
RESET
GATE 2
BUFFER
Clock
Receive
Line

FIG.5

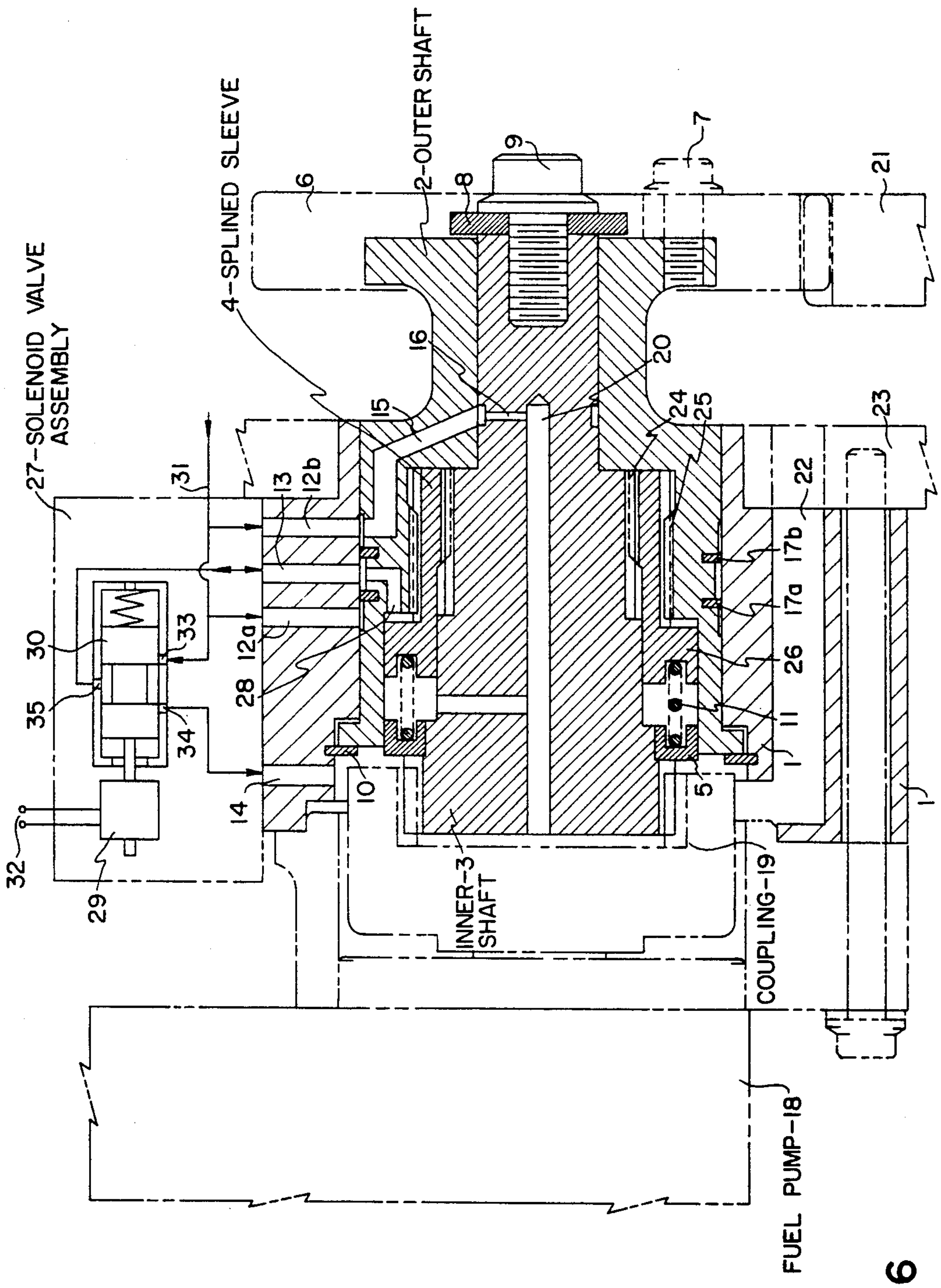
27-SOLENOID VALVE ASSEMBLY
4-SPLINED SLEEVE
2-OUTER SHAFT
INNER-3 SHAFT
COUPLING-19
FUEL PUMP-18
1
5
6
7
8
9
10
11
12a
12b
13
14
15
16
17a
17b
20
21
22
23
24
25
26
28
29
30
31
32
33
34
35

FIG.6

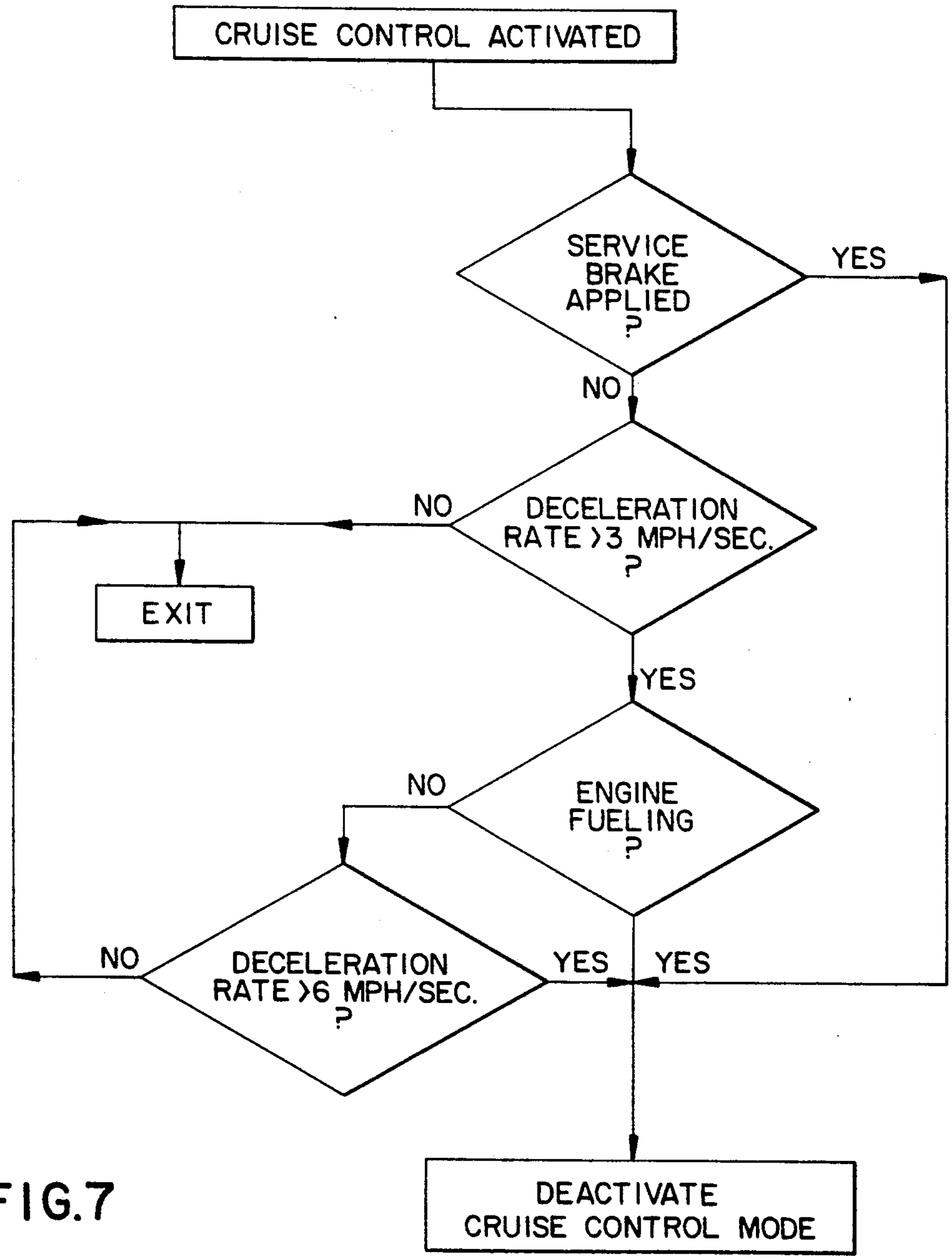
CRUISE CONTROL ACTIVATED
SERVICE BRAKE APPLIED ?
YES
NO
NO
DECELERATION RATE >3 MPH/SEC. ?
EXIT
YES
NO
ENGINE FUELING ?
NO
DECELERATION RATE >6 MPH/SEC. ?
YES
YES
DEACTIVATE CRUISE CONTROL MODE

FIG.7

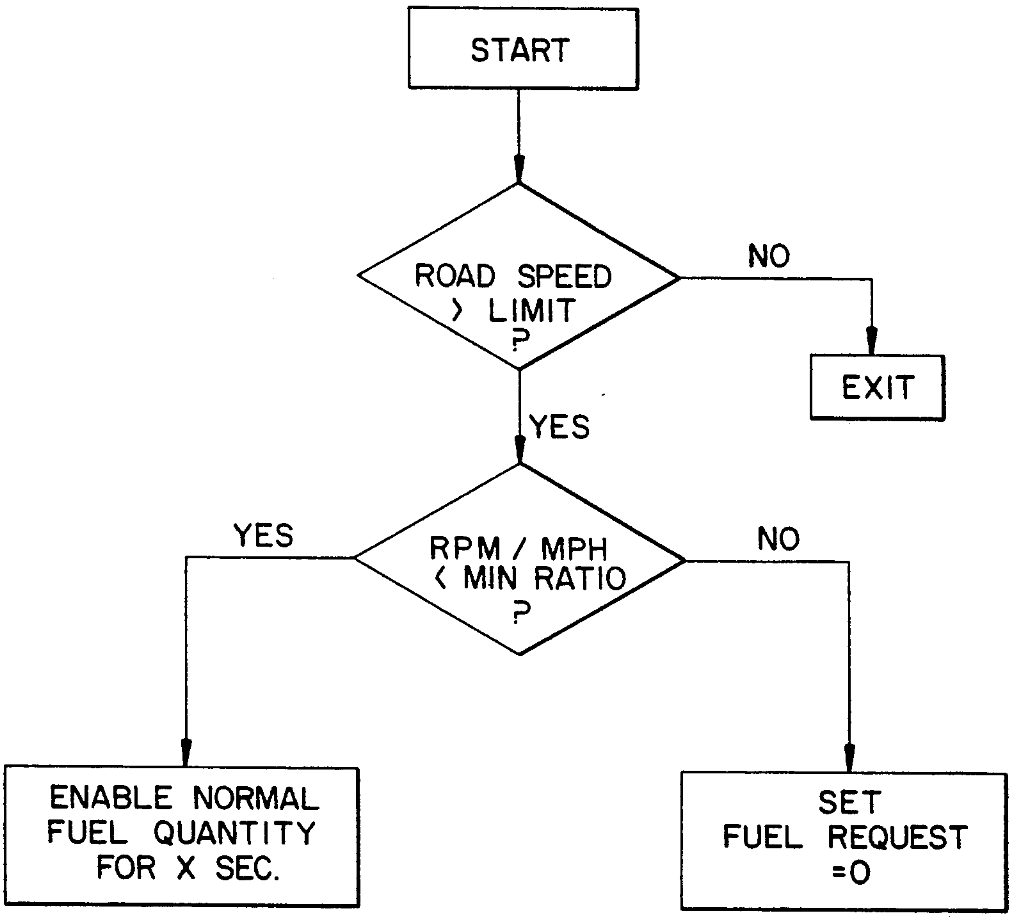
START
ROAD SPEED
> LIMIT
?
NO
EXIT
YES
YES
RPM / MPH
< MIN RATIO
?
NO
ENABLE NORMAL
FUEL QUANTITY
FOR X SEC.
SET
FUEL REQUEST
=0

FIG. 8

MOTOR VEHICLE MAGAGEMENT AND CONTROL SYSTEM INCLUDING SOLENOID ACTUATED FUEL INJECTION TIMING CONTROL

BACKGROUND OF THE INVENTION

This invention relates generally to control systems for motor vehicles, and more particularly to integrated electronic motor vehicle management and control systems specifically useful in heavy duty vehicles such as trucks, in which various engine and vehicle functions such as engine timing and speed control, road speed control, vehicle safety functions, fuel exhaust emissions monitoring, fuel economy and diagnostic and maintenance functions are performed and monitored by an integrated microprocessor based control module system.

In the past, most engine and vehicle control functions in heavy duty vehicles were performed mechanically in response to very simple parameters such as engine speed. The execution of such functions was thus limited and optimization in terms of fuel economy, engine performance and engine emissions quantities was not possible. In addition, certain diagnostic and maintenance functions were left to human performance and thus such functions were not necessarily performed optimally or performed in a manner interrelated with the performance and parameters of other vehicle functions.

SUMMARY OF THE INVENTION

The present invention provides a management and control system for a motor vehicle in which engine speed and timing control and various vehicle functions such as engine system monitoring, display, diagnostics and maintenance are controlled by a microprocessor based electronic control module. The control system is further provided with programming capability for optimizing control functions with respect to particular vehicle parameters based on the type of vehicle within which the control system is installed, including such parameters as engine size and type, tire size and properties, and carrier ratio.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of an electronic vehicle and engine management and control system according to one embodiment of the present invention;

FIG. **2** is a detailed block diagram of the vehicle management and control module of FIG. **1**;

FIG. **3** is a detailed block diagram of the fuel injection control module of FIG. **1**;

FIG. **4** is a graphical illustration of the calculation of engine timing according to a method of the present invention;

FIG. **5** is a circuit diagram of a detection circuit for detecting the occurrence of data transmission on a serial data communication line as illustration in FIG. **2**;

FIG. **6** is a cross-sectional view of a novel fuel injection timing device used in conjunction with the control module of FIG. **2**;

FIG. **7** is a flow chart of a cruise control safety algorithm; and

FIG. **8** is a flow chart of an out-of-gear algorithm for road speed governing.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. **1** is a block diagram of an electronic control system for a heavy duty vehicle according to one preferred embodiment of the present invention. The system is based on two control modules, a vehicle management and control module **100** and a fuel injection module **200**, interconnected by a serial data communication line **10** which conforms to standards set by the Society of Automotive Engineers (S.A.E.). The control modules **100** and **200** are also connected by a general data bus **20** through which data relating to engine speed and fuel quantity are transmitted. The serial data communication line **10** is also connectable to an external computer such as a personal computer or equivalent data processing device, which allows external programming and modification of data used in the performance of the various algorithms by the control modules.

The vehicle management control module **100** has inputs connected to a plurality of sensors **101** which will be further described in conjunction with FIG. **2**. In response to the sensor signal inputs, the vehicle management control module **100** produces a fuel injection timing signal **103**, speedometer and tachometer data signals **105**, a signal to alert an operator of the vehicle of a fault condition by activating an audible or visual driver alarm **107**, signals driving various fault lamps **109** to indicate a problem with data received by the control module **100**, and appropriate data through communication lines **10** and **20** to the fuel injection control module **200** to coordinate proper fuel injection.

The fuel injection control module **200** has inputs connected to various sensors **201** to be described in further detail with reference to FIG. **3**, and outputs a fuel quantity signal **203**, a DYNATARD® enable signal **205**, and a fuel shut-off enable signal **207**. The DYNATARD® system converts the operation of the engine to an air compressor by opening the exhaust valves near the end of a compression stroke to increase engine braking. The DYNATARD® system is activated by a dashboard toggle switch.

The operation of the vehicle management and control module **100** will be more clearly understood with reference to FIG. **2**. The vehicle management and control module **100** is composed of a microprocessor **1001**, a random access memory **1005**, and an EPROM **1003**, and an EEPROM **1004**. The inputs to the microprocessor **1001** comprise a number of pulse width modulated (PWM) inputs **1007**, a plurality of digital data inputs **1009**, and a plurality of analog inputs **1011**. The pulse inputs include a pulse signal from an mph sensor which is mounted near the vehicle's transmission output shaft so as to provide an electrical pulse each time one of the teeth of a tone wheel mounted on the transmission output shaft passes the tip of the sensor. The frequency of the mph sensor output pulses is proportional to the rotational velocity of the transmission output shaft. The road speed of the vehicle can thus be calculated by factoring the number of teeth on the tone wheel, the gear ratio between the transmission output shaft and the vehicle axle shaft, and the rolling circumference of the drive axle tires. These data values can be programmed into the module memory for each specific type of vehicle in which the system is installed. The timing event sensor is mounted proximate the fuel injection pump camshaft of the vehicle engine and generates a pulse when the fuel injection pump camshaft attains an angular position corresponding to port closure or beginning of fuel injection for a predetermined plunger of the injection pump. The engine position sensor is mounted proximate the engine crankshaft and generates a pulse when the crankshaft attains an angular position related to top dead center (TDC) of the corresponding piston of the cylinder to which the plunger is coupled, on its power stroke. The data line **20** is a pulse width modulation signal line which communicates engine speed and fuel quantity data to the microprocessor **1001** from the fuel injection control module **200**.

The digital inputs comprise a plurality of switches including a clutch switch, an engine shutdown override switch, and speed control switches for cruise control, engine idle speed, and engine speed control for power take off (PTO) functions. A coolant level sensor is mounted within the radiator of the engine and provides a coolant level signal representing the amount of coolant in the coolant system.

The analog inputs include an oil pressure signal from an oil pressure sensor mounted within the vehicle crankcase to measure the oil pressure of the system.

A coolant temperature sensor is also provided in the coolant system and transmits a serial data signal to the microprocessor over the SAE data link **10**.

The microprocessor also includes a plurality of PWM outputs **1013** and dc current outputs **1015**. The pulse outputs **1013** include a fuel request signal which is transmitted to the fuel injection control module **200**, and tachometer and speedometer signals which are transmitted to display devices on the vehicle dashboard. The tachometer signal is also inputted to the fuel injection control module **200** through the data line **20** to provide a redundant signal to the fuel injection control module which is used in the calculation of the amount of fuel to be injected by the fuel pump.

The current outputs **1015** include outputs to drive a fault lamp **109** to indicate the presence of a fault in the control module, a driver alarm **107** which warns the driver of a problem with the operation of the engine which requires immediate attention, and a timing actuator signal **103** which is applied to the fuel injection pump to control the timing of fuel injection into the cylinders of the engine.

The fuel injection control module **200** is further described with reference to FIG. **3**. The fuel injection control module **200** is a commercially available device obtainable from Robert Bosch, for example. The control module is a microprocessor based system and includes basic functional components including a microprocessor **2001**, and random access and read only memories **2002** and **2003**. The microprocessor is connected via interfaces to the SAE serial data communication link **10** and the data line **20** to enable communication with the vehicle management and control module **100** as well as to other various control devices in the vehicle. The control module **200** reads input signals from an accelerator pedal position sensor **2004**, an engine speed sensor **2005**, a coolant temperature sensor **2006**, a fuel rack position sensor **2007**, and a torque limiter switch **2008**. The accelerator pedal position sensor includes a potentiometer connected to the accelerator pedal in the vehicle cab and provides a voltage signal proportional to the position of the acceleration pedal relative to the floor of the vehicle cab. The engine speed sensor is mounted proximate the engine crankshaft and generates a pulse signal whose frequency is proportional to the speed of rotation of the engine crankshaft. The coolant temperature sensor **2006** provides a digital signal representative of engine coolant temperature. The fuel rack position sensor **2007** provides a voltage signal proportional to the position of the fuel rack of the fuel injection pump, which relates to the amount of fuel injected during each cycle of engine rotation. The torque limiter switch **2008** is a transmission mounted toggle switch which is activated by the vehicle operator. In response to the five input parameters, and supplemental speed and fuel quantity data information from the control module **100**, the injection control module **200** determines the amount of fuel to be supplied by the fuel injection pump to the engine and generates a fuel rack actuator drive signal **2009**, which is a pulse width modulated signal that controls the position of the fuel rack by energizing a proportional solenoid. The module **200** produces a signal **2011** which prevents DYNATARD operation when fuel is being injected into the engine. The fuel shut-off signal **2010** provides a safety measure by energizing a solenoid valve to allow fuel to be supplied to the fuel pump. In the case where power is removed from the fuel injection control module, the fuel shut-off signal **2010** will go low to deenergize the solenoid and cut off the flow of fuel.

The various functions of the vehicle management and control module **100** will now be described. FIG. **4** illustrates a timing diagram for determining the engine timing. Control module **100** receives a timing event sensor pulse at time T_1 which indicates the beginning of fuel injection to a specified cylinder of the engine. At time T_2, the engine crankshaft reaches an angular position equal to top dead center (TDC) of the piston in the specified cylinder. The engine position sensor is configured to produce a pulse at a crankshaft position related to the top dead center, which is generally longer than the interval from port closure to top dead center to allow a more accurate timing measurement to be taken. The difference in time ΔT between the reception of the timing event sensor pulse and the engine position sensor pulse represents a measure of angular rotation of the crankshaft in degrees. Since the time between T_2 and T_3 is known in advance, the calculation of timing in degrees before top dead center (BTDC) can be calculated.

Desired engine timing is based on experimental criteria related to the amount of fuel being injected and the engine speed in rpm. Desired engine timings as a function of rpm and fuel quantity are stored in a look up table in the module memory. Once the desired engine timing is determined in accordance with the engine speed calculated from the engine position sensor signal and the fuel quantity from the fuel injection control module, the microprocessor determines a change in current for the injection timing actuator signal **103**. Signal **103** is provided to a solenoid of a fuel injection timing device which will be described later with reference to FIG. **6**. The change in timing is designed to reduce the difference between the desired engine timing and the measured engine timing to zero. The new timing information is communicated to the fuel injection control module via the SAE serial data communication link **10**.

Control module **100** constantly monitors engine oil pressure, engine coolant level and coolant temperature to determine whether the engine is operating within prescribed parameter limits. Ranges of oil pressure, coolant level and coolant temperature have been determined empirically to indicate engine malfunction.

These ranges are stored in the control module memory as either single values for all engine operating conditions, or as functions of engine speed, temperature, power output, or other operating parameters. Upon reaching a first limit beyond normal operating parameters, the control module will activate the driver alarm **107** to alert the operator that the engine should be stopped. If the operator has not shut off the engine in response to the alarm, and the signal values have reached a second level beyond normal operating parameters, the control module will transmit a fuel request signal **111** to the fuel injection control module on the data line **20** that will set the amount of fuel being injected to bring the engine to idle speed, and further transmits a command on the SAE serial data link **10** directing the fuel injection control module to stop the engine. A shutdown override switch can be provided on the vehicle instrument panel which, when activated, delays the automatic shutdown of the engine by some preset period of time, such as 30 seconds, to allow the vehicle operator to move the vehicle safely off the road before losing engine power.

The control module **100** monitors vehicle road speed and engine speed in conjunction with information from various switches indicating application of brakes, clutch, and switches mounted on the instrument panel, to maintain vehicle operation within specified limits. These limits, such as minimum and maximum engine speeds and maximum vehicle road speed can be programmed into the control module memory via the SAE serial data communication link from an external computer such as a PC, which can be interfaced with the control module through a serial port connector attached to the data communication link **10**. If the control module determines that any modifications are needed to maintain vehicle and engine operation within the prescribed limits, the fuel quantity required to maintain the desired operating parameters is calculated and its value is transmitted as a fuel request signal **111** to the fuel injection control module, with a confirming signal being sent via the SAE data communication link **10**.

The control module **100** continuously monitors the validity of all inputs in order to detect invalid input states. Upon detection of an input being outside an acceptable range, the control module starts a timer to allow the state of the input to settle back to normal. If the invalid condition has not cleared upon timing out of the timer, a fault condition will be assumed. Upon detection of a fault, the fault lamp **109** will be turned on to indicate a presence of a fault, and a fault message will be sent on the SAE data link **10** to advise other devices of the failure. The normally utilized data for the fault will be replaced by a "bad data" signal advising other devices to ignore the sensor data. A default value is then utilized for calculations requiring data from the faulty sensor.

The control module **100** also performs a cruise control function in which an operator can set a predetermined vehicle speed through actuation of a switch on the instrument panel which will then cause the control system to adjust fuel injection quantity in order to maintain the desired speed.

Since the cruise control function must be disengaged upon application of the service brakes to maintain safe operator control of the vehicle, correct operation of the service brake indication switch is continuously monitored. Referring to FIG. **7**, when in the cruise control mode, the control system monitors the deceleration rate of the vehicle by calculating the derivative of the vehicle road speed. If the vehicle decelerates at a rate greater than or equal to an empirically derived rate above which it would be impossible to achieve without the application of service brakes, the cruise control function will automatically be disabled. However, since deceleration rates above the derived rate can occur without application of service brakes in certain conditions, such as application of the engine brake or climbing a grade, the control system of the present invention monitors the fuel quantity signal to determine whether fueling of the engine is occurring or not. If, in a cruise control mode, the engine is fueling to maintain a specific speed, it would be impossible to experience a deceleration rate greater than the empirically derived rate of 3 mph/sec, unless the service brakes are applied. In this condition, the cruise control function will be automatically disabled. However, if, in the cruise control mode, the engine is not being fueled, which would be indicative of climbing a grade, the control system will use a deceleration rate higher than the derived rate, such as 6 mph/sec without service brake application, to determine whether the service brake switch has failed.

In the case where the control module detects a vehicle road speed above the preset road speed limit, the module generates a fuel request signal which causes the fuel injection control module to stop fueling the engine to insure that the vehicle operator would not be able to exceed the stored limit. It is possible, however, for a loaded vehicle to exceed the stored road speed limit while going down hill. In such a case, the control module would transmit a fuel quantity request signal of zero to disable any additional increase in vehicle speed. If the vehicle transmission should jump out of gear and into neutral at such time, the operator will not be able to fuel the engine to increase engine speed sufficiently to place the transmission back into gear. To eliminate such an occurrence, the control module detects a ratio of engine speed to vehicle road speed and compares this calculated ratio with a prestored minimum engine speed to road speed ratio. FIG. **8** is a flow chart explaining this operation. The minimum stored ratio is determined based on the minimum possible engine rotational speed at the road speed limit. As long as the actual vehicle speed is above the stored road speed limit and the transmission is in gear, the engine speed-to-vehicle speed ratio will be above the stored minimum. However, if the engine speed-to-vehicle speed ratio is below such minimum, the transmission must be out of gear. Upon the occurrence of such a condition, the road speed limiting function will be disabled for a specified period of time to allow the operator to rev up the engine and place the transmission back into gear.

The control routines of FIGS. **7** and **8** are executed as part of a larger overall control loop which is continuously repeated by the control module microprocessor.

FIG. **6** is a cross-sectional diagram of a fuel injection timing device for advancing and retarding the timing of fuel injection to correspond to the desired engine timing represented by the timing actuator signal **103** from the management and control module **100**. The fuel injection timing device consists of a housing **1** enclosing, an annular outer shaft **2**, a cylindrical inner shaft **3**, a splined sleeve **4**, and a solenoid valve assembly **27**. The housing **1** is mounted on the engine **23**. The outer shaft **2** is driven by a suitable engine gear **21** through a gear **6** which is mounted at the end of the shaft **2** by a screw **7**. The cylindrical inner shaft **3** is coupled to the outer shaft 2 by the splined sleeve 4. The sleeve 4 has linear splines 24 on the inner surface thereof which mesh with corresponding linear splines on the outer surface of the inner shaft 3. Splined sleeve 4 also has helical splines 25 on the outer surface thereof which mesh with corresponding helical splines on the inner surface of the outer shaft 2. The inner shaft is retained within the outer shaft in the axial direction by means of a thrust washer 8 and a screw 9 at one end thereof. The opposite end of the shaft 3 is coupled to a camshaft of fuel pump 18 through a splined coupling 19 which is mounted on the fuel injection pump camshaft. All moving parts of the timing device are lubricated with engine oil from engine oil supply 31 through ports 12*a* and 12*b* in housing 1, port 15 in shaft 2, and ports 16 and 20 in inner shaft 3. Outer shaft 2 is axially retained within housing 1 by means of a shoulder on the shaft and a retaining ring 10.

Solenoid valve assembly 27 is mounted on a top flange of the housing 1 and consists of a solenoid 29, a spool valve 30, input port 33, output port 35, and drain port 34 which is connected to drain port 14. The fuel injection timing actuator signal 103 is coupled to the solenoid 29 via current signal lines 32. The spool valve is shown in a null position which corresponds to a partially energized solenoid, the current required to flow through the partially energized solenoid being null current. At null position, port 33 is partial opened allowing a minimal amount of oil to flow through ports 33 and 35 to compensate for oil leakage out of work space 28. When engine timing is to be advanced, an increased electric current is applied to the solenoid 29 which moves spool valve 30 to the right which enables increased oil flow through supply port 33, output port 35, and modulated oil pressure port 13. This allows increased oil flow into work space 28 between a shoulder of splined sleeve 4 and outer shaft 2 which causes sleeve 4 to move to the left to advance fuel injection timing by advancing the phase angle between the outer shaft 2 and the inner shaft 3. When it is desired to retard engine timing, the fuel injection actuator signal current is reduced below the null level which causes solenoid 29 to move spool valve 30 to the left completely closing supply port 33 and opening drain port 34. As a result, oil in work space 28 flows out through parts 13, 35, and 34 into drain port 14, by action of a spring 11 mounted between piston 26 of sleeve 4 and a spring seat 5 which biases sleeve 4 to the fully retarded position. Any time that the solenoid valve returns to the null position, the sleeve 4 remains in the position where it was last moved. Two piston seal rings 17*a* and 17*b* constitute the only dynamic seals used in the injection timing device for sealing the modulated oil pressure in port 13 from the lubricating oil in ports 12*a* and 12*b*.

The fuel injection timing device of FIG. 6 allows engine timing to be controlled by a sophisticated injection control algorithm implemented by the management and control module 100 which takes into account numerous operating parameters of the engine and thus represents a significant improvement over prior art fuel injection timing devices which were able to control engine timing as a function of engine speed only.

The invention having been thus described, it will be obvious to those skilled in the art that the same may be varied in many ways. Such variations are not to be considered a departure from the spirit and scope of the invention, all such modifications are intended to be included within the scope of the following claims.

What is claimed is:

1. A management and control system for a motor vehicle, comprising:

electronic vehicle control means for controlling operations of the vehicle and an engine mounted within said vehicle, including

means for receiving a timing event signal representing the injection of fuel into a specific cylinder of said engine from a fuel injection pump,

means for receiving an engine position signal representing a predetermined position of a piston of said specific cylinder relative to Top Dead Center (TDC) occurring after the detection of said timing event signal,

means for calculating engine timing as a function of the time difference between said engine position signal and said timing event signal,

means for calculating engine angular velocity as a function of the frequency of said engine position signals,

means for receiving a fuel quantity signal representing the amount of fuel being injected into the cylinders of said engine,

means for determining a desired engine timing as a function of said engine angular velocity and said received fuel quantity signal,

means for calculating the difference between said desired engine timing and said calculated engine timing,

means for developing a timing advance/retard signal proportional to said calculated difference for advancing or retarding the engine timing to reduce the difference between said desired and calculated engine timings to zero,

means for receiving an oil pressure signal representing the amount of engine oil pressure in said engine,

means for receiving a coolant level signal representing the amount of engine coolant in said engine,

means for receiving a coolant temperature signal representing the temperature of said engine coolant,

means for comparing said oil pressure, coolant level and coolant temperature signals with stored signal values indicating engine malfunction, generating an alarm signal warning an operator of possible engine damage at a first level of malfunction, and generating an engine shutdown signal for stopping operation of said engine at a second level of malfunction,

means for receiving a signal proportional to vehicle road speed and calculating the road speed of said vehicle,

means for storing a maximum vehicle road speed,

means for storing minimum and maximum engine speeds,

means for comparing said calculated road speed and engine angular velocity with said stored road and engine speeds,

means for developing a fuel quantity request signal for controlling the amount of fuel supplied to said engine to keep said road and engine speeds within said stored ranges,

means for calculating the deceleration rate of said vehicle,

means for receiving a service brake signal representing application of vehicle service brakes, means for comparing said deceleration rate with said fuel quantity signal in the absence of said service brake signal and disengaging a cruise control function when the rate of deceleration exceeds a first value when fueling, and when the rate of deceleration exceeds a second value higher than said first value when not fueling,

means for calculating a ratio of engine speed-to-road speed,

means for storing a minimum engine speed-to road speed ratio, and

means for comparing said calculated ratio with said stored ratio, determining that the transmission of said vehicle has jumped out of gear when said calculated ratio is less than said stored ratio, and overriding said fuel quantity request signal, when said road speed is higher than said stored maximum road speed;

electronic fuel injection control means for controlling the injection of fuel into the cylinders of said engine, including

means for receiving an accelerator pedal position signal representing the position of an accelerator pedal of said vehicle indicating the road speed desired by an operator,

means for receiving an engine speed signal representing the angular velocity of said engine,

means for receiving a fuel rack position signal representing the position of a fuel rack on a fuel injection pump of said engine,

means for receiving said fuel quantity request signal from said electronic vehicle control means, and

means for developing a fuel rack actuation signal for controlling the position of said fuel rack to adjust the amount of fuel being injected into said cylinders, in response to the values of said accelerator pedal position signal, engine speed signal, fuel rack position signal, and fuel quantity request signal;

fuel injection timing means responsive to said timing advance/retard signal for modifying the timing of fuel injection into said cylinders relative to piston position from TDC; and

a serial data communication line interconnecting said electronic vehicle control means and said electronic fuel injection control means for transmitting digital data therebetween.

2. A management and control system for a motor vehicle according to claim **1**, wherein said serial data communication line conforms to SAE (Society of Automotive Engineers) standards for such communication lines, said system further comprising:

a detection circuit for detecting the transmission of data on said serial data communication line, including

means for generating a clock pulse signal,

counter means for counting said clock pulse signals up to a predetermined count,

logic means connected to outputs of said counter means for providing a transmission enable signal and disabling clock pulse signal input when said counter means has reached said predetermined count, and

means for resetting said counter means when said serial data communication line is transmitting data.

3. A management and control system for a motor vehicle according to claim **1**, further comprising:

a serial data connector coupled to said serial data communication line for interconnecting said serial data communication line with an external data processor to enable imputing of said maximum road speed, said minimum and maximum engine speeds, and values of other parameters used in calculations performed by said electronic vehicle control means.

4. A management and control system for a motor vehicle according to claim **1**, wherein said fuel injection timing means comprises:

a cylindrical housing;

an annular outer shaft within said housing being driven by said engine;

a cylindrical inner shaft within said outer shaft being coupled to a camshaft of said fuel injection pump;

a splined sleeve coupling said outer shaft to said inner shaft and movable in an axial direction to change the phase angle of rotation between said outer and inner shafts; and

sleeve driving means responsive to said timing advance/retard signal for driving said splined sleeve in said axial direction for modifying the timing of fuel injection to correspond to said desired engine timing.

5. A management and control system for a motor vehicle according to claim **4**, wherein said sleeve driving means comprises a solenoid valve assembly including a solenoid for receiving said timing advance/retard signal, a spool valve selectively movable by said solenoid when energized by said timing advance/retard signal, said spool valve controlling the amount of oil pressure applied to said splined sleeve which in turn controls the axial position of said splined sleeve relative to said outer and inner shafts.

6. A management and control system for a motor vehicle, comprising:

electronic vehicle control means for controlling operations of the vehicle and an engine mounted within said vehicle, including

means for receiving a signal proportional to vehicle road speed and calculating the road speed of said vehicle,

means for calculating the deceleration rate of said vehicle,

means for receiving a service brake signal representing application of vehicle service brakes, with a fuel quantity signal in the absence of said service brake signal and disengaging a cruise control function when the rate of deceleration exceeds a first value when fueling, and when the rate of deceleration exceeds a second value higher than said first value when not fueling,

means for calculating a ratio of engine speed-to-road speed,

means for storing a minimum engine speed-to road speed ratio, and

means for comparing said calculated ratio with said stored ratio, determining that the transmission of said vehicle has jumped out of gear when said calculated ratio is less than said stored ratio, and overriding a fuel quantity request signal, when said road speed is higher than said stored maximum road speed.

7. A fuel injection timing device for a fuel injection pump of an internal combustion engine, comprising:

a cylindrical housing;

an annular outer shaft within said housing being driven by said engine;

a cylindrical inner shaft within said outer shaft being coupled to a camshaft of said fuel injection pump;

a splined sleeve coupling said outer shaft to said inner shaft and movable in an axial direction to change the phase angle of rotation between said outer and inner shafts; and

sleeve driving means responsive to a timing advance/retard signal for driving said splined sleeve in said axial direction for modifying the timing of fuel injection to correspond to a desired engine timing represented by said timing advance/retard signal.

8. A fuel injection timing device according to claim **7**, wherein said sleeve driving means comprises a solenoid valve assembly including a solenoid for receiving said timing advance/retard signal, a spool valve selectively movable by said solenoid when energized by said timing advance/retard signal, said spool valve controlling the amount of oil pressure applied to said splined sleeve which in turn controls the axial position of said splined sleeve relative to said outer and inner shafts.

* * * * *

EXHIBIT 18

United States Patent [19]

Auman et al.

[11] **3,925,753**

[45] **Dec. 9, 1975**

[54] **SPEED COMPENSATED FUEL CONSUMPTION WARNING DEVICE**

[75] Inventors: **John T. Auman,** Washington; **Wesley A. Rogers,** Grosse Pointe Park; **Trevor O. Jones,** Birmingham, all of Mich.

[73] Assignee: **General Motors Corporation,** Detroit, Mich.

[22] Filed: **Feb. 10, 1975**

[21] Appl. No.: **548,682**

[52] **U.S. Cl.** .... **340/52 R;** 340/62

[51] **Int. Cl.**^{2} **B60Q 1/00**

[58] **Field of Search** .... 340/52 R, 52 D, 53, 62, 340/262, 263; 180/103, 105 R, 105 E, 106

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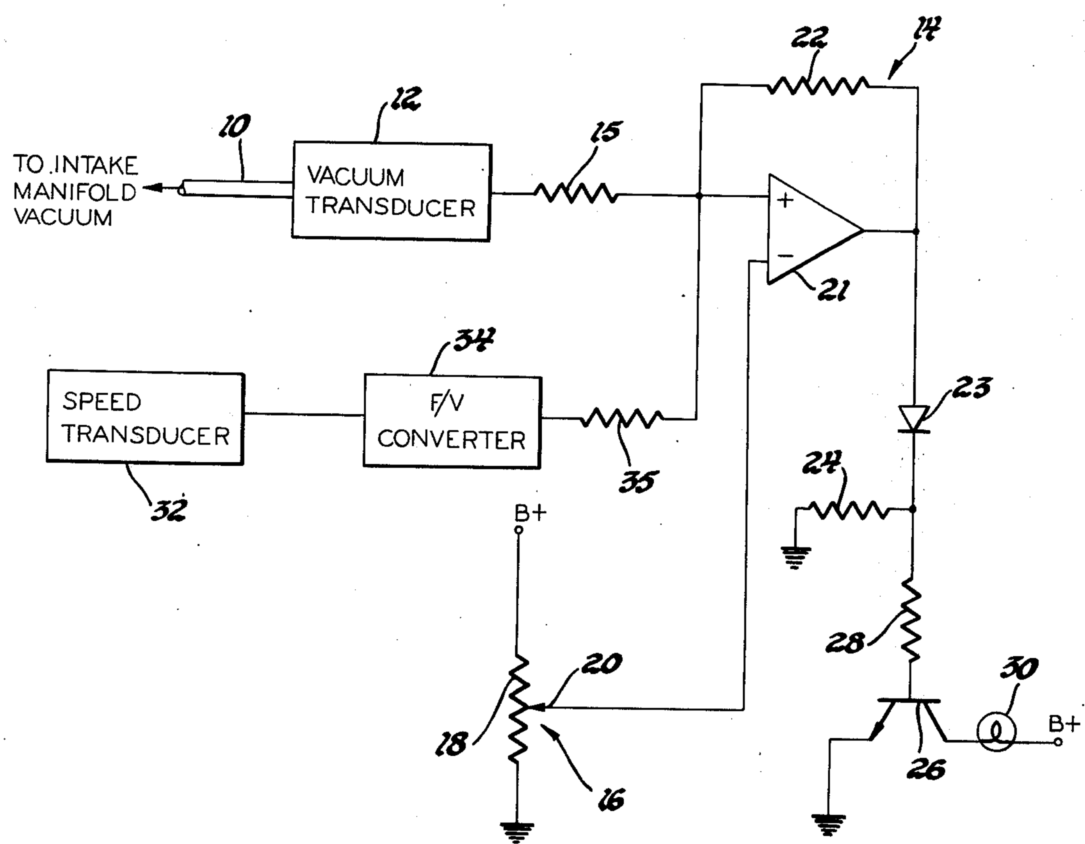
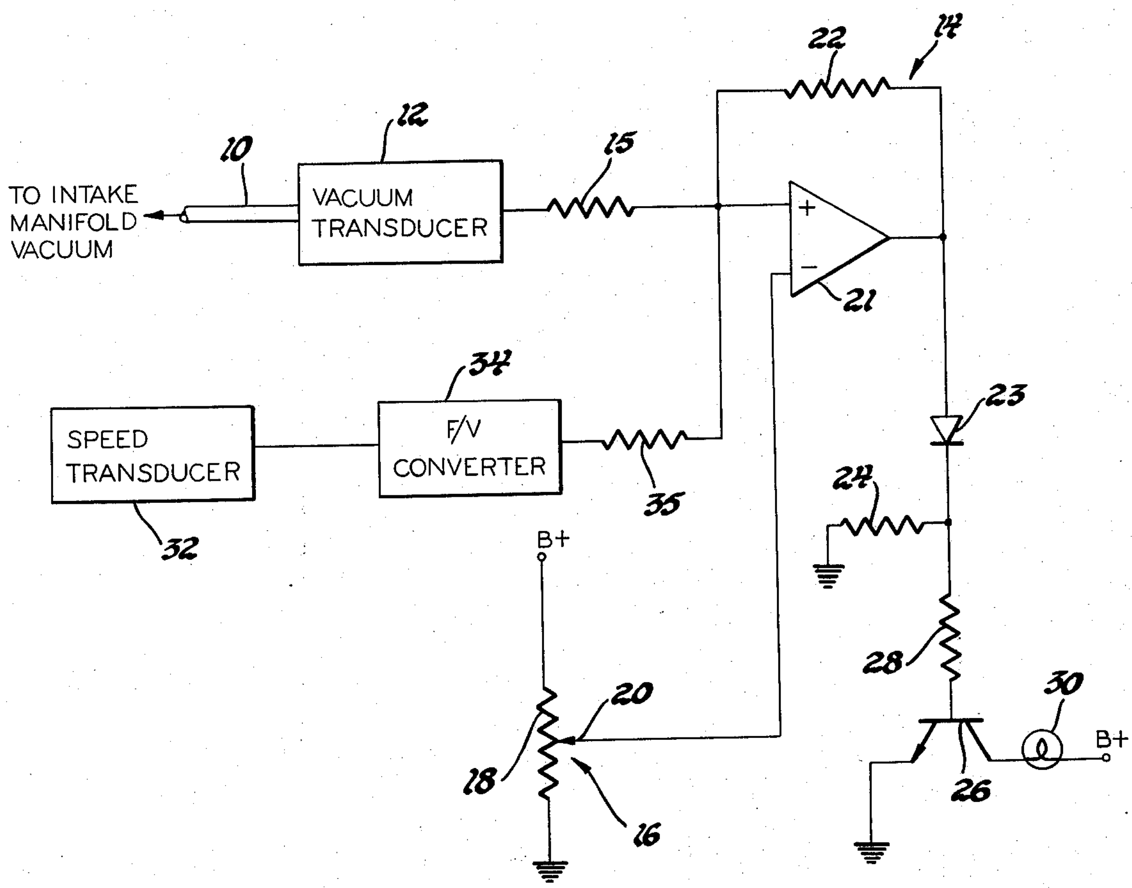
Primary Examiner—Alvin H. Waring
Attorney, Agent, or Firm—Howard N. Conkey

[57] **ABSTRACT**

A warning system for providing an indication when the fuel consumption of a throttle controlled vehicle having an internal combustion engine with an intake manifold exceeds pre-established levels. A vacuum transducer generates a signal having a magnitude representing the instantaneous intake manifold vacuum level. A vehicle speed transducer generates a speed signal having a magnitude varying with vehicle speed which, in combination with a reference signal, establishes a manifold vacuum trigger level which represents, at each instantaneous vehicle speed, fuel consumption in excess of a pre-established level for that speed. A comparator compares the manifold vacuum trigger level with the vacuum signal and energizes an indicator when the vacuum signal represents an intake manifold vacuum level below the manifold vacuum trigger level so as to provide an indication of fuel consumption in excess of the pre-established level for the instantaneous vehicle speed.

2 Claims, 1 Drawing Figure




TO INTAKE MANIFOLD VACUUM
10
12
VACUUM TRANSDUCER
15
22
14
+
−
21
23
SPEED TRANSDUCER
34
F/V CONVERTER
35
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B+
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18
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26

SPEED COMPENSATED FUEL CONSUMPTION WARNING DEVICE

This invention relates to a fuel consumption warning device and more particularly to a warning system for a vehicle having a throttle controlled internal combustion engine with an intake manifold which provides a warning when the intake manifold pressure decreases to a pre-established level which is varied as a function of vehicle speed.

Systems for providing a warning to a vehicle operator when the vehicle intake manifold pressure decreases to a pre-established level in order to provide an indication of uneconomical operation of the vehicle are generally known. In all of these known systems, an intake manifold vacuum level at which a warning is provided is selected which is applicable at all vehicle operating speeds. Although the selected level may be truly indicative of excessive fuel consumption at one operational speed, it may not be indicative of excessive fuel consumption at all other speeds.

In view of the foregoing, it is the general object of this invention to provide an improved speed compensated fuel consumption warning device for use with a vehicle powered by a throttle controlled internal combustion engine having an intake manifold.

It is another object of this invention to provide a fuel consumption warning device for a vehicle powered by an internal combustion engine having an intake manifold which provides a warning when the vehicle intake manifold pressure decreases below a level which is varied as a function of vehicle speed.

These and other objects of this invention may be best understood by reference to the following description of a preferred embodiment and the drawing which is a schematic diagram illustrating the preferred embodiment of the invention.

Referring to the drawing, there is illustrated a warning device for providing an indication of excessive fuel consumption by a vehicle powered by a throttle controlled internal combustion engine having an intake manifold. A conduit **10** pneumatically couples the intake manifold vacuum to a vacuum transducer **12.** The vacuum transducer **12** is effective to generate a voltage having a magnitude which progressively changes with a progressively increased intake manifold vacuum level. In the preferred embodiment, the magnitude of the voltage generated by the vacuum transducer **12** progressively decreases with an increasing intake manifold vacuum level. The voltage generated by the vacuum transducer **12** is coupled to the positive input of a summing switch **14** through a resistor **15.** The resulting current supplied by the vacuum transducer **12,** hereinafter referred to as the vacuum signal, progressively decreases with increasing intake manifold vacuum level.

A potentiometer **16** includes a resistive element **18** coupled between a positive voltage source B+ and ground potential and a wiper arm **20.** The positive voltage source B+ may take the form of the positive terminal of the vehicle battery whose negative terminal is grounded. The wiper arm **20** is coupled to the negative input of the summing switch **14.** The potentiometer **16** functions to supply a current, hereinafter referred to as the reference signal, having a magnitude substantially equal to the magnitude of the vacuum signal at a specified intake manifold vacuum level which has been determined to represent excessive fuel consumption when the vehicle speed is zero. The summing switch **14** takes the form of a high gain differential amplifier **21** with a feedback resistor **22** as illustrated in the drawing.

The output of the summing switch **14** is coupled to the anode of a diode **23** whose cathode is coupled to ground through a resistor **24** and to the base electrode of an NPN transistor **26** through a resistor **28.** The emitter electrode of the transistor **26** is coupled to ground and the collector electrode thereof is coupled to the positive voltage source B+ through a lamp **30.** The lamp **30** may be located at the vehicle instrument panel or any other location where it is readily observable by the vehicle operator. Alternatively, the lamp **30** may be replaced with a buzzer to provide an audible indication.

When the output of the summing switch **14** is a positive voltage, the transistor **26** is biased conductive to energize the lamp **30** and conversely, when the output is negative, the transistor **26** is biased nonconductive and the lamp **30** is extinguished.

With only the elements described above, the lamp **30** would be energized to provide a warning whenever the manifold vacuum level decreased below a level represented by the reference signal supplied by the potentiometer **16.** Although this level may truly be indicative of excessive fuel consumption at one specific vehicle speed it may not be indicative of excessive fuel consumption at other vehicle speeds. For example, the manifold vacuum level representing excessive fuel consumption increases from the level represented by the reference signal supplied by the potentiometer **16** when set as indicated above as vehicle speed increases. By vehicle testing, the magnitude of this increase for each vehicle speed may be determined.

To provide a manifold vacuum trigger level which increases with increasing vehicle speed, a speed transducer **32** is provided which generates a series of voltage pulses having a frequency progressively increasing with increasing vehicle speed. The speed transducer **32** may take the form of a slotted disc rotated by a vehicle wheel adjacent a magnetic pickup whose output is a series of voltage pulses having the frequency related to vehicle speed. These voltage pulses are supplied to a frequency-to-voltage converter **34** whose output is a voltage having a magnitude progressively increasing with increasing vehicle speed. The output of the frequency-to-voltage converter **34** is coupled to the positive input of the summing switch **14** through a resistor **35.** The resulting current supplied by the frequency-to-voltage converter **34,** hereinafter referred to as the speed signal, has a magnitude progressively increasing with increasing vehicle speed.

By conventional circuit design techniques, the magnitude of the speed signal may be made to equal the difference between the magnitude of the reference signal and the magnitude of the vacuum signal when the manifold vacuum is at the level determined to represent excessive fuel consumption at the instantaneous speed represented by the output of the speed transducer **32.**

By combining the speed signal in proper sense with the reference signal, the manifold vacuum level at which the output of the summing switch **14** swings positive to effect energization of the lamp **30,** hereinafter referred to as the manifold vacuum trigger level, may be increased as a function of vehicle speed. This is accomplished by the coupling of the speed signal from the frequency-to-voltage converter **34** to the positive input of the summing switch **14** so as to be summed in subtractive fashion from the reference signal supplied by the potentiometer **16.**

In operation, when the vehicle speed is zero, the output of the frequency-to-voltage converter **34** is also zero and the summing switch **14** generates a positive voltage to bias the transistor into conduction and energize the lamp **30** when the vehicle is operated in a manner such that the intake manifold vacuum level decreases below the vacuum level represented by the magnitude of the reference signal supplied by the potentiometer **16.** This signal provides an indication of fuel consumption in excess of the predetermined amount at zero vehicle speed.

At increased vehicle speeds, the frequency-to-voltage converter **34** generates the speed signal which is coupled to the positive input of the summing switch **14.** Consequently, the required vacuum signal output of the vacuum transducer **12** to cause the summing switch **14** to generate a positive signal output decreases corresponding to the desired increase in the manifold vacuum trigger level. When the vehicle is operated in a manner such that the manifold vacuum decreases below the manifold vacuum trigger level established at the instantaneous vehicle speed, the output of the summing switch **14** swings positive to effect energization of the lamp **30** to provide an indication of fuel consumption in excess of the predetermined amount at that speed.

The potentiometer **16** may be positioned in the vehicle compartment so as to allow the vehicle operator to adjust the wiper arm **20** and shift the vacuum trigger level for all vehicle speeds and thereby selectively establish desired fuel consumption warning levels. For example, if the vehicle is under a heavy load, the vacuum level at each vehicle speed which is indicative of excessive fuel consumption may be less than when the vehicle is under normal load. The vehicle operator may compensate for the heavy load condition by adjustment of the wiper arm **20** to vary the magnitude of the reference signal and provide for lower manifold vacuum trigger levels at all vehicle speeds.

In the preferred embodiment illustrated in the drawing, the summing switch **14** summed the output of the frequency-to-voltage converter **34** and the potentiometer **16** in subtractive fashion since the output of the vacuum transducer **12** progressively decreased with progressively increasing manifold vacuum. As can be seen, if the signals generated by the various transducers varied in a different manner, they must be combined in the proper sense to achieve the desired manifold vacuum trigger level change in response to vehicle speed changes. For example, if the vacuum transducer **12** supplied a signal which had a magnitude progressively increasing with increasing intake manifold vacuum level, the output of the frequency-to-voltage converter **34** would then be summed in additive fashion with the reference signal at the positive input of the summing switch **14** and the vacuum signal would be coupled to the negative input thereof.

What has been described is a fuel consumption warning device for use with a vehicle having an internal combustion engine with an intake manifold, wherein a warning of excessive fuel consumption is provided when the intake manifold vacuum level decreases below a manifold vacuum trigger level which is varied as a function of vehicle speed.

The detailed description of the preferred embodiment of this invention for the purpose of explaining the principles thereof is not to be considered as limiting or restricting the invention since many modifications may be made by the exercise of skill in the art without departing from the scope of the invention.

We claim:

1. A fuel consumption warning device for use with a vehicle powered by a throttle controlled internal combustion engine having an intake manifold, comprising: a vacuum transducer pneumatically coupled with the intake manifold for generating a vacuum signal having a magnitude progressively changing with a progressively increased manifold vacuum level; means for generating a speed signal having a magnitude substantially equal to the difference between the magnitude of the vacuum signal at a manifold vacuum level representing a predetermined excessive fuel consumption at zero vehicle speed and the magnitude of the vacuum signal at a manifold vacuum level representing a predetermined excessive fuel consumption at the instantaneous vehicle speed; means combining said speed signal and vacuum signal and generating an output signal when the magnitude of the combined signals differs with a fixed polarity from the magnitude of the vacuum signal at the manifold vacuum level representing the predetermined excessive fuel consumption at zero vehicle speed; and an indicator responsive to the output signal for producing an operator observable indication representing excessive fuel consumption at the instantaneous vehicle speed.

2. A fuel consumption warning device for use with a vehicle powered by a throttle controlled internal combustion engine having an intake manifold, comprising: a vacuum transducer pneumatically coupled with the intake manifold for generating a vacuum signal having a magnitude progressively changing with a progressively increased intake manifold vacuum level; means for generating a reference signal having a magnitude substantially equal to the magnitude of the vacuum signal at an intake manifold vacuum representing a predetermined excessive fuel consumption at zero vehicle speed; a vehicle speed transducer for generating a speed signal having a magnitude progressively changing with a progressively increased vehicle speed, whereby throughout a predetermined speed range, the magnitude of the sum of the speed signal and the reference signal is equal to the magnitude of the vacuum signal at an intake manifold vacuum representing a predetermined excessive fuel consumption at the instantaneous vehicle speed; means for combining the vacuum signal, the speed signal, and the reference signal and generating an output signal when the magnitude of the sum of the reference signal and the speed signal represents a manifold vacuum level exceeding the manifold vacuum level represented by the vacuum signal; and an indicator responsive to the output signal for producing an operator observable indication representing excessive fuel consumption at the instantaneous vehicle speed.

* * * * *

EXHIBIT 19

PCT

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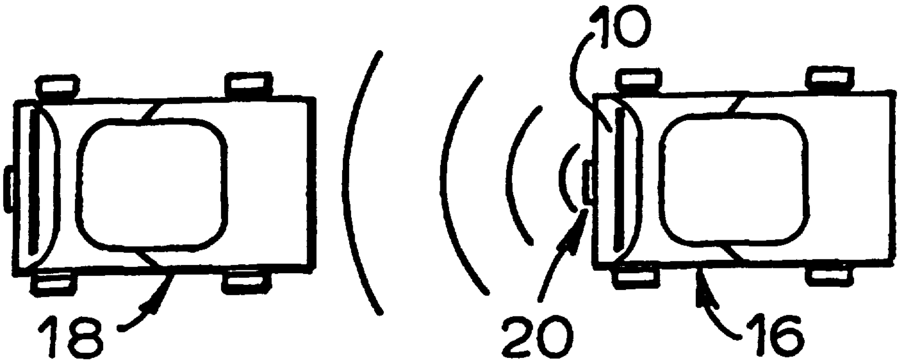
(57) Abstract

The system comprising a controller fitted to a subject vehicle (16) and sensor means (20) operable to sense a distance of separation and relative velocity of a trailing vehicle (18). Also input to the controller is a velocity signal derived from a velocity sensing means (97) determining the ground speed of the subject vehicle using a doppler radar system. The controller calculates a safety envelope and activates a visible warning device attached to the rear of the subject vehicle if the trailing vehicle penetrates the safety envelope. An enhanced safety envelope determined by adverse road conditions is also established, any incursion into the enhanced envelope resulting generally in the visible warning being at a less prominent level. If however the closing speed of the trailing vehicle exceeds a predetermined threshold, penetration of the enhanced envelope results immediately in the full warning being displayed with full prominence to the driver of the trailing vehicle. The system has application to improving the safety of road vehicles.



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SAFETY SYSTEM FOR VEHICLES

The invention relates to vehicle safety systems including warning means which provide safety information for example to drivers of following vehicles.

A known warning means comprising a vehicle display system is described in WO93/15931 which provides a display system which indicates discrete ranges of deceleration of a vehicle and which can also provide a display to indicate that the vehicle is stationary. All the features of that display system are incorporated in this specification especially when referring to a progressive brake warning (PBW) or vehicle stationary indicator (VSI) display. A known ground speed measuring device is disclosed in WO92/01951 which uses a double horned radar device, again the teachings of that specification are incorporated herein.

The invention seeks, inter alia, to improve known vehicle display systems and ground speed measuring systems.

According to one aspect of the invention there is provided a safety system for vehicles comprising a controller fitted in use to a subject vehicle, sensor means fitted to the subject vehicle in use and operable to sense a distance of separation and/or a relative velocity of a trailing vehicle and operable to input data signals representative thereof to the controller, velocity sensing means operable to sense the velocity of the subject vehicle relative to the ground and to input to the controller a velocity signal representative thereof, wherein the controller is operable to processes the received velocity signal and data signals to determine the existence of an unsafe condition, and the safety system further comprising warning means controlled by the controller and operable to warn a driver of the trailing vehicle of the existence of the unsafe condition.

Preferably the controller is operable to determine the existence of the unsafe condition by determining a safe distance corresponding to a safety envelope to the rear of the subject vehicle within which any incursion by the trailing vehicle constitutes the existence of an unsafe condition.

This provides the advantage of assisting the driver of the trailing vehicle to more accurately determine the safe distance, drivers typically tending to underestimate the safe distance in the absence of any such warning system.

The safe distance may be determined to be substantially the safe stopping distance of a vehicle travelling at the velocity of the trailing vehicle.

The safe stopping distance may be determined to be proportional to the velocity of the subject vehicle.

Preferably the warning is terminated after the measured value reaches a safe value. The warning can be provided by a display operably carried by the subject vehicle and positioned for viewing by the driver of the trailing vehicle, and the display can comprise a row of lights.

The system may comprise means for warning that the subject vehicle is stationary. The system can further comprise means for providing warning of different levels of deceleration of the subject vehicle. The warning means can comprise an orange light display for the relative speed and/or relative separation conditions and a red light display for the vehicle stationary and/or levels of deceleration conditions. The relative separation and/or relative speed warning may be overridden by the level of deceleration warning.

The system in a preferred embodiment has a radar device having two receiver antenna which device operably communicates with a controller which is able thereby to determine the direction of motion of the vehicle, and warning means which is automatically actuated by the controller to provide a warning when the vehicle moves.

A further warning means can be automatically activated when the vehicle reverses and may comprise an array of lights and/or means for generating sound.

The controller may be operable to determine an enhanced safe distance corresponding to an enlarged safety envelope and the warning means may be further operable to indicate a first level of warning corresponding to incursion by the trailing vehicle into the enlarged safety envelope and a second level of warning which is more prominently presented to the driver than the first level of warning and corresponds to any incursion into the safety envelope.

The size of the enhanced safe distance and enlarged safety envelope will generally be predetermined so as to correspond to typical parameters appropriate for driving under adverse road conditions. These parameters may for example be stored in a look up table allowing the parameters to be determined from the signals received by the controller together with the parameters defining the normal safety envelope.

The safety system may comprise ground condition communication means operable to input to the controller a signal representative of the condition of the ground and or other driving conditions and wherein the controller is operable to determine the enhanced safe distance corresponding to the enlarged safety envelope according to the extent to which the ground condition communication means indicates adverse ground conditions likely to affect traction between the subject vehicle and the ground.

The enhanced safety distance and enlarged safety envelope may thereby be made adaptable to the prevailing driving conditions and the ground condition communication means would preferably function automatically to input data such as whether rain, ice or snow was presenting a driving hazard, the source of the data being either on board sensors or telemetric links to an external system providing relevant data.

Preferably the sensor means is operable to sense both the distance of separation and the relative velocity of the trailing vehicle and the controller is operable to determine whether the relative velocity of the trailing vehicle relative to the subject vehicle when entering the enlarged safety envelope is greater than a threshold value of relative velocity and, if so, is operable to actuate the warning means to indicate the second level of warning.

This has the advantage of delivering a warning with full prominence to the driver of the trailing vehicle before the trailing vehicle has reached the main safety envelope in order to give the maximum available warning to the driver that his closing speed to the subject vehicle is excessive.

In a preferred embodiment the ground condition communication means comprises means fitted to the subject vehicle for sensing at least one of rain, snow and ice and communicating a signal representative thereof to the controller.

The sensor means for sensing the distance and velocity of the trailing vehicle may comprise a radar system transmitting and receiving radar pulses, from which received pulses information is derived sufficient to determine both the proximity and relative speed of the trailing vehicle.

The safety system may comprise communication means operable between the controller of the subject vehicle and a warning device fitted in use to the trailing vehicle, whereby the warning means is operable to indicate a warning to the driver of the trailing vehicle via the warning device.

The velocity sensing means may comprise a conventional speed sensing device fitted to the vehicle's transmission train and may for example include a hall effect sensor.

The velocity sensing means may alternatively comprise a sensor mounted on the subject vehicle and responsive independently of elements of the subject vehicle's transmission train to movement of the ground relative to the subject vehicle.

In a preferred embodiment the velocity sensing means comprises a sensor constituted by a doppler shift radar device.

An advantage of such sensing means is that it is free from the errors inherent in determining velocity via the transmission train which arise from variation in tyre diameter due to varying inflation pressure, tyre wear or other factors.

The controller may also be operable to actuate an impact absorbing device deployed internally or externally of the subject vehicle.

The impact absorbing device may comprise an air bag inflatable so as to be deployed externally of the subject vehicle and/or bumpers extensible by means of hydraulic rams operable to absorb energy upon impact.

The effects of impact may thereby be attenuated prior to the point of collision between the subject vehicle and an object which may be a trailing vehicle for example.

Another aspect of the invention provides a system for vehicles having means for determining the magnitude of acceleration and deceleration of the vehicle and output means enabling the magnitude of acceleration and deceleration to be interpreted by a third party remote from the vehicle. The output means can comprise a visible display having a first form of representation for acceleration and a second form of representation for deceleration. The display can comprise an array of lights mountable on the side of a vehicle. A first coloured array can represent acceleration and a second coloured array can represent deceleration and preferably the number and/or intensity of actuated lights of a given colour represents the magnitude of the acceleration or deceleration.

This aspect of the invention has application for example to racing cars and motorcycles where a visible display mounted on either or both sides of the vehicles enable spectators and cameras to perceive the rate of acceleration or deceleration of the vehicle thereby adding interest and enjoyment. Such displays would not be visible necessarily to the leading or trailing drivers so as to cause minimal interference with the conduct of racing.

Also disclosed herein is a management system for a vehicle comprising a ground speed sensor having means for determining the true speed and direction of travel of the vehicle and means for communicating the speed and direction of travel of the vehicle to a controller which operably controls a second vehicle device in response to the speed or direction information.

Preferably the system is adapted to perform any one, or any combination of the following functions: active sensing for cruise control, or comparison with actual wheel speeds for anti-lock braking systems and/or active traction control, provision of any one of the following: driving speed over ground display, distance covered, fuel economy measurement, elapsed journey time and estimating time of arrival at destination, average fuel economy over journey; automatic triggering of airbags; change gear in electronic automatic transmission vehicles.

Such a system can also include the features of all the other aspects of the invention.

According to a further aspect of the invention there is disclosed a safety system for vehicles comprising an anti-lock braking system fitted to a subject vehicle and operable to regulate operation of the subject vehicle's brakes in response to a signal generated by a speed sensor and representative of the speed of the subject vehicle relative to the ground, characterised in that the speed sensor is a radar system operable to direct radiation towards the ground and to determine the speed by receiving and analysing radiation reflected from the ground.

The radar system may be operable to determine speed by measurement of a doppler shift in the frequency of the reflected radiation.

According to a further aspect of the invention, there is disclosed a safety system for vehicles comprising at least one impact energy absorbing device fitted to a subject vehicle, sensor means fitted to the subject vehicle and operable to detect the proximity and closing speed of an object external to the subject vehicle, determining means responsive to output signals of the sensor means for determining whether the object is about to impact with the subject vehicle and actuating means responsive to the determining means to actuate the at least one impact energy absorbing device so as to be deployed at a position externally of the subject vehicle so as to be between the object and the subject vehicle.

The impact energy absorbing device may be an inflatable bag device comprising two or more inflatable bags deployed when inflated so as to constitute successive layers including an inner bag proximate the subject vehicle and an outer bag distal to the subject vehicle.

The safety system preferably comprises deflation means operable to deflate one or more of the bags in response to pressure within the respective bag exceeding a predetermined pressure level.

The deflation means may be operable to deflate bags in successive layers at pressure levels which decrease progressively from the inner bag to the outer bag whereby in use the outer bag is deflated prior to deflation of the inner bag in response to impact between the object and the subject vehicle.

The deflation means may comprise rupturable membranes forming parts of side walls of respective bags and arranged to rupture at respective predetermined pressure levels.

In a preferred embodiment the air bag device comprises three inflatable bags.

(The preferred comprising a plurality of air bag devices located so as to be deployed at the front, rear, left side and right side respectively of the subject vehicle

Alternatively the impact energy absorbing device comprises at least one bumper extensible by means of hydraulic ram means capable of absorbing energy when the bumper receives an impact.

A yet further aspect of the invention provides a safety system for vehicles comprising a ground speed measuring device and/or input detection means and a controller operable to activate a spraying device to release safety chemicals such as foams when an accident is likely.

Another aspect provides an antenna for a radar system comprising means for coupling the antenna to a radar system to enable electromagnetic radiation from the radar to be transmitted through the antenna and for reflected radiation to be passed back to the radar through the antenna, said antenna further comprising a body portion which is wedge-shaped. The wedge can taper to a tip of less than 1mm thickness. Preferably the antenna is made at least partially of PTFE.

Yet another aspect of the invention provides a housing for a radar system having means for communicating electromagnetic radiation into a waveguide which directs the radiation along two paths in two separate directions each leading to an output, the housing being adapted to accommodate receiving antennas in each of the radiation paths, the housing further comprising wedge-shaped antenna at the outputs for transmitting and collecting reflected radiation. The receiving antenna accommodation can be separated by half a wavelength of the radiation.

Another aspect of the invention provides a housing for a radar system having an inlet for electromagnetic radiation which leads to a waveguide which directs the radiation along two paths to two separate outlet/inlet horns wherein the horns taper along their length in one transverse dimension relative to their longitudinal axis.

The horns can taper outwardly. The horns can be turned inwardly such that radiation emitted from one horn is directed to intersect with the radiation from the other. Preferably the housing is adapted to accommodate two receiving dipoles equidistantly spaced from a point where the two paths meet.

Embodiments of the inventions will now be described, by way of example only, with reference to the accompanying drawings, in which:-

FIGURE 1 is a schematic front elevational view of vehicle display systems according to the invention;

FIGURE 2a is a schematic plan view of two vehicles fitted with a vehicle display according to the invention;

FIGURE 2B shows a second embodiment of the display shown in Figure 1 in an active state;

FIGURE 3 shows a front elevational view of part of the radar system according to the invention;

FIGURE 4 is a plan view from below of the radar part shown in Figure 3;

FIGURE 5 is a rear elevational view of the radar device shown in Figures 3 and 4; whilst

FIGURE 6 is a sectional view taken along 6-6 of Figure 5;

FIGURE 7 provides five views (A to E) of a wedge device suitable for use in a radar system according to the invention;

FIGURE 8 provides three views of a second embodiment of a wedge according to the invention;

FIGURE 9 is a sectional side view of a second radar system according to the invention;

FIGURE 10 is a plan view of a vehicle having an airbag system according to the invention; and

FIGURE 11 provides two sectional side elevation views of a door panel having airbags according to the invention.

Referring to Figure 1 there is shown a display system 10 according to the invention comprising a safety display constituted by a first light array 12 for providing warning signals relating to relative parameters between a subject vehicle 16 and trailing vehicle 18 as shown in Figure 2a.

A display comprising a second light array 14 can provide information relating to the level of deceleration of the subject vehicle and/or whether the vehicle is stationary or not. Thus the second light array 14 is similar to that described in WO93/15931 and can be operated in the same manner as described therein or alternatively using the system to be described here. The second light array 14 comprises a central lamp 15a and four pairs of lamps 15b, 15c, 15d and 15e. Central lamp 15a can be a central high mount stop lamp (CHMSL) which is triggered by a switch on the brake pedals of a vehicle and not used under PBW or VSI conditions. Pairs of lamps 15b to 15e can then act in the same manner as lamps 10 to 17 described in WO93/15931 for example.

When acting as a vehicle stationary indicator (VSI) a preferred from of display is to illuminate all lamps 15 in the second light array 14 at a starting point in a cyclic variation in the number of lamps illuminated. The second stage is to deactivate central lamp 15a, then to illuminate all lamps, followed by deactivating both lamps 15b and then lighting all lamps. This is followed by deactivating both lamps 15c momentarily and then activate all lamps and so on until all pairs of lamps have been deactivated in succession and the cycle begins again. For example, the time period for each step could be less than 1 second and preferably in the order of 0.1 second.

As can be seen from Figures 1 and 2b, the individual lamps 15 are preferably distinguishable from one another. The width of separating sections 11 between lamps 15 can be as much as the width of the lamps for example. In another form, section 11 can have a variable width to ensure that the lamps remain distinguishable when a trailing vehicle 18 is some distance behind. A proximity sensor, if used only for the function of determining separation need only comprise a one horn version of the radar described later.

Thus the stationary indication signal is found to be very effective since a clear array of lamps, such as red lamps, is displayed at the rear of the subject vehicle 16 which is apparently expanding due to the outward motion of the deactivated pairs of lamps. With regard to use of second light array 14 as progressive brake warning display (PBWD) it is found that the initial levels at which the pairs of lamps 15 are illuminated are optimally for deceleration in the ranges 0.05-0.1g and 0.1-0.25g, say. Advantageously, by using a ranging device, or proximity sensor, these ranges can be varied depending on the proximity and/or closing speed of the trailing vehicle 18. For example the initial level of PBW could be illuminated for deceleration in the range 0.025 to 0.05g; the second level becoming 0.05 to 0.1g, for example, and so on. Thus, of course, the PBW signal could be illuminated at the same time as the first light array 12 to provide an enhanced danger warning to a driver of a trailing vehicle, or other forms of display as described later could be provided.

In an improved system over that described in WO93/15931, a radar system similar to that described in WO92/01951, or as described later herein, can be used to provide information regarding subject vehicle velocity and direction of travel. By sampling ground speed measurements rapidly and using a time reference a microprocessor control system can for example provide accurate information about a vehicle's acceleration or deceleration at any given time. Accordingly, such a system can suitably be used to control the display shown on the second light array 14.

Such a microprocessor control system linked to such a ground speed sensor can be used to provide a velocity readout to the driver of the subject vehicle 16, also information regarding the distance covered in a given journey can be relayed to the driver or otherwise logged. A key feature is that the speed sensor can very accurately measure actual, true or absolute, speed over the ground, or changes therein. It is not dependent for example on the diameter of tyres as is a system which counts the rate of rotation of a vehicles' tyres. Such known systems are prone to large errors in the order of 5% of the actual speed and critically this error increases with use of the tyres due to wear (and a reduction of tyre diameter) and also critically with increasing speed of vehicle.

By inputting information to the microprocessor regarding the fuel consumption of an engine, fuel economy can be calculated and for example information can be provided to the driver regarding the most appropriate gear to be selected. Information regarding acceleration or deceleration can be provided to the driver. Additionally, in a preferred form, an acceleration and deceleration display is provided by an array of lamps comprising two rows, one to indicate the level of acceleration for example in green and a second row to indicate the level of deceleration in red. Such an array of lamps can be attached to the side of a racing car for example such as a formula one vehicle in order to provide spectators with an indication of the changing speed of the racing car. Of course, alternative displays on the vehicle might be used instead of rows of lamps.

By providing a keypad or other communication means for a driver to input information to the microprocessor, a sophisticated vehicle management system can be provided.

For example, the driver could inform the system of his present location and destination such that the system can calculate the distance of journey from a database of journey distances. The driver can then be provided with distance remaining information and estimated times of arrival, as well as average fuel economy over journey. Alternatively, the information might be stored rather than displayed to the driver and extracted for example when servicing the vehicle in order to observe if any significant change in performance of the vehicle has taken place.

The ground speed sensing system of WO92/01951 as adapted herein, can also be used in active sensing for cruise control applications. Additionally, comparison of ground speed with wheel speed can be used in anti-lock braking systems and traction control systems for either two or four wheel vehicles for example. Thus, accurate ground speed measurement can be used to control the optimum rate of pumping of brakes in an ABS system. In particular, an intelligent ABS system can be provided which when the vehicle is travelling at low speeds, overrides the anti-lock braking system in order to allow wheel locking which can be useful in certain conditions such as in snow or similar conditions. Similarly, the accurate ground speed measurements can be used to compare the speed of revolution of tyres, or other traction means such as trail wheels or tank treads for example, of a vehicle in order to enhance traction control systems. In known systems an independent vehicle speed measurement is not made and thus the present system can be used to accurately predict the required tyre revolution rate for a given speed.

The display constituted by the first light array 12 shown in Figure 1 comprises an array of seven lamps 13 which are operated using a microprocessor control system not shown. The control system is designed to activate display 12 to provide a warning signal to a driver of the trailing vehicle 18 when the trailing vehicle is closing too rapidly on the subject vehicle 16 for example, alternatively a warning signal is displayed when the trailing vehicle 18 is too close to the subject vehicle 16. Even if they are travelling at the same speed for example, there are known safe stopping distances such as those published by the Minister of Transport, in which a vehicle will stop when the brakes are applied. Accordingly, by knowing the velocity of the subject vehicle 16 for example preferably using the radar ground sensing system described herein, which provides therefore a true ground speed, or other means in communication with a microprocessor control system and by using a proximity sensor 20 to determine the separation of the subject vehicle 16 from the trailing vehicle 18 a safety envelope can be created behind the subject vehicle 16. Intrusion in the envelope by the trailing vehicle 18 causes an initial level of lamps 13 in array 12 to be lit.

For example, all lamps 13 could be illuminated. Alternatively, only lamps 13a and 13b might be illuminated in the first instance when the safe distance is broken by the trailing vehicle 18 and pair 13c might be illuminated if the trailing vehicle then encroaches a further predetermined distance and similarly 13d could be activated upon a further encroachment. For example, the safe separation distance (or stopping distance) of vehicles travelling at 30mph is 25 metres such that in an example lamp 13a might be illuminated if the trailing vehicle 18 encroaches more than 25 metres behind the subject vehicle 16, lamp 13b could be illuminated in addition to lamp 13a if the trailing vehicle gets closer than 20 metres. Lamp

13c could be illuminated if the trailing vehicle comes closer than 15 metres and 13d could be illuminated when the trailing vehicle reaches 10 metres from the subject vehicle 16. In a further example, all the lamps may be turned on and off if the trailing vehicle gets still closer.

Thus a warning system has been described using a ground speed sensor for a subject vehicle 16 coupled by a microprocessor with a proximity sensor 20. In a more sophisticate version, proximity sensor 20 could be a radar device described herein for measuring velocity and could therefore be used to measure the relative velocity of a subject vehicle 16 and trailing vehicle 18. By knowing the closing speed of the trailing vehicle 18 predetermined values could be used to trigger warning displays if the closing speed is too great. For example, a look-up table or database could again be provided for unsafe closing speeds. This look-up table might again be varied according to the velocity of the subject vehicle 16 in a similar manner to the safe stopping distance, or safety envelope distance. Therefore, whilst the safety envelope distance at 30mph is 25 metres, if the trailing vehicle is closing too rapidly, say, a difference in speed of 30mph, then the warning signal could be activated even when the trailing vehicle 18 is 50 metres behind the subject vehicle 16.

In an alternative form, the activation of the warning display, in other words the value of the safe limit, depends on the prevailing road conditions. It might be, for example that, a keypad or other communication means is provided so that the driver can input information regarding weather conditions. Alternatively, a sensor could be provided which is linked to the microprocessor to indicate whether the road is wet and the severity of the wet, icy or snowy conditions. Alternatively, such information could be provided on a local basis using a regional radio system to update a microprocessor memory via a radio receiver. In this way hazardous weather conditions can automatically be put into a vehicle management system comprising the processor herein described. Additionally, this system is advantageous in that when the vehicle is driving over long distances changes in weather conditions from one region to another can automatically be input to the microprocessor. The information regarding the weather might be obtained for example by enabling the warning system controller to ascertain if the windscreen wipers are in use or have been in use recently due to rain (and not used with a water spray to clean the windscreen). Alternatively, or as well, frost sensors, such as air temperature sensors (with adjustment for wind chill e.g. through look-up data) can be used. Thus, safe stopping distances can be adjusted for prevailing weather conditions, again by providing stored values according to weather and possibly for different severities of poor weather. Alternatively, a two level warning system can be provided wherein, a first warning, e.g. turn on all lamps 13, when a trailing vehicle 18 encroaches within the safe stopping distance of the subject vehicle 16 for poor weather, and a second warning e.g. flash all or some lamps 13, if the trailing vehicle encroaches within the safe stopping distance for good conditions. The latter warning is intended to be especially irritating to cause the driver to pull back. Multiple levels of warning for closer encroachment could be an increase in the frequency and/or intensity of the flashing lamps. For example flash rates could be increased in 2Hz increments from 2Hz upwards for increasing proximity. Also, it is possible to illuminate lamps 13 in different patterns, e.g. randomly, or 13a alone then all pairs 13b, 13c and 13d together.

Thus, the display constituted by the first light array 12 could be used in a two-stage signal for example illuminating only lamps 13a and 13b in good weather conditions but illuminating all seven lamps 13a to 13g when weather conditions are poor even though the value of the safety envelope has been increased.

Naturally, when the trailing vehicle 18 falls away from the subject vehicle 16 beyond the safety envelope limit or decelerates to a level below the unsafe closing speed, then the warning display can be automatically deactivated.

In a preferred form of the display system 10 the row of lamps 15 are red whilst lamps 13 are yellow. They are preferably positioned in the lower part of the rear window of the subject vehicle 16 or similar position so that they can easily be seen the by a driver of the trailing vehicle 18.

In an alternative form of the safety warning system, rather than providing the first light array 12, it would be possible to link the microprocessor to an existing fog lamp on the subject vehicle 16 and to activate the fog lamp automatically when any of the present conditions are violated. Naturally, rather than using a database of look-up tables, the microprocessor might use an algorithm to calculate safe values for any given set of conditions.

In an alternative form, only a single row of lamps is provided so that the first light array 12 is dispensed with. The individual portions of the second light display such as 15a and 15b could comprise reflectors or translucent coverings of different colours in front of bulbs actuated for the different systems (safety envelope, VSI, PBW). In another preferred form, say seven red LED's are provided for each lamp portion (15a say) to represent the progressive brake warning display and the vehicle stationary indication whilst seven yellow LED's are provided for each segment to represent the safety warning display. In this case, the progressive brake warning system could take priority over the safety envelope information and for example expand the number of red lights could chase yellow lights outwards such that depending on the level of deceleration and the extend of violation of the safety distances, both red and yellow lights could be displayed at the same time. For example, if the proximity violation signal was set, causing illumination of central lamp 15a and pair of lamps 15b, any light braking would automatically change lamp 15a to red (in this manner acting as a CHMSL) whilst lamps 15c could also be actuated to emit yellow light as well as lamps 15b. Naturally, since the subject vehicle 16 is decelerating at this time, further yellow lamps might be illuminated if the trailing vehicle 18 does not take appropriate action by decelerating itself.

In an alternative form, the severity of encroachment or level of deceleration can be displayed by increasing the intensity of the lamps actuated in the display system 10. A useful way of varying the light intensity is to drive LED's using a pulse train, the frequency of which is increased in order to increase intensity. For example, by driving a first lamp or LED array at say 67 Hertz (or other frequency above that perceived by the eye as flashing) a first level of intensity is perceived. As a second stage of illumination, a first and second lamp might be driven at, say, 90 Hertz or approximately a 30% increase in rate. A further level of severity depicted by the warning display can be achieved by increasing the number of lamps displayed, for example, lamps 15a to 15c and increasing the rate of illuminating by a further 30%. A yet further level can be achieved for example by illuminating lamps 15a to 15d and further increasing the repetition rate by say 40% so that the lamps are actuated twice as quickly as the original rate. This results in an increase in intensity of the lamp of some 40 to 50%. By way of example of the display, Figure 2b shows the situation of light braking discussed earlier and also vehicle encroachment within the safety envelope. Hence, CHMSL 15a is illuminated and also essential and in a pair of lamps of the first light array 12 are illuminated.

Beneficially the rise time to near maximum intensity of an LED is much shorter than that for a standard bulb, this means, for example, that a much quicker initial display effect can be achieved as well as enabling the pulse control just described for relatively short 'on' pulses without loss of performance. A further advantage of using LEDs is that they can emit light e.g. directionally and thus the drivers of cars in lanes adjacent the subject vehicle 16 need not have the safety display forced on them, or at least not a bright display. Means can be used to make the LEDs appear as one light - such as by a focusing lens, or the display can allow the LEDs to be seen individually.

For all the systems described a similar safety display can be provided inside the trailing vehicle 18 which is visible to the driver. Thus communication means between vehicles can be used.

Referring to Figures 3 to 5 there is shown a first embodiment of a housing 30 comprising a front plate 31 for a radar device according to the invention. Housing 30 comprises an input channel 42 which splits into two channels 40 which lead to two outlet/inlets or horns 32 and

34. A radiation generator 36 produces electromagnetic radiation of a suitable wavelength such as in the microwave or radio wavelength regime. For example, microwave radiation in the order of 24.125 giga Hertz can be used where the dimension E of input waveguide or channel 42 could be 4.32mm. The basic operation of the radar is known from WO92/01951 and it will be appreciated therefore that the radiation passes through channels 40 and horns 32 and 34 which then also act as receivers which return reflected radiation back to channel 40 where a signal is received by dipole antennas or, as referred to in the art, diodes 44 suitably positioned equidistantly from axis C running through channel 42. The diodes 44 can be positioned one quarter wavelength apart from axis C such that dimension D could be about 17mm and naturally the wavelength of the radiation could be varied in order to ensure that the diodes 44 are suitably positioned. Other electronics used in the processing of the signal from diodes 44 can be placed in cavity 38 between the horns 32 and 34. Preferably the cavity is protected by a plate 52 as shown in Figure 4 which extends across cavity 38 from the ends of housing 30.

It can be seen from Figure 4 that whilst horns 32 and 34 are flared in the front elevation shown in Figure 3, they have a uniform depth. This is quite unlike known housings of this type wherein the horn is also tapered in this direction. This provides the benefit of reduced manufacturing costs when preparing front plate 31 for housing 30. For example, the housing block can be cast, moulded or milled or otherwise suitably formed but does not now require a difficult shape to be produced for the horns 32 and 34. As shown in the front elevational view of rear plate 48 of housing 30 and in particular in Figure 6 of the section taken along line 6-6, the rear wall 50 of back plate 48 is flat from left to right and so it too is no longer tapered in the transverse direction. Additionally, by providing a large cavity particular advantages are obtained in being able to place all the electronics used to drive the radar within this cavity. This is also found to reduce manufacturing costs as well as reduce electromagnetic interference in operation. Additionally, benefits are obtained in the ease of fitting the radar system to the subject vehicle 16 for example or other body since only the housing itself needs to be attached and a simple communication channel can then be connected to the radar to communicate with the vehicle or other system. For example a simple cable connection could be used for a communication path and this could also provide a path for power supply to the radar.

In an alternative embodiment a wedge such as 60 or 70 as shown in Figures 7 and 8 respectively is used in place of a horn on a radar device of Figure 3. For example, housing plate 31 could be used by removing horns 32 and 34 along with the rest of the casing to leave a rectangular aperture at point 46 at the ends of channel 40. A wedge 60 or 70 having a suitably sized connecting lug 62 or 72 respectively can then be inserted into the channel at point 46 to provide both a transmitter and receiver for the radar. A radar 90 is shown in Figure 9 which could comprise wedges 60 or 70.

As can be seen from Figure 7e, the antenna 60 can be seen to be wedge shaped, tapering in its transverse dimension from a rectangle at the connecting end adjacent to lug 62 to a tip 66 at the other end. Three views are provided of a further embodiment of a wedge shaped antenna 70 where its dimensions could for example be as follows: 80, 10.68mm; 81, 10mm; 82, 13mm; 83, 60mm; 84, 10.68mm; 85, approximately 1mm but preferably less; 86, 4.68mm; and 88, 6mm. The antenna could for example be made from PTFE but other suitable materials could be used which are transparent to microwaves and, radiowaves, or the particular type of radiation being used.

As can be seen from the drawings, the antenna tapers in only one dimension and is therefore relatively simple to manufacture. The orientation of the antenna relative to a suitably adapted housing 30 is such that antenna 60 or 70 is positioned so that its inwardly directed taper is in the same direction as the outwardly directed taper of horns 32 and 34 shown in Figure 3. Thus, if inserted at points 46 in Figure 3, antenna 60 would appear as shown in Figure 7a. A particular benefit of using wedge antennas is that they themselves prevent the ingress of dirt or other particles into the radar housing.

As is known from WO92/01957, there are certain critical factors necessary to obtain accurate directional and speed information from a radar of the type having two mixing points for reception of a signal by two diodes. The skilled man is therefore referred to that document for reference to how to obtain the information from such a system, and all such information is incorporated herein by reference.

It is found that by reducing the cost of manufacture and improving for example the ease of fitting of a suitable radar system, a device can be provided which can more economically be produced and viably used to obtain the benefits of the system.

The reduction in cost of this type of radar enable it to be used for example in proximity sensing to determine the separation of an object from the radar system as well as in speed and direction monitoring. Therefore, a radar system of the above designs can be used in relation to the display system described in WO93/15931 to provide both the information for determining deceleration of a vehicle independent of the braking system and also for providing a proximity sensor in order to terminate the display signal as described in that patent. Since the data devised from such a system provides directional information, it can be linked to any safety system described herein to give a warning regarding the direction of movement for example of a vehicle. This is beneficial for large vehicles especially when reversing and an audible as well as visual warning can be given.

Figure 9 shows a radar system 90 capable of the various functions described herein, where the waveguide horn 60 are additionally perfected by a housing comprising a series of shields 92, 93 and 94 which protect the radar waveguide and horns from outside elements. Each of the protection panels 92 to 94 comprise an aperture 95 which enables a beam B to be reflect on an internal reflector 91 thereby enabling beams to be received and transmitted from horn 60. The radar system 90 comprising an incoming waveguide 96 from a radar or microwave source for example, and receiving diodes not shown.

Beneficially the radar, or ground speed sensor 90, is easy to manufacture, low cost and can house all the electronics at the back of its casing thereby reducing space requirement and enabling ease of fitting to the underside of a vehicle chassis for example. Advantageously, the surrounding casing 97 protects the antenna 60 and electronics from water and dirt for example. Thus, the attenuation of signals due to these factors can be mitigated.

Figure 10 shows a vehicle V having an airbag system according to the invention. The airbag system comprises airbags 100, 102, 104 and 106 which protrude outwardly from the side and end panelling of the vehicle. The entire side and end surfaces of a vehicle could be protected with such an airbag system in a preferred form. In Figure 10 the airbags 100 to 106 are shown in an expanded operable position ready to absorb impact from another vehicle or crash barrier for example.

Figure 11 shows one airbag e.g. 102, in a contracted state within a recess 108 in the vehicle side panel P. The airbag can be expanded using for example a pressurized gas system 110, in an emergency. Each airbag and airbag chamber can be inflated separately. For example, airbags at the front of the vehicle can be activated upon rapid deceleration of the vehicle detected by a ground speed sensor described herein for example. As a very final response level in the intelligent safety envelope system described herein, airbag 106 could be expanded or deployed if the safety system detects that the trailing vehicle 18 is approaching vehicle V at a rate that impact is inevitable.

In a preferred form as shown here, the airbags e.g. 102 comprise a series of airbag compartments such as 118, 120 and 122. All three airbags are housed within recess 108 and protected by device 116 which can attach to the vehicle side panelling. In the expanded state, all three protrude from the vehicle side panelling as to provide cushioning against impact. Preferably, the compartments are rupturable separately from one another and are not of the known vented type. More preferably the compartments are rupturable at different internal pressures by for example airbag 118 ruptures at a lower pressure than airbag 120 which in turn explodes at a lower pressure compared to airbag 122. Thus a cascade of energy absorbing impacts between the airbags and an external body is provided.

For example, the individual airbag compartment 118 etc can be made for example from a somewhat elastic resilient material which is provided with a rupturable device of some description which is calibrated to allow gas to escape from the compartment when the internal pressure within the compartment exceeds a predetermined level. In an alternative form, the internal bag bursts at the lowest pressure with the cascade working in the opposite sense described above. In alternative forms, any number of bags or compartments can be provided in a series extending outwardly from the vehicle from say 2 to 10 or more.

Beneficially, the airbags help to prevent intrusion of an outside object into a vehicle. Additionally, the corners of a vehicle can be protected by providing overlapping airbags from the sides and ends of a vehicle as shown at position O in Figure 10. The airbags could be made from extremely strong materials such as plastics or fibrous composites for example which resist bursting other than by the designed rupturable means. Thus, the airbags will protect the driver or passengers in the vehicle from sharp objects since the bags will tend to resist intrusion of a sharp object due to the strong materials.

The side input airbags/compartments can be inflated upon detection of a closing object using a proximity sensor positioned to detect objects at the side of the vehicle. Preferably the sensor enables calculation of the closing speed of the object and whether impact is inevitable. Inflation of any of the external airbags could also be used to cause inflation of any internal airbags.

The air bags of Figure 10 may be replaced by bumpers disposed along the rear of the subject vehicle and optionally the sides and front of the subject vehicle, the bumpers being mounted on rapidly extensible hydraulic rams of a type which facilitate the absorption of impact energy. Instead of inflating air bags as described above, the hydraulic rams could be actuated by the controller in order to deploy the bumpers in order to provide means for absorbing impact energy. The controller would therefore be operable to determine from proximity and closing velocity information whether an impact with a trailing vehicle or other object was likely to be about to occur and to actuate the impact energy absorbing means accordingly so as to deploy either the air bag or bumper devices to positions externally of the subject vehicle and between the object and the subject vehicle at the expected point of impact.

Throughout the description and claims the term trailing vehicle is used to indicate a vehicle separate from the subject vehicle and which is generally proceeding so as to follow the subject vehicle, typically along a common roadway or railway.

CLAIMS

1. A safety system (10) for vehicles comprising a controller fitted in use to a subject vehicle (16), sensor means (20) fitted to the subject vehicle in use and operable to sense a distance of separation and/or a relative velocity of a trailing vehicle (18) and operable to input data signals representative thereof to the controller, velocity sensing means (97) operable to sense the velocity of the subject vehicle relative to the ground and to input to the controller a velocity signal representative thereof, wherein the controller is operable to processes the received velocity signal and data signals to determine the existence of an unsafe condition, and the safety system further comprising warning means (10) controlled by the controller and operable to warn a driver of the trailing vehicle of the existence of the unsafe condition.

2. A safety system as claimed in claim 1 wherein the controller is operable to determine the existence of the unsafe condition by determining a safe distance corresponding to a safety envelope to the rear of the subject vehicle within which any incursion by the trailing vehicle constitutes the existence of an unsafe condition.

3. A safety system as claimed in claim 2 wherein the safe distance is determined to be substantially the safe stopping distance of a vehicle travelling at the velocity of the trailing vehicle.

4. A safety system as claimed in any of claims 1 and 2 wherein the safe stopping distance is determined to be proportional to the velocity of the subject vehicle.

5. A safety system as claimed in any of claims 2 to 4 wherein the controller is operable to determine an enhanced safe distance corresponding to an enlarged safety envelope and wherein the warning means is operable to indicate a first level of warning corresponding to incursion by the trailing vehicle into the enlarged safety envelope and a second level of warning which is more prominently presented to the driver than the first level of warning and corresponds to any incursion into the safety envelope.

6. A safety system as claimed in claim 5 comprising ground condition communication means operable to input to the controller a signal representative of the condition of the ground and or other driving conditions and wherein the controller is operable to determine the enhanced safe distance corresponding to the enlarged safety envelope according to the extent to which the ground condition communication means indicates adverse ground conditions likely to affect traction between the subject vehicle and the ground.

7. A safety system as claimed in any of claims 5 and 6 wherein the sensor means is operable to sense both the distance of separation and the relative velocity of the trailing vehicle and wherein the controller is operable to determine whether the relative velocity of the trailing vehicle relative to the subject vehicle when entering the enlarged safety envelope is greater than a threshold value of relative velocity and, if so, is operable to actuate the warning means to indicate the second level of warning.

8. A safety system as claimed in claim 7 wherein the ground condition communication means comprises means fitted to the subject vehicle for sensing at least one of rain,

snow and ice and communicating a signal representative thereof to the controller.

9. A safety system as claimed in any preceding claim wherein the sensor means comprises a radar system transmitting and receiving radar pulses, from which received pulses information is derived sufficient to determine both the proximity and relative speed of the following vehicle.

10. A safety system as claimed in any of claims 5 to 9 wherein the warning means comprises a display (10) carried by the subject vehicle and positioned for viewing by the driver of the trailing vehicle.

11. A safety system as claimed in any of claims 5 to 10 further comprising communication means operable between the controller of the subject vehicle and a warning device fitted in use to the trailing vehicle, whereby the warning means is operable to indicate a warning to the driver of the trailing vehicle via the warning device.

12. A safety system as claimed in any preceding claim wherein the velocity sensing means comprises a sensor (97) mounted on the subject vehicle and responsive independently of elements of the subject vehicle's transmission train to movement of the ground relative to the subject vehicle.

13. A safety system as claimed in claim 12 wherein the velocity sensing means comprises a sensor constituted by a doppler shift radar device.

14. A safety system as claimed in any preceding claim wherein the controller is operable to actuate an impact

absorbing device (100, 102, 104, 106) deployed internally or externally of the subject vehicle.

15. A safety system as claimed in claim 14 wherein the impact absorbing device comprises an air bag (100, 102, 104, 106) inflatable so as to be deployed externally of the subject vehicle and/or bumpers extensible by means of hydraulic rams operable to absorb energy upon impact.

16. A safety system for vehicles having means fitted in use to a subject vehicle for determining the magnitude of acceleration and deceleration of the subject vehicle and connected to a visible display mounted on the subject vehicle operable to indicate to an observer remote from the vehicle the magnitude of acceleration and deceleration.

17. A safety system as claimed in claim 16 wherein the visible display comprises an array of lights mounted on the side or sides of the subject vehicle.

18. A safety system as claimed in claim 17 wherein a first coloured array of lights represents acceleration and a second coloured array of lights represents deceleration, the number and/or intensity of actuated lights of a given colour representing the magnitude of the acceleration or deceleration respectively.

19. A safety system for vehicles comprising an anti-lock braking system fitted to a subject vehicle and operable to regulate operation of the subject vehicle's brakes in response to a signal generated by a speed sensor and representative of the speed of the subject vehicle relative to the ground, characterised in that the speed sensor is a radar system (97) operable to direct radiation towards the

ground and to determine the speed by receiving and analysing radiation reflected from the ground.

20. A safety system as claimed in claim 19 wherein the radar system is operable to determine speed by measurement of a doppler shift in the frequency of the reflected radiation.

21. A safety system for vehicles comprising at least one impact energy absorbing device (100, 102, 104, 106) fitted to a subject vehicle, determining means responsible to output signals of the sensor means for determining whether the object is about to impact with the subject vehicle and actuating means responsive to the determining means to actuate the at least one impact energy absorbing device so as to be deployed at a position externally of the subject vehicle so as to be between the object and the subject vehicle.

22. A safety system as claimed in claim 21 wherein the impact energy absorbing device is an inflatable bag device comprising two or more inflatable bags (118, 120, 122) deployed when inflated so as to constitute successive layers including an inner bag (122) proximate the subject vehicle and an outer bag (118) distal to the subject vehicle.

23. A safety system as claimed in claim 22 comprising deflation means operable to deflate one or more of the bags in response to pressure within the respective bag exceeding a predetermined pressure level.

24. A safety system as claimed in claim 23 wherein the deflation means is operable to deflate bags in successive layers at pressure levels which decrease progressively from

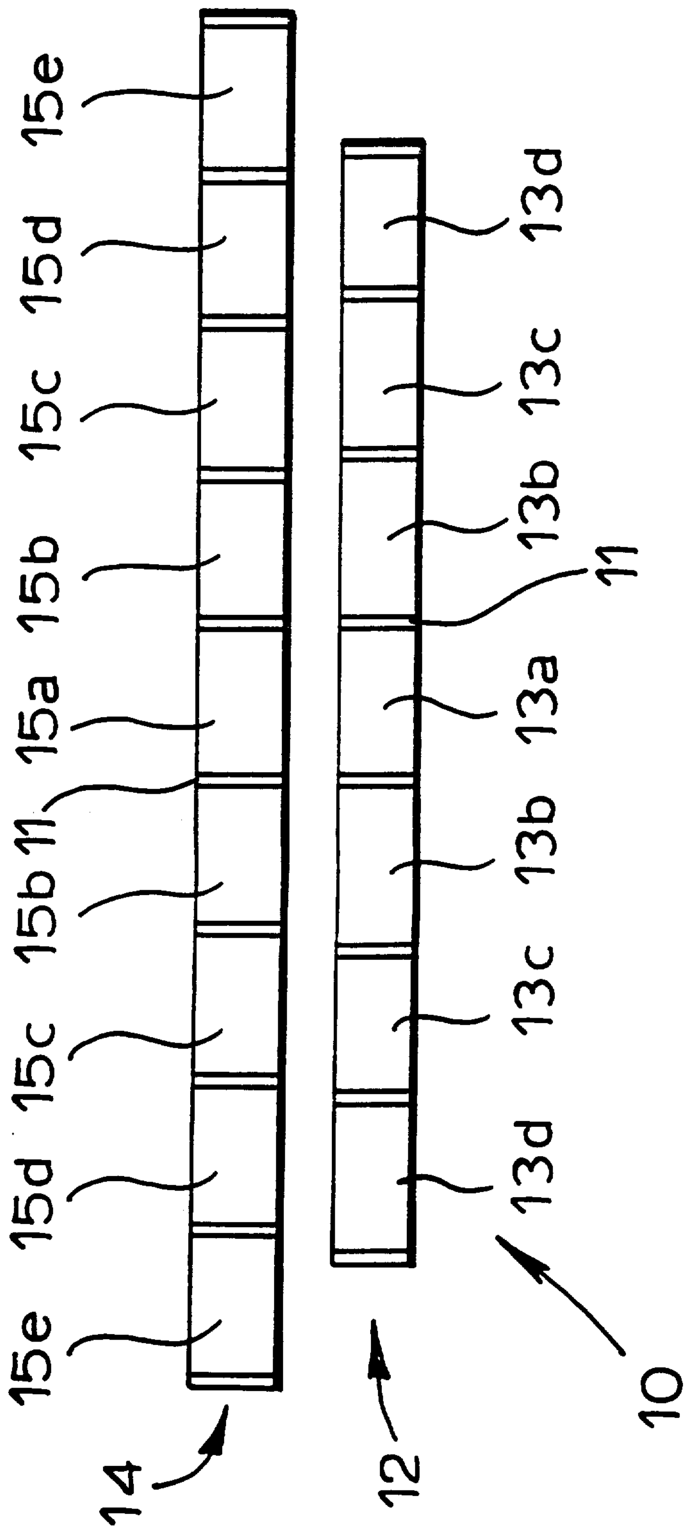
the inner bag to the outer bag whereby in use the outer bag is deflated prior to deflation of the inner bag in response to impact between the object and the subject vehicle.

25. A safety system as claimed in any of claims 23 and 24 wherein the deflation means comprises rupturable membranes forming parts of side walls of respective bags and arranged to rupture at respective predetermined pressure levels.

26. A safety system as claimed in any of claims 21 to 25 wherein the air bag device comprises three inflatable bags.

27. A safety system as claimed in any of claims 21 to 26 comprising a plurality of air bag devices (100, 102, 104, 106) located so as to be deployed at the front, rear, left side and right side respectively of the subject vehicle.

28. A safety system as claimed in claim 21 wherein the impact energy absorbing device comprises at least one bumper extensible by means of hydraulic ram means capable of absorbing energy when the bumper receives an impact.



15e
15d
15c
15b
15a
11
15b
15c
15d
15e
14
12
13d
13c
13b
11
13a
13b
13c
13d
10

FIG.1

2/7

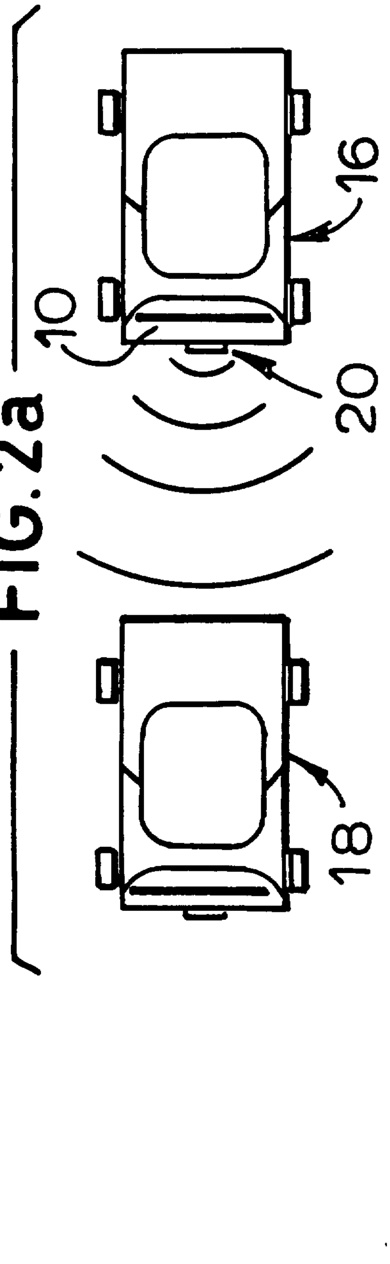


FIG. 2a

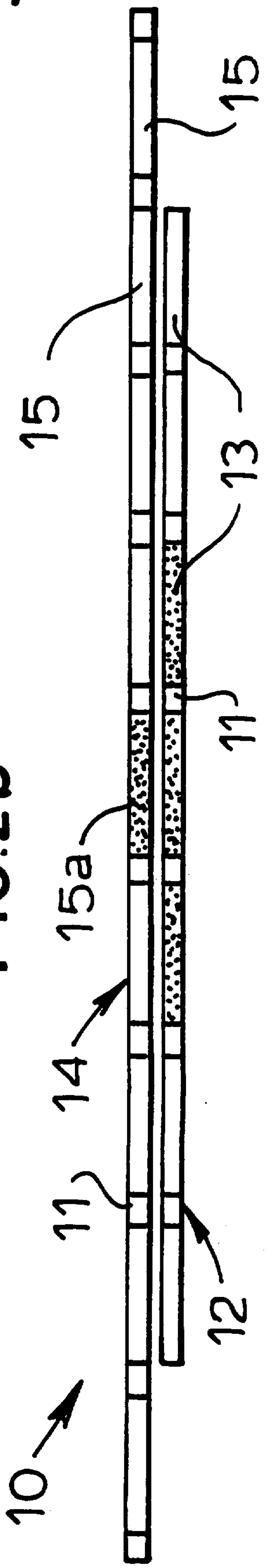
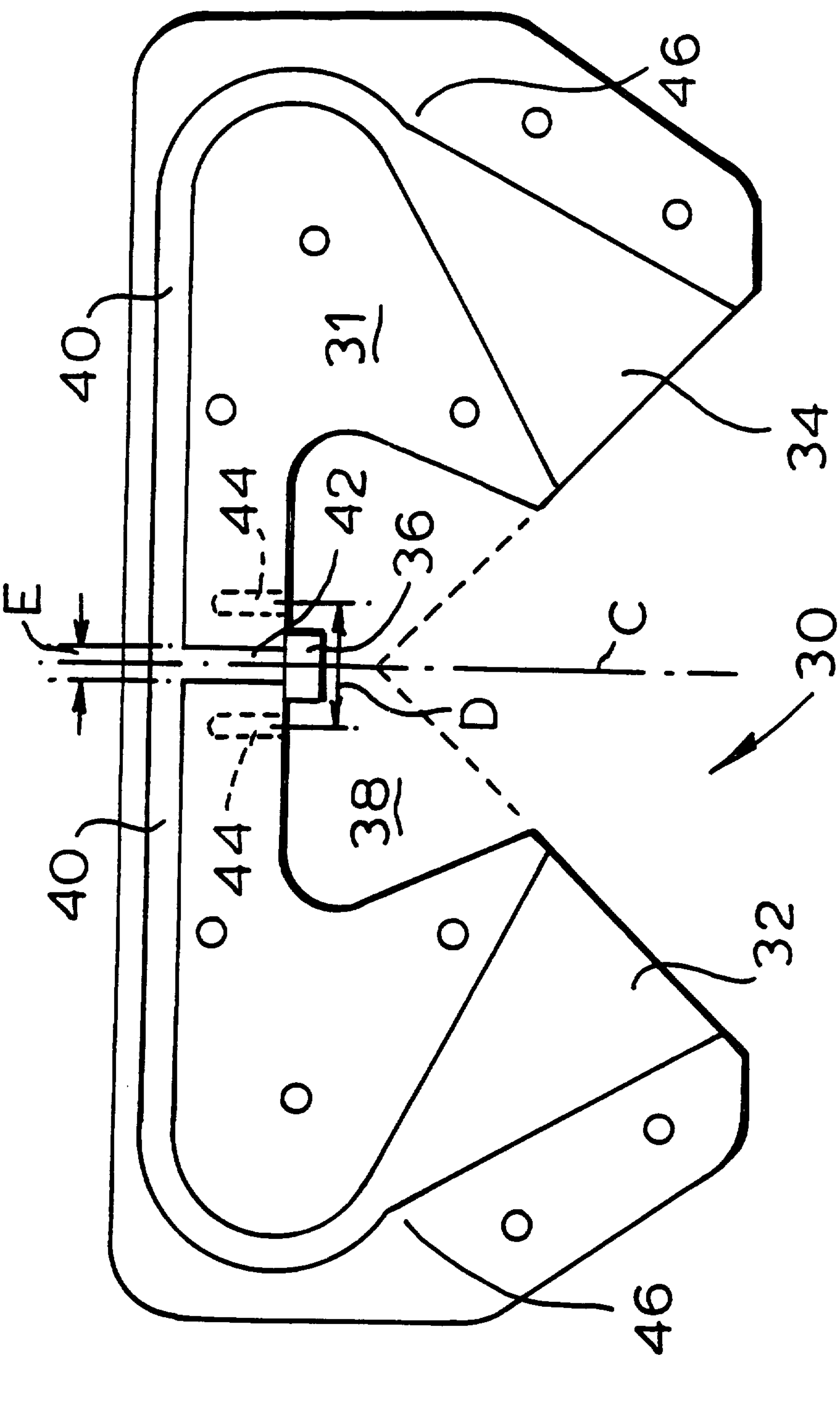


FIG.2b

FIG.3



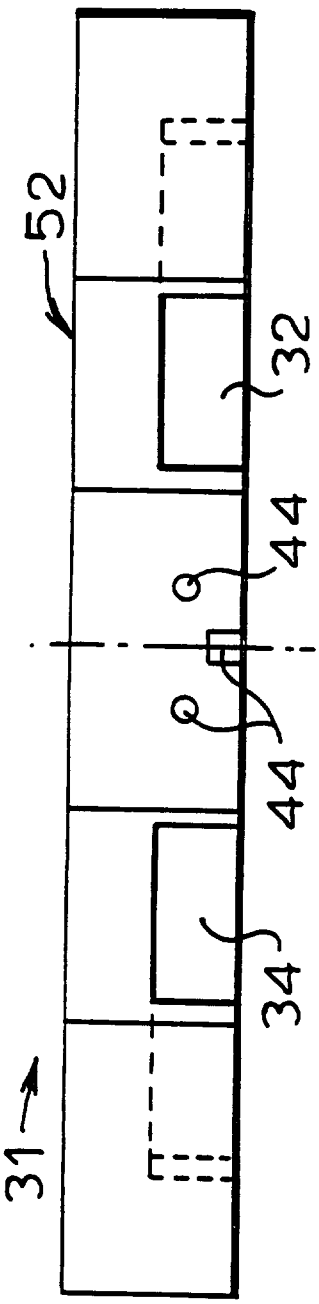


FIG. 4

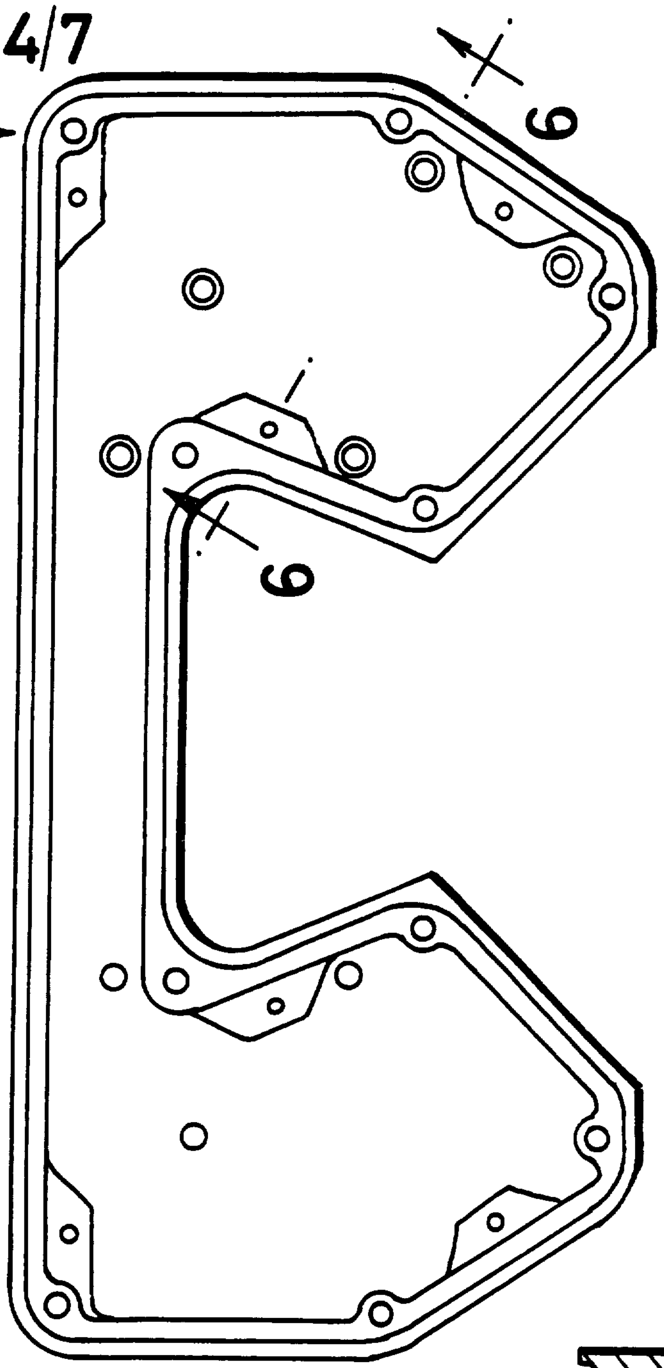


FIG.5

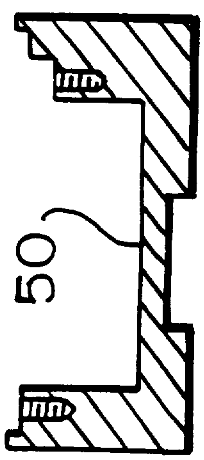
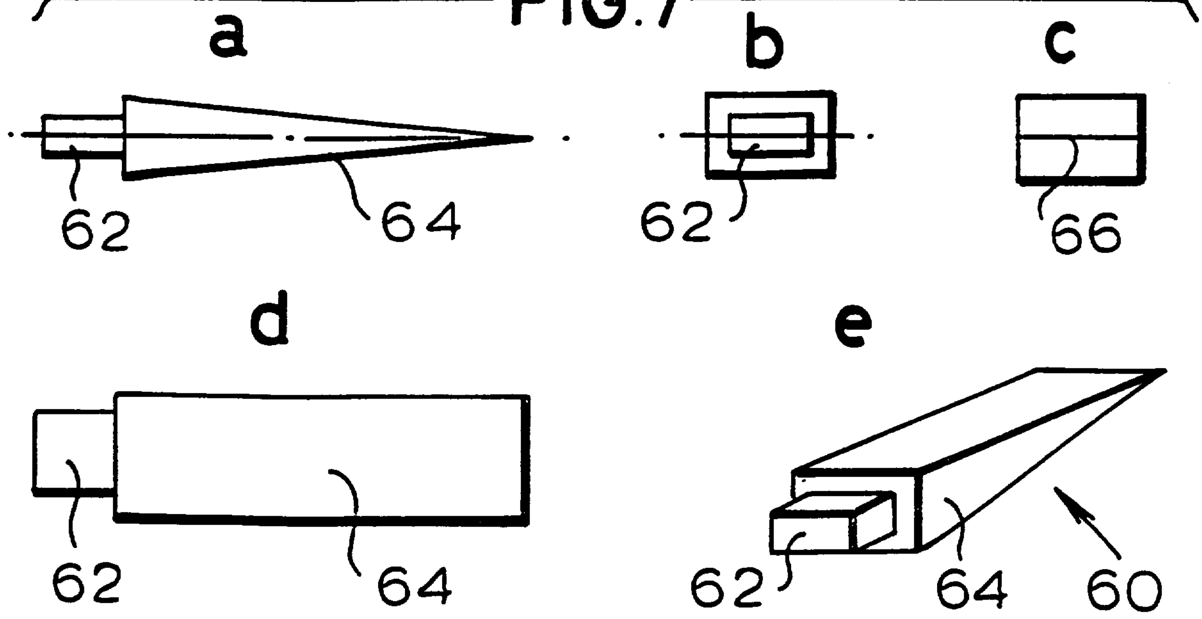


FIG.6

FIG.7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62
64
62
66
d
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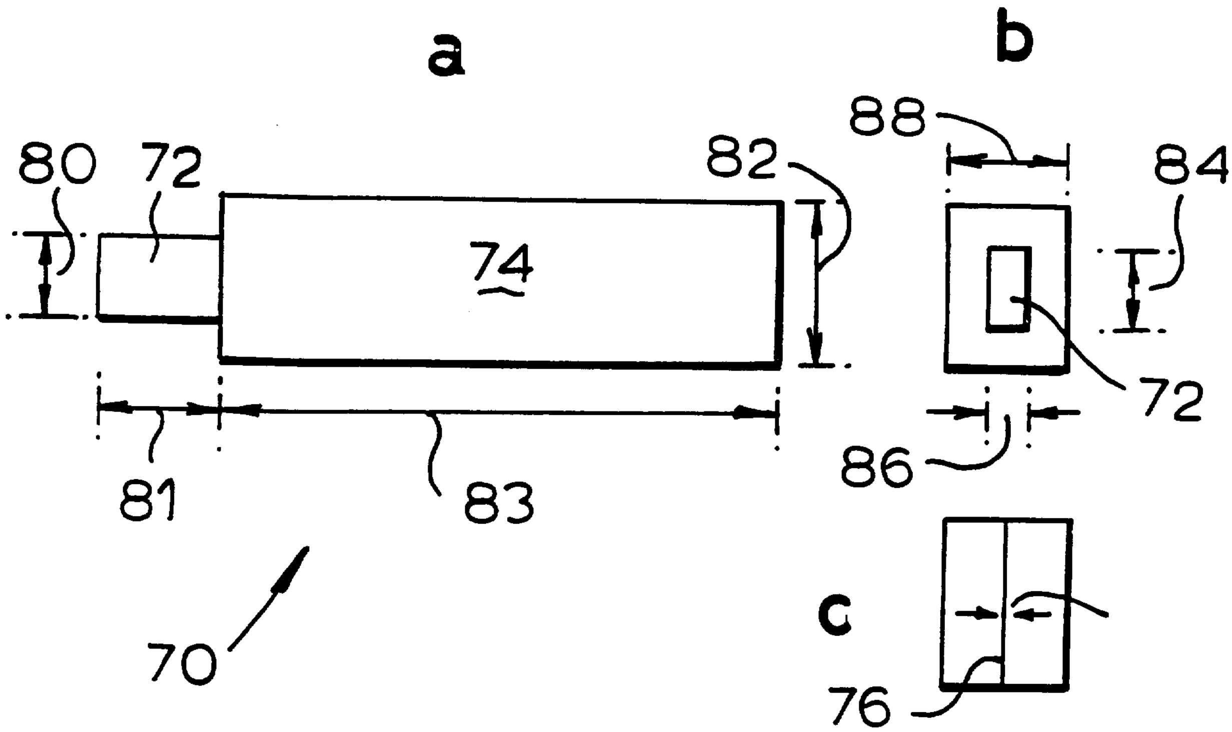
64
62
64
60

FIG.8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b
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82
88
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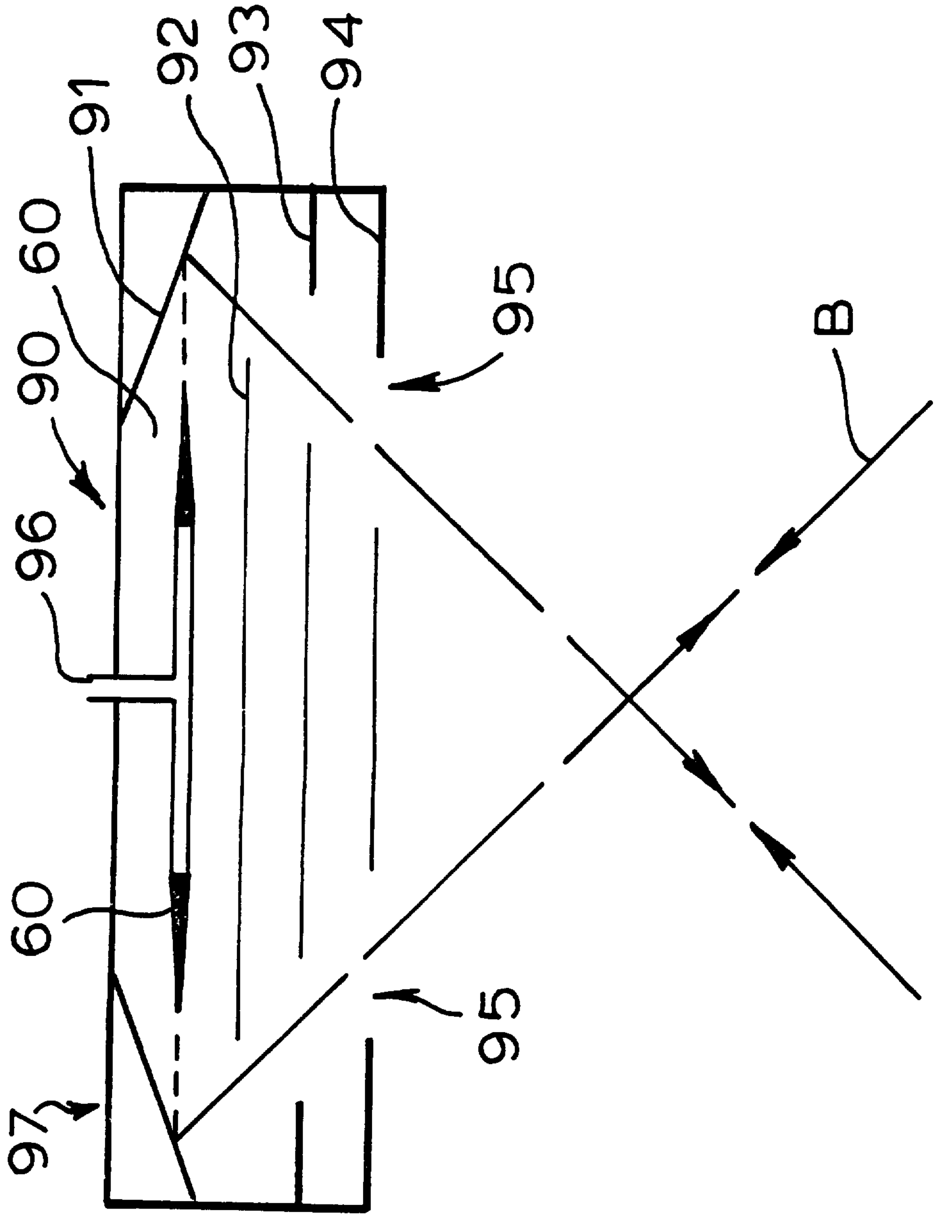
83
86
70
c
76

FIG.9



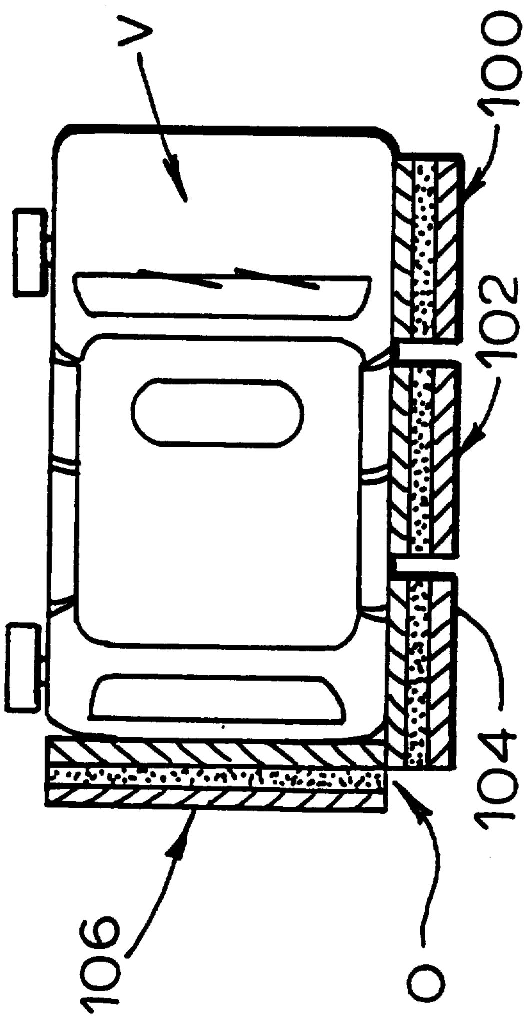


FIG.10

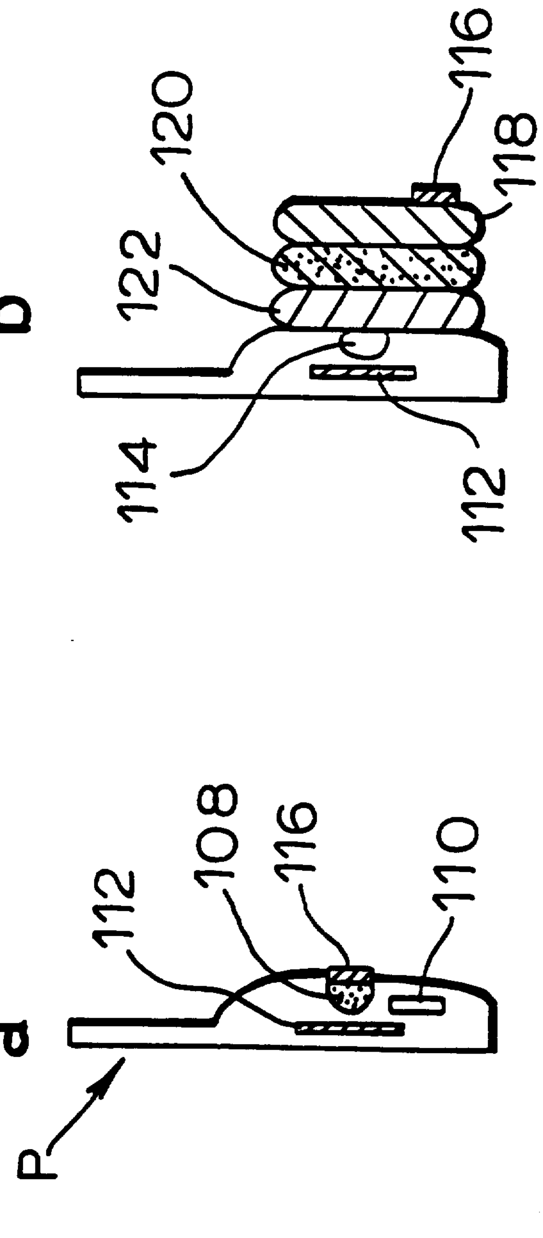


FIG.11

EXHIBIT 20

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In Re Patent of	:	Harvey SLEPIAN et al.
Patent No.	:	5,954,781
Issued	:	September 21, 1999
Title	:	METHOD AND APPARATUS FOR OPTIMIZING VEHICLE OPERATION
Application Serial No.	:	08/813,270
Filed	:	March 10, 1997
Requester	:	Volkswagen Group of America, Inc.

CERTIFICATE OF SERVICE

I hereby certify that a copy of the attached "**REQUEST FOR *EX PARTE* REEXAMINATION OF U.S. PATENT NO. 5,954,781 PURSUANT TO 37 C.F.R. § 1.510**" is being served in its entirety by first class mail on the patent owner at the following address as provided for in 37 C.F.R. § 1.33 (c):

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on this 22nd day of May 2014.

/Clifford A. Ulrich/
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