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## OBD-2 DIY project

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# Stand Alone OBD-

## Interpret 'trouble codes' without a PC


Folker Stange and Erwin Reuss

**This handy analyser makes a simple job of rummaging through the information stored by the client–accessible part of your car's computer. It works with all current OBD-2 protocols and can read and erase trouble codes stored in the vehicle and reset the MIL display. All this without the help of a PC or a visit to a service station.**

Since the turn of the millennium more and more new car models have been fitted with the latest version of the on board diagnostic interface OBD-2. With the increasing sophistication of modern engine management many new owners have seen the benefits of an OBD analyser such that it is fast becoming an essential part of the garage tool kit along with the torque wrench and spark plug spanner.

It has been reported that sometimes when owners fit a new car radio or sat-nav system to their car the vehicle management system unnecessarily registers a fault, similarly some owners who have modified the engine to accept an alternative fuel have noticed that the engine management can incorrectly interpret the engine condition and trigger an error. In some cases the engine management can even be switched into an emergency condition. Whatever the cause the outcome is the same; a dashboard mounted MIL (malfunction indicator light) comes on, a fault condition is stored and it is necessary to make an (expensive) visit to the nearest garage to have the 'trouble' put right and the MIL reset. With the OBD analyser described here in your glove box it is a simple job to connect to the OBD socket, find out what the trouble is, reset the error and continue on your journey. On cost grounds alone the price of the analyser will be more than repaid by avoiding just a single unnecessary visit to a dealership garage.

A number of OBD analysers have been featured in the electronics press (including *Elektor Electronics*) describing an interface between the OBD connector and a laptop. The approach we have adopted here is however far less cumbersome, this stand-alone unit does not require a notebook or battery, recognises all the usual OBD-2 or EOBD protocols and is small enough to stow in your car's glove box. Operation is quite straightforward using just two buttons, 580 of the commonest trouble codes can be recognised and described on its running text display.

### The Circuit

The OBD-2 analyser employs an AT-90CAN128 microcontroller from the AT-mega128 family from Atmel. This par-

# 2 Analyser

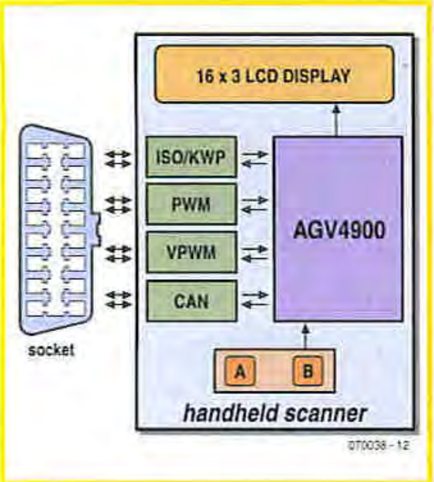



Figure 1. Block diagram of the OBD-2 analyser.

ticular model has an on-board CAN bus interface as shown in **Figure 1**. The controller is supplied pre-programmed with the AGV4900 firmware which handles the user-interface including push buttons, buzzer, LEDs and LCD.

Pin assignments the OBD-2 connector are given in **Figure 2**. In order to support all the current OBD-2 protocols the analyser needs to be able to interface to several bi-directional interfaces:

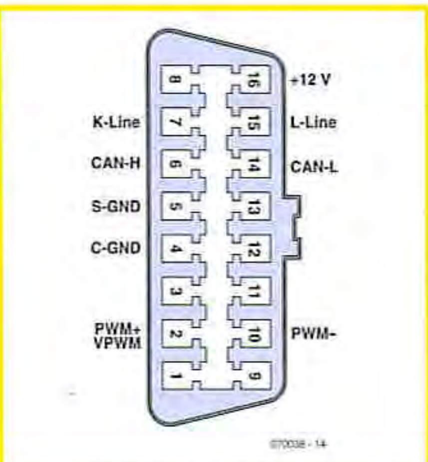



Figure 2. Pin definitions of the OBD-2/EOBD connector.

## Specification

- Automatic or manual selection of OBD-2 protocol
- Very fast automatic protocol scan (0.1 to 2.6 s per protocol)
- Fast software boot sequence (ready to go around a second after switch on)
- Read and display important vehicle information (depending on the vehicle)
- Real-time sensor reading (selectable)
- Vehicle chassis number display (if supported by the vehicle manufacturer)
- Readout and display of the trouble code memory
- Read out and display of Freeze-Frame data
- Erasure of trouble code memory
- Language selection (English or French)
- 580 trouble codes with description in running text
- All existing OBD protocols for private vehicles are supported:
  ISO9141-2
  ISO14230-4 (KWP2000)
  J1850 PWM
  J1850 VPWM
  ISO15765-4 (CAN, 11/29 Bit, 250/500 kbits/s)
- Power for the analyser is supplied from the vehicle's OBD-2 connector (12 V)
- Backlit 3-line LC display with adjustable contrast
- Acoustic signal gives audible feedback and beeps when trouble codes recognised
- LED Indicators for connection status and data traffic flow
- Simple operation using just two push buttons
- Connection for a standard OBD-2 cable
- Handheld format: 80x135x30 mm (wxhxd), weight 150 g (approx.)
- Supplied as a kit through Elektor SHOP

- K/L interface
- PWM interface
- VPWM interface
- CAN interface

The first three of these in the circuit diagram (**Figure 3**) have been implemented using transistors and comparators configured to meet the interface standards. The specified pull up resistors for the K and L signals have a rela-

## Points to note

The OBD analyser is only suitable for vehicles fitted with an OBD-2/EOBD connector.

EOBD is fitted to vehicles sold in the EU:

- after 01.01.2001, for petrol engine vehicles.
- after 01.01.2004, for diesel engine vehicles.

Before the analyser is plugged into any vehicle manufactured before these dates, it is important to check compatibility with the OBD-2 standard. The website of Florian Schäffer [3] contains a databank of vehicles where you check to see if yours is OBD-2 compatible.

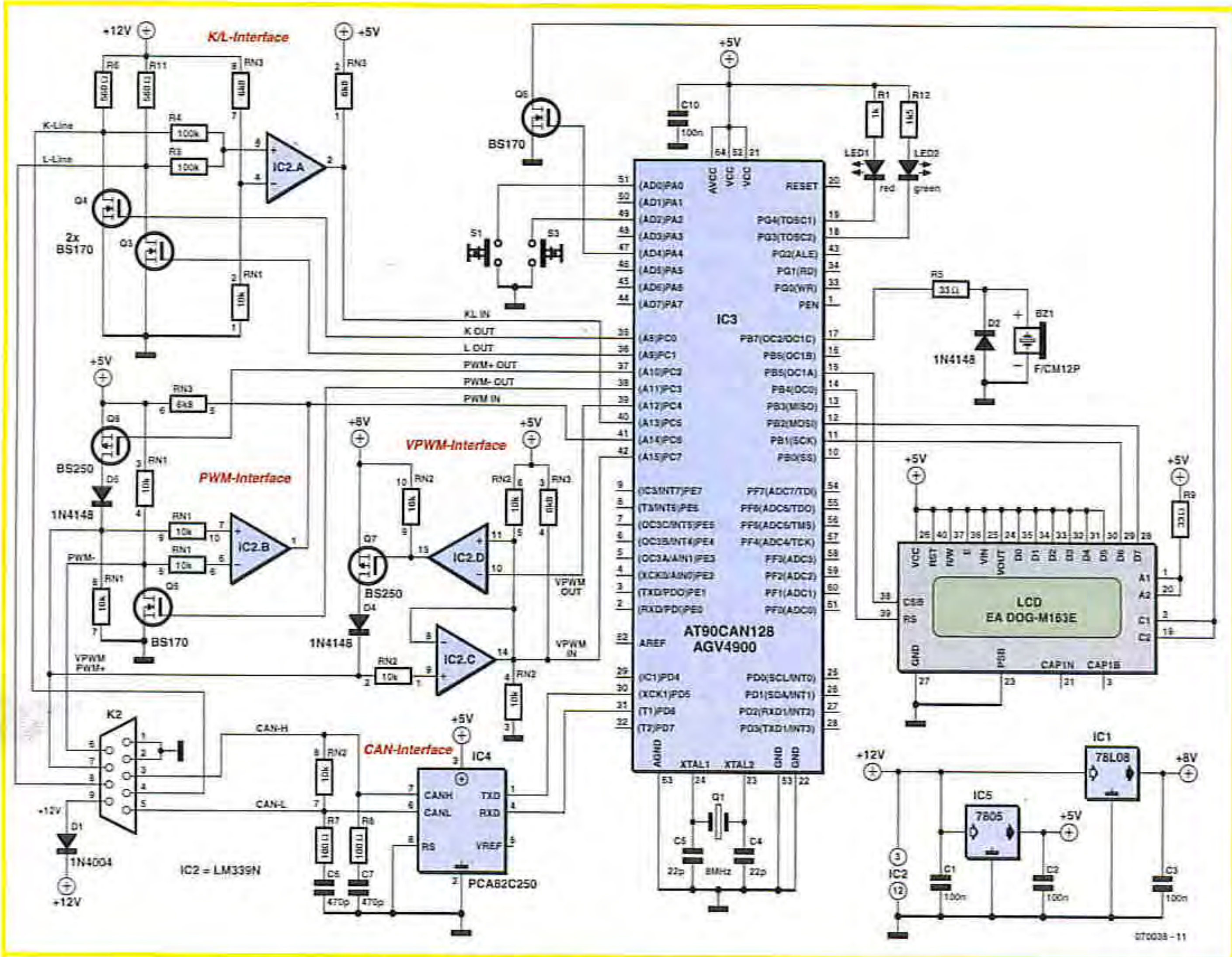



**Figure 3. The AVR microcontroller with on-board CAN interface is the main part of the circuit diagram.**

tively low impedance so MOSFETs have been used here as drivers. The CAN bus driver IC type PCA82C250 takes care of the CAN interface.

The user-interface software is logically designed such that just two push buttons are required to operate the analyser and select all possible menu options. Connections for the buzzer, the 'connect' and 'Data Traffic' LEDs should not require any further explanation. Control of the three-line LCD is a little more complex, a five wire SPI interface connects the display to the controller. LED backlights ensure that the display is night time readable. The relatively low controller clock speed (8 MHz) is a good compromise, producing a low level of EMI emissions while still giving ample operating speed for this application.

## The Firmware

The heart of the OBD-2 analyser is the pre-programmed microcontroller with the designation AGV4900 [1] available solely from Stange Distribution [2]. The software was developed by co-author Erwin Reuss. Like similar OBD projects the firmware for this analyser is only available pre-programmed into the microcontroller where it is copy protected. The source files are not available for download. Without this software copy protection is would not be possible to offer the analyser in kit form. There is no possibility for the home constructor to assemble a low-cost version of this design unless of course all the necessary software is written from scratch.

A menu option switches all display information between either English or French (for the convenience of our Canadian readers). Stange Distribution are specialists in OBD related equipment and produce several OBD-2 controllers for applications in the field of OBD development.

All the OBD analyser functions can be selected from the menu using just two keys. One feature of the software is the very quick boot procedure which ensures that the device is ready for use in little more than a second after switch-on. The most important 580 trouble codes have a plain text description of the fault which is displayed in running text (in the language chosen). This feature helps promote a quick and effective diagnosis of the problem. In the vast majority of cases there will be no need to look up the code in an OBD trouble code book.

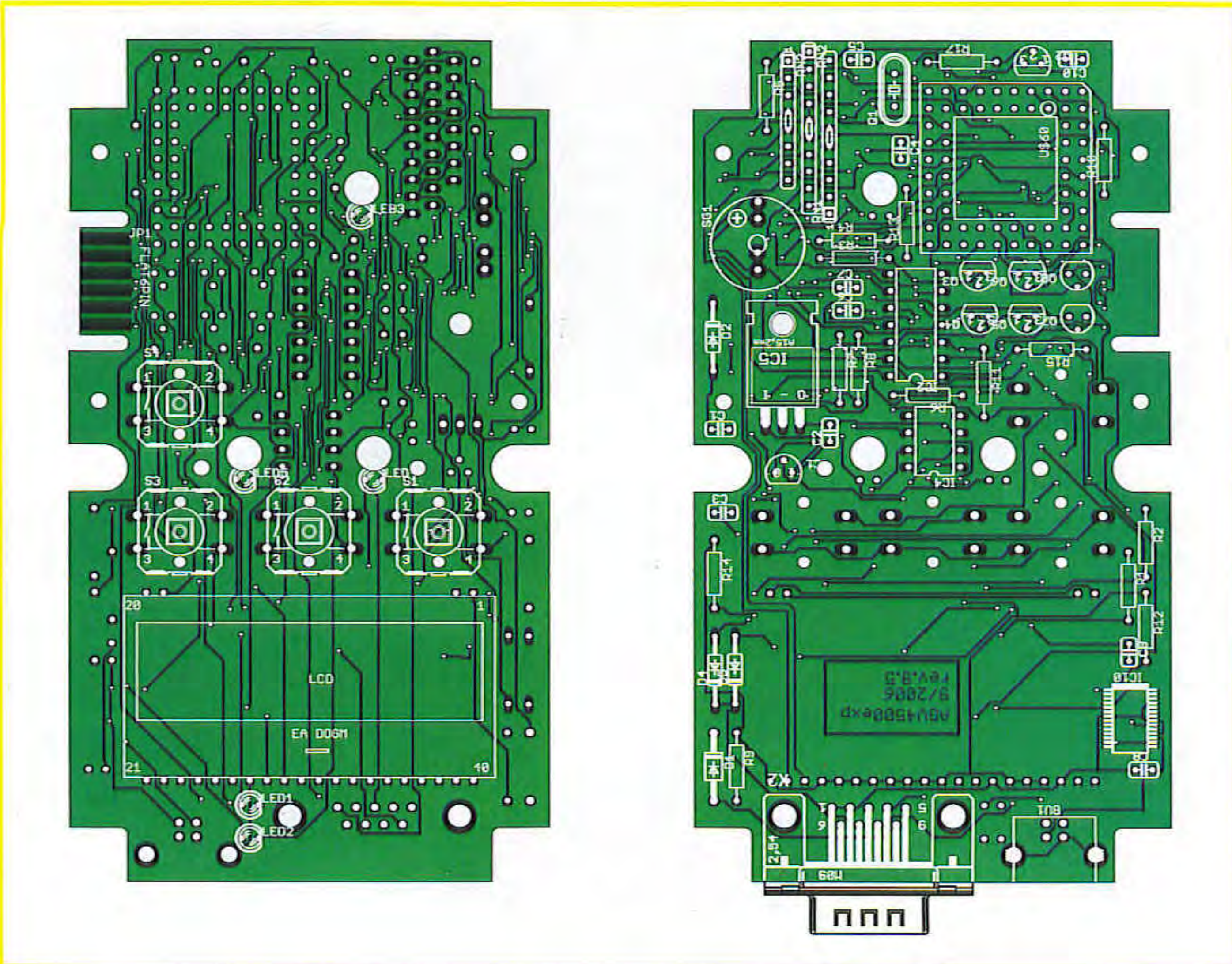



Figure 4. The PCB is an SMD-free zone.

## Putting all the bits together

Attention has been paid to the PCB layout (**Figure 4**); SMD components have not been used for this design to simplify component mounting. The PCB is produced to industry standard using FR4 type board with gold plating. Gold is chemically inert and gives the board almost unlimited shelf life. The plating also ensures that there should be no problems of corrosion which have been reported when lead-

## COMPONENTS LIST

### Resistors
RR1 = 1kΩ
R3,R4 = 100kΩ
R5,R9 = 33Ω
R6,R11 = 560Ω
R7,R8 = 100Ω
R12 = 1kΩ5
RN1,RN2 = 10kΩ SIL-10 array
RN3 = 6kΩ8 SIL-8 array

### Capacitors
C1,C2,C3,C10 = 100nF
C4,C5 = 22pF
C6,C7 = 470pF

### Semiconductors
D1 = 1N4004
D2,D4,D5 = 1N4148
IC1 = 78L08
IC2 = LM339N
IC3 = AT90CAN128 (Atmel; QIL case), programmed as "AGV4900" (Stange Distribution)
IC4 = PCA82C250 (Philips)
IC5 = 7805
LED1 = 3mm, red
LED2 = 3mm, green
Q3-Q6 = BS170 (TO92)
Q7,Q8 = BS250 (TO92)

### Miscellaneous
Q1 = 8MHz quartz crystal (HC49/S)
LC-Display 3x16 lines, type EA DOGM163E; with background light: EA LED55X31-A
S1,S3 = PCB mount pushbutton type 40-XX B3F (Omron) with matching aluminium cap
DC buzzer
X2 = 9-way sub-D plug (male), PCB mount
IC socket 14-way
IC socket 8-way
QIL socket (4 segments of 16 pins)
PCB
Case with front panel foil
Mounting materials

Note: Kit of parts no. 070038-71 contains all components, the case (with front panel foil fitted), mounting materials and OBD-2 cable, see Elektor SHOP advert or www.elektor-electronics.co.uk

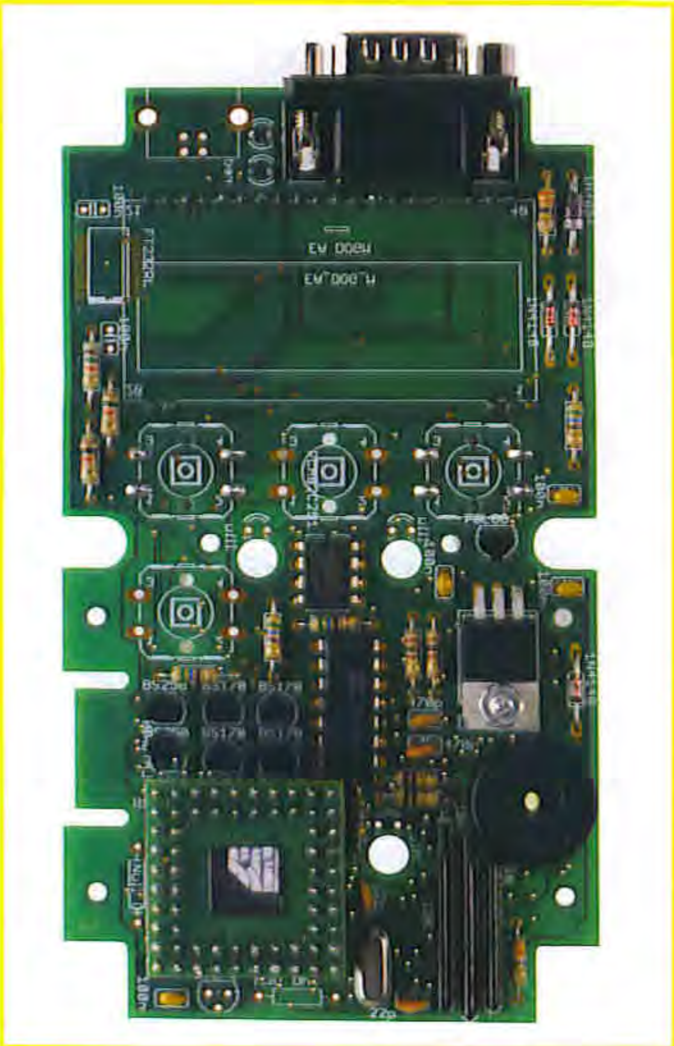


Figure 5. The PCB component side.

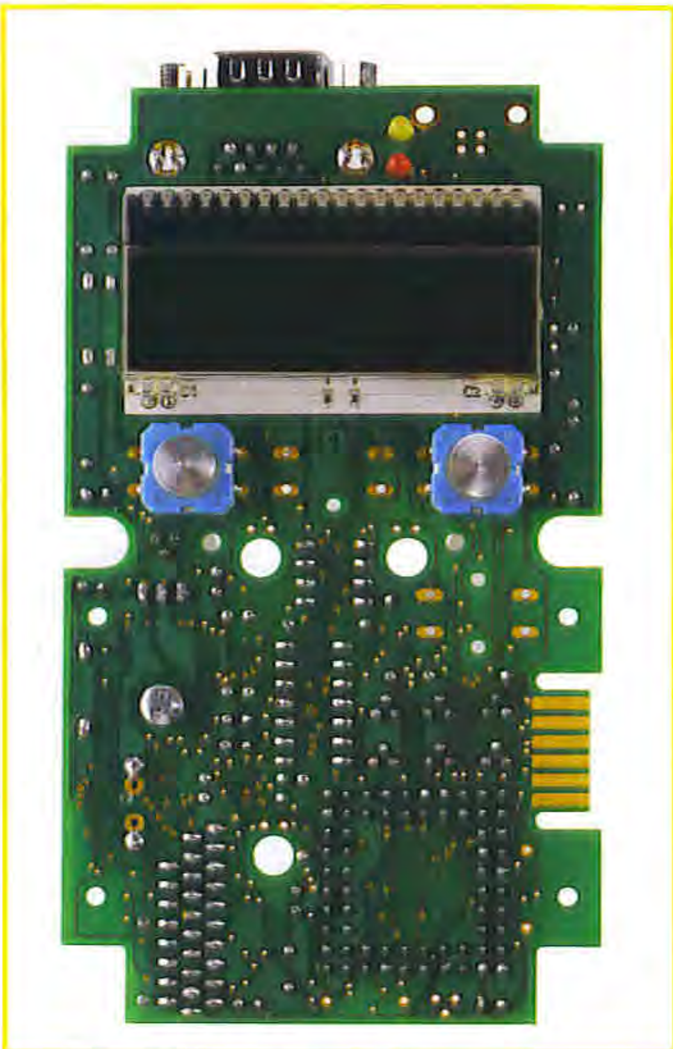


Figure 6. The two push buttons, LEDs and LCD are mounted on the other side of the PCB.

free solder is used on unplated boards. Gold has excellent tinning properties and allows the use of either lead-free or lead/tin solder. Apart from the need to take care with component placement and soldering, no special electronic skills or programming competence is needed to complete this project.

Except for the two LEDs 'connect' and 'data-traffic', the two pushbuttons and the LC display all other components are mounted on the PCB side printed with the component outlines and identification (**Figure 5**). Mounting the component starts with soldering each of the individual resistors into place followed by the diodes, capacitors, crystal, IC sockets, resistor networks (make sure they are the right way round), voltage regulator and then the transistors. The 7805 should first be mechanically secured before the leads are soldered in place. Once the buzzer and the sub-D connector are fitted the board can be flipped over and the pushbuttons, display and LEDs soldered into place.

The AT90CAN128 chip from Atmel used in this project is unfortunately only available in either the TQFP or MLF/QFN outline and neither of these are really suitable for a self-build project. The controller is therefore supplied (in MLF outline) already mounted on a small carrier board. It is only necessary to fit an intermediate pin/socket arrangement to connect the carrier board to the main PCB. The pin layout of this connector is the same as a QIL64 package (Quad in line, 64 Pins). All the components for this connector are included in the kit, to ensure success it will be necessary to follow the instructions carefully, a mistake here will be difficult to correct.

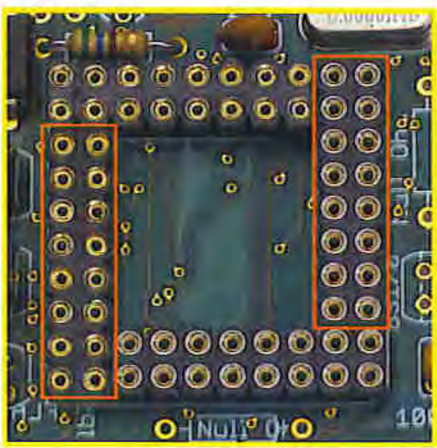


Figure 7. The controller board connector is made up of four sections.

The complete socket is made up of four strips (**Figure 7**) fitted to the main PCB, each strip is fixed in place initially by soldering just one pin of each of the strips, this allows the final layout of the complete socket to be easily adjusted until it exactly matches the layout.

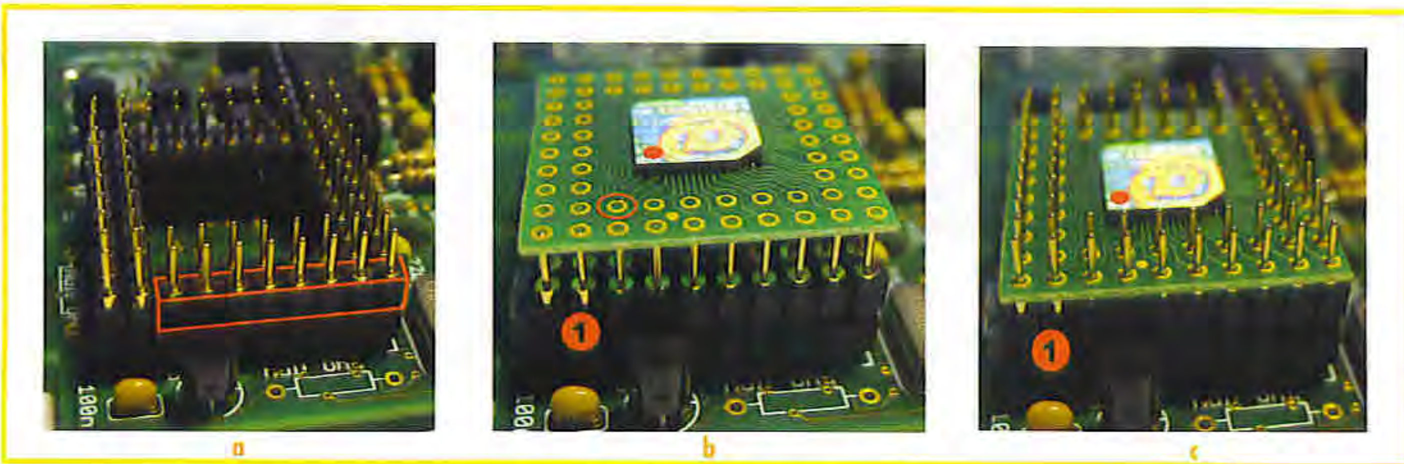



Figure 8. The three steps to mount the controller board.

Once you are sure that the four strips are accurately aligned (check that they are also all at the same height on the board) all the remaining pins can be carefully soldered to complete the socket.

The carrier board can now be fitted with the pins. The supplied pin strips must be carefully separated into 8-pin lengths. Any rough corners can be smoothed down with a fine file. The strips are pushed fully into the socket **Figure 8a** (They only fit one way round: the thinner tapered pins go into the socket).

The controller board can now be positioned onto the pins (**Figure 8b**) ensuring that pin 1 is correctly aligned (to the left by C10). The 64 pins can now be carefully soldered onto the controller board (**Figure 8c**).

Once all the components have been fitted a short test can be carried out by connecting a 12-V supply to the sub-D connector (pin 9 = +12 V, pin 1 or 2 = 0 V). The current drawn by the analyser should not exceed about 150 mA. The display backlight will be lit and the boot loader version number will appear on the display followed by the greeting message. The short self-test is now complete.

The finished PCB can now be mounted in the case: Fit the pushbutton caps and the sub-D cover, remove the protective film from the display and with the display facing downwards position the PCB into the front cover of the case. The small countersunk screws can now be carefully screwed in and tightened. Lastly, fit the remaining half of the case and the OBD-2-Analyser is now ready for action!

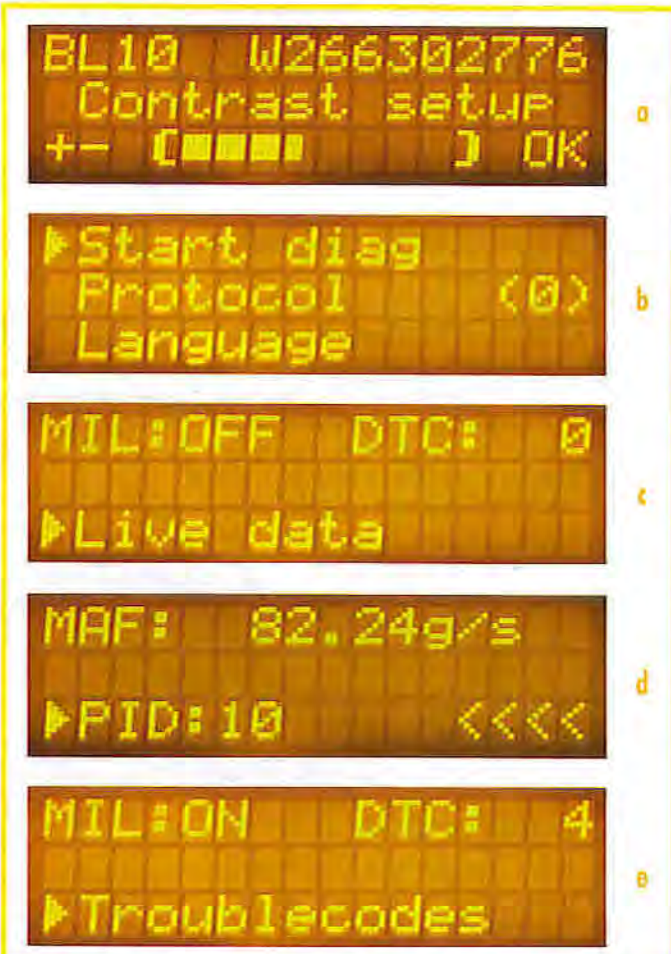



Figure 9. Displays: (a) Contrast setting, (b) Start menu, (c) Status display, (d) MIL/DTC PID Menu, (e) DTC trouble code number.

## Analyser operation

The first requirement before the OBD-2 analyser can be used is that the car is fitted with the corresponding OBD-2 connector (see the advice given in 'points to note' elsewhere in this article). If it is, the supplied OBD-2 cable is inserted into the OBD-2 connector in the car. The connector shouldn't be too difficult to locate, regulations insist that it must be mounted in the vehicle within 1 metre of the driver's seat. A concise operating manual for the analyser is available to download from www.elektor-electronics.co.uk. A shortform manual is also supplied in the kit of parts so we will not delve too deeply into the finer points here. An online simulator is also available on our website so you can familiarise yourself 'virtually' with the analyser operation.

At switch-on it is possible to alter the display contrast (**Figure 9a**). This is achieved by holding down keys A and B and plugging the analyser into the OBD-2 socket. The contrast changes each time key A is pressed. Once you are happy with the setting release key A and press B to store it. This basic method is used to control the analyser: Key A cycles you through the menu options while key B confirms a selection or provides a response from the equipment.

The display now shows the greeting 'ELEKTOR OBD2 1.4' with the start menu (**Figure 9b**) following shortly after-


Figure 10. Trouble code menu showing a description of the trouble in running text.


Figure 11. The Freeze frame menu (PID select).

wards with the options: *Start Diag*, *Protocol* and *Language*. When the analyser is regularly used on the same vehicle and you are sure of the correct protocol then it can be selected otherwise option code 0 tells the analyser to automatically find the correct protocol. A press on key B begins the scan (if the vehicle interface is not compatible with OBD protocol the test ends with a failure message). When the scan has run the display will show the state of the MIL/DTC indicating if any troubles were present (**Figure 9c**). Selecting the option *Live Data* with button B will show the actual value of a parameter. The chassis number or *vehicle ID* can be read and the communication *Protocol* displayed as well as the option to rescan.

The current reading of a sensor (*live data*) is given in the PID (parameter identifier) menu. The example shown in **Figure 9d** is a reading of the intake Mass Air Flow (MAF in g/s). Pressing key B takes you back to the previous menu. When a failure has been detected by the engine management system the analyser will indicate that the MIL is on (*MIL:ON*), and the number of stored DTCs (Diagnostic Trouble Code) is given (**Figure 9e**) .There is now a choice between displaying the *trouble codes* or *freeze frame* data. For trouble codes the code number is displayed along with (in most cases) a detailed description of the fault (see **Figure 10**).

When the trouble codes are displayed, pressing key A brings up an option to clear the codes from the vehicle's memory.

More information about the failure can be gleaned by selecting Freeze Frame. When an error is detected by the engine management system the on board computer will take a snapshot or freeze frame of all sensor readings and store them in the vehicle's memory. A check of this data can provide a valuable insight into the cause of the failure. In selecting freeze frame trouble codes it is possible to select successive sensor values stored around the time that the failure occurred.


The example in **Figure 11** indicates a sensor reading when trouble was logged; trouble F000 a PID 0D (speed) of VSS = 33 km/h measured. Button A takes you through successive parameters while button B returns to the previous menu.

The downloadable user's manual contains overviews of all the menu options, selections and display messages. When you want to get more familiar with its operation, try the online simulator mentioned earlier, or better still put your order in and build your own OBD-2 Analyser! An extra file containing soldering and assembly hints can also be downloaded from the *Elektor Electronics* website.

(070038-I)

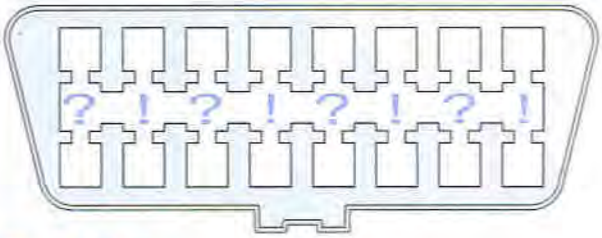
### Literature

[1] Datasheet for the AGV4900-Controller: www.obd-diag.de

[2] Source of the AGV microcontroller: www.stange-distribution.de

[3] http://www.blafusel.de/misc/OBD-2_scanned.php

# OBD between Ecology, Marketplace and Big Brother




Dr. Thomas Scherer

**OBD — the On Board Diagnostic for vehicles — was originally conceived as a system to reduce exhaust emissions and produce better air quality. Since its introduction, the ecological aspect of the diagnostic system has taken something of a back seat. These days the OBD is a key element in vehicle servicing for all garages. It has also become something of a marketing tool in the competition between dealership garages and independent garages. Information gleaned from the OBD connector can also be of interest to the manufacturer's sales department. When the next generation OBD-3 system is introduced, it may be able to pass vehicle information over a radio link to a roadside monitor as we drive by, and the politicians will convince us the system is in our best interests to improve air quality...**

Back in 1930 the state of California had just six million inhabitants and an astonishing (at that time) two million cars. Ten years later almost every adult male Californian owned a car. In 1943 the city of Los Angeles suffered from choking smog (see video [1]). Exhaust gases were not thought to be the prime suspect at the time. In 1947 a national programme to monitor air quality across America was instigated. A milestone in environmental politics was reached in 1960 when research began into the effects on the atmosphere of exhaust gases. The link had been proven and in 1967 the Californian Air Resources Board (CARB) was setup with the remit to improve air quality. In 1971 CARB introduced a nitrogen oxide (NOx) emission limit on cars sold in the state and in 1976 reduced the lead content of petrol. In the same year Volvo became the first car manufacturer (**Figure 1**) to produce a vehicle with an electronically controlled three-way catalytic converter and lambda probe. This was not just an ecological and environmental breakthrough but also marked the beginning of electronic engine management in mass produced vehicles. By 1984 in California legislation was in place for all cars sold to be fitted with a system which monitored the exhaust gases and warned the driver when the limits had been exceeded. Already by 1982 work was in progress to standardise an on-board diagnostic system which could measure exhaust emissions. By 1988 all car makers endorsed this standard and OBD-1 was born.

**Figure 1.**
**The daddy of them all: A 1977 Volvo 240 – The first volume car model to be fitted with an electronically controlled three-way catalytic converter.**


**Figure 2.** An OBD-Analyser. The Bosch KTS 115 is a handheld device similar to the stand-alone OBD analyser feature in this magazine.

California was the pioneer in exhaust emission regulation and here in Europe manufacturers were obliged to fit catalytic converters to cars sold in America but they were not available for the home market. Manufacturers were reluctant to fit them as standard because of the increased production costs. Effective lobbying by environmental groups across Europe has however succeeded in turning the situation around. Particle filters for diesel engines are also not yet obligatory, Peugeot have developed a highly stable and effective filter system that could have been fitted as standard to their vehicles since 2000 but so far it has only been offered as an extra. Diesel powered cars represent around 50 % of new car sales in some parts of the EU. The next generation of standards for cars ('Euro 5') have issued a directive which limits the emission of Particulate Matter (PM) to 5 mg of per kilometre which means that all new diesel engines manufactured from 2009 will need to be fitted with a particulate filter. The directive is less than six months old.

## OBD-2 and EOBD

The original standard was relatively crude. It only monitored the oxygen sensor (the lambda probe), a possible emission recycler, fuel system and provided motor control based on the level of emissions. A flashing dashboard mounted lamp or MIL (**M**alfunction **I**ndicator **L**ight) was fitted and any detected errors were stored in a memory which could be examined via a serial interface by garage technicians during the next service.

Unfortunately the regulations were not specific enough so that each car maker came up with their own version of the interface. This caused havoc for many small independent garages who found it necessary to purchase third party OBD readers and adapters to allow them to carry out servicing on different makes of car. Even with these tools some manufacturers imposed restrictions so that not all the data could be read by a third party.

The weakness of the OBD-1 specification led to the OBD-2 standard which was released by CARB in 1994 and became mandatory for all vehicles sold in the state of California. Two years later it applied to all cars sold in America. EOBD is the European variant of OBD-2 and is essentially the same as the American model. This standardisation has a number of benefits to the manufactures by lowering production costs and also for independent garages by standardising test equipment. The wheels of EU bureaucracy grind exceedingly slowly so it was not until five years after the American regulations had been imposed that EOBD finally became mandatory for petrol engined cars sold in Europe in 2001 and then 2004 for diesel engined vehicles.

Vehicles fitted with the 16-pin EOBD diagnostic connector can not only pass sensor information as described in the standards document but also manufacturer specific information. OBD-2 and EOBD have far more sensor data, parameters and failure conditions than before. Many DTCs (**D**iagnostic **T**rouble **C**odes) and protocols are standardised. Worn out catalytic converters can also be detected along with other failure conditions brought about by general wear and tear.

## Whose data is it anyway?

Apart from producing cleaner exhaust gases other aspects of the diagnostic system have become apparent. The car makers are installing ever more complex systems which can store far more information than the standard OBD-2 interface requirements. Smaller independent workshops do not have the resources or access to special manufacturer-specific diagnostic tools to read all the information stored in the vehicles management system. Buyers are persuaded that only dealership garages can offer a full service. For this reason it is essential and indeed intended to maintain a certain degree of interface standardisation so that independent garages are freely able to use the diagnostic information stored on board. Without this many independent garages would no longer be able to carry out vehicle servicing let alone fault tracing or repairs.

The outcome would be that independent garages would eventually disappear and the customer would be left with little alternative but to use a dealership garage. Not a free market but a monopoly controlled by the car makers, without competition prices would inevitable rise. On the other side of the coin manufacturers are anxious that certain information for example about their engine control techniques [2] [3] should be protected from their competitors' prying eyes. They have invested heavily in vehicle development and the future of their company depends to some extent on how well they protect their investment. The line between protected manufacturer specific data and open data which can be used for vehicle servicing is not so easy to draw and goes beyond the current EOBD standard.

Does anyone ever ask what happens to all the information that is downloaded from their car when it goes in for

**Few people question what car manufactures do with all the data they download from a car when it goes in for a service.**

a service? It would seem to make sense as long as the information was made anonymous for the vehicle manufacturer to use it to identify any trends that may indicate a weakness in the design of a particular model or engine. Surely we would all benefit if cars were designed to be more reliable? What would you say as the owner of a standard Ford Focus if the Ford dealership started sending you sales brochures about the new sports Focus ST? you probably wouldn't give it a second thought but what if you have been specifically targeted by the sales department because the last time you took your car in for a service it was 'noticed' from the diagnostic data that you tend to be a little heavy footed in the accelerator department? Would this be a harmless use of the data? How about if you have a major mechanical failure just after the vehicles warranty expires and before you can even begin pleading your case to the garage manager, a mechanic connects to the EOBD and announces that the breakdown was not surprising considering the way you drive!
These examples are of course entirely hypothetical but not outside the realms of possibility, the technology is available and so is the data, the modern EOBD system is no longer just an air purifier but also a Vehicle Data Recorder...

## What does OBD-3 have to offer?

As technology becomes more and more sophisticated the question of how we can protect our right to privacy becomes ever more difficult to answer. No sooner had OBD-2 been successfully adopted than work begun on its successor OBD-3. In the meantime technological progress has made it possible to incorporate much more powerful and complex systems which would not have been feasible ten years ago. The initial indications are that OBD-3 will not just be an improved OBD-2 with faster processors and more memory capacity. The whole concept is undergoing a radical rethink. It is anticipated that the systems will be implemented throughout the world so the final proposal will be the result of the input from many interested parties and committees, needless to say the whole procedure will not be swift.
Some of the suggestions that have been mooted sound a little implausible if not laughable and are probably the result of feasibility studies rather than a considered design approach. It has been suggested for example that the number of vehicle sensors will be increased to measure such mundane things as the vehicle doors so that the next time the car is serviced the mechanic will be able to inform you that "the drivers door has been opened 623 times in the last year and the passenger door only 346 times, the hinges on the drivers door will need to be greased during the service, do you want us to do the passenger door as well?"
Much less bizarre is the suggestion (which many car manufacturers are currently working on) that the on-board OBD connector will be replaced by a radio link. In much the dame way as the RFID system is designed, each vehicle would have its own unique identity. One mode of operation would be used principally during servicing where large amounts of stored parameters would be analysed by the car mechanic to optimise the car's performance and change settings. Another mode could transfer a limited amount of information in a very short burst. When, for example the car is driven past a roadside monitoring system. This possibility of monitoring individual vehicles in a continuous traffic flow suggests a number of interesting applications; it would be possible to log each vehicles chassis number along with its instantaneous exhaust emission parameter and feed the information into a central computer where it can be evaluated. The owner of any vehicle over the emission limit may then be issued with a fine or advised to get the vehicle serviced in the next few days. Looking at the system in a slightly more sinister light we would now have the infrastructure in place and the information available to be able to track the movement of every vehicle... Big Brother would be proud of us.
The impact of 9/11 in 2001 has made the world a less secure place. Improved security is usually the reason given whenever steps are taken to increase the level of public surveillance but in this case it would be under the guise of 'efficient emission monitoring'. The probability that air quality will be significantly improved with a continuous level of surveillance compared to the current yearly MOT emission test is quite low. The first rule of criminal investigations when searching for a motive is *'cui bono'* (who benefits?) and it may be applicable to the deployment of an expensive nationwide monitoring infrastructure which eventually may have a more profound impact on our civil liberty than just the innocent ecological aim of monitoring exhaust emissions.

(070246-1)


[1] www.arb.ca.gov/videos/clskies.htm

[2] Chip Tuning, Elektor Electronics July/August 2005, p. 24 ff.

[3] Warp speed on demand, Elektor Electronics January 2007, p. 62 ff.

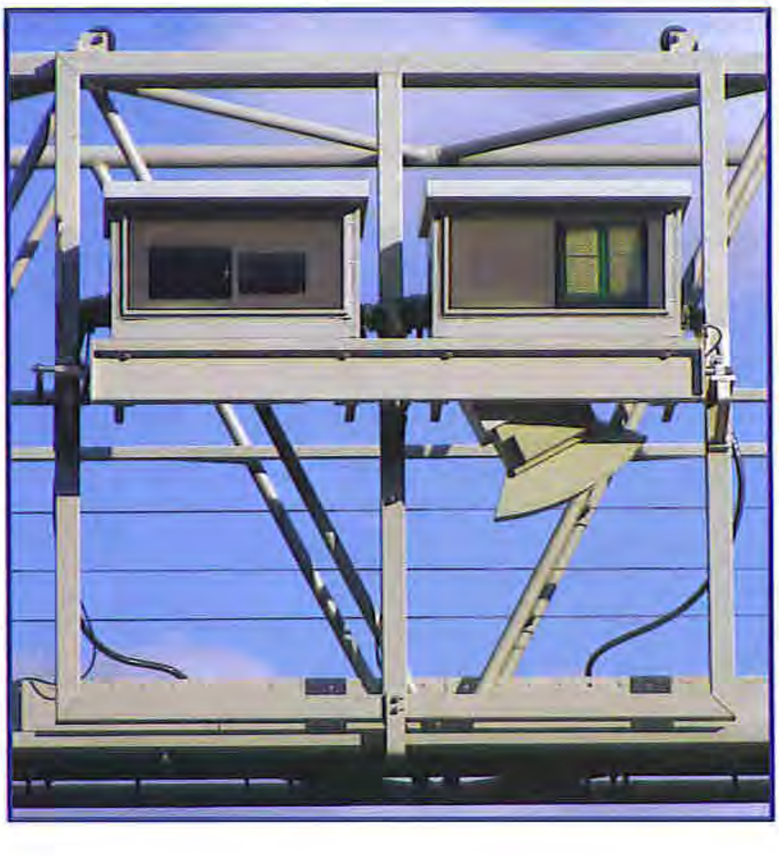



**Figure 3.**
**Big Brother's little helpers: cameras on gantries over German autobahns being introduced to log vehicle movements. Similar systems are being trialled in the UK. photo: Stefan Kühn (www.webkuehn.de).**