On-board OBD-2 Analyser

Car diagnostics on LCD

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Onboard OBD-2

Florian Schäffer

You can use the OBD-2 / EOBD diagnostic connector required in all recent cars to read out a lot of interesting data if you have a suitable interface adapter and a notebook computer. An even more practical solution is to use the stand-alone analyser described here, which can be used as a hand-held unit or fitted in your car. Diagnostic data is evaluated using an ATmega16 and shown on an LCD with four rows of 20 characters. Up to eight parameters can be constantly shown on the display while you're driving. Having this information at your fingertips can be especially handy if you have car trouble.

It seemed like an obvious idea: why not use the OBD-2 analyser described in the 2005 Summer Circuits issue more than just twice a year? After all, the car's OBD-2 interface provides interesting data all the time while the vehicle is underway, although using a notebook computer as a display while travelling is rather impractical. Just as with navigation systems, the only suitable approach is to use a portable display or a built-in display with convenient dimensions.

No sooner said than done. Fortunately, the OBD data is not so complex that the processing power of a PC is actually necessary to handle it. A microcontroller with a serial port is perfectly adequate, and an easy-to-read alphanumeric LCD is a lot more suitable than a cumbersome notebook screen for displaying the data in a car.

The microcontroller hardware consists of the Mini Mega Board described in another article in this issue. It is fitted with an Atmel ATmega16 microcontroller, which fetches the data from the OBD-2 analyser via a serial interface, analyses the data, and presents it on the LC display. The board already has all the components necessary for this application, except a pushbutton switch on PA0 for configuring the display parameters.

As the available readings vary from one vehicle to the next, the display should be freely configurable so the digital cockpit can be adapted to every vehicle that can supply data to the OBD-2 Analyser. To find out which vehicles fall in that category, you can consult the *Elektor Electronics* forum or the database referenced in the link list at the end of this article. Thanks to this configurability, each user can personally decide which of the available readings should be displayed and whether to display the readings in short form or long form.

Combo

As the OBD-2 Analyser and the Mini ATMega Board (**Figure 1**) both have a full-fledged serial interface, it's easy to establish a communication link between the two boards. With regard to mechanical mating of the two boards to form a stand-alone analyser, refer to the capsule instructions listed in the 'Step by Step' inset.

The boards can be powered from the OBD-II connector. However, the supply voltage on that connector is unswitched, so it's worth having a look at the fuse box to see whether a

Analyser

Car diagnostics on the go

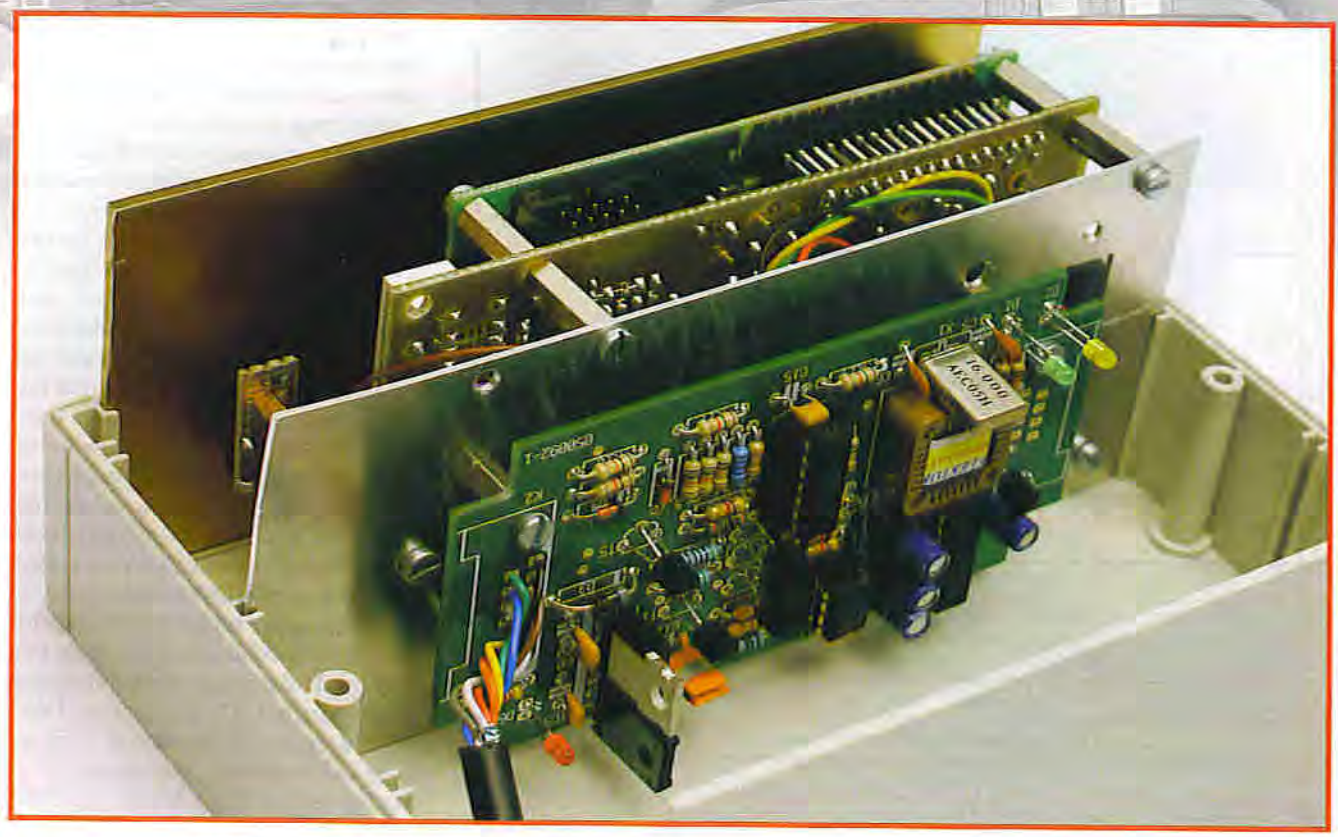


Figure 1. OBD-2 Analyser board and ATmega board after assembly.

'switched ignition plus' terminal is available so the boards will only be powered when the ignition switch is on. That's more practical than pulling the OBD plug or using an additional switch.

One problem that cannot be ignored for in-car used is the large temperature range. Many inexpensive LCD modules are not designed for the freezing temperatures that can occur in cars in the winter. Freezing of the liquid crystal medium can cause permanent damage. Most modules are more tolerant with regard to the upper end of the temperature range. The module shown in components list for the Mini Mega Board has an operating temperature range of –20 °C to +70 °C, and it can withstand temperatures as low as –30 °C without damage when not operating. However, the maximum allowable current for the LED backlight is reduced at temperatures above +25 °C.

What do you want to see?

Information about the ignition timing advance or exact intake air volume is probably not as interesting in normal driving situations as the engine speed (rpm) or vehicle speed, to mention two examples. It's commonly known that standard speedometers read slightly high despite using electronic drive, with the deviation being as much as 10 km/h depending on the speed. Interestingly enough, a significantly more accurate value is output by the OBD system. Comparative measurements using a stopwatch and a GPS receiver showed that the OBD-II system provides a very accurate indication of the true speed, and the OBD-controlled digital cockpit display provides an accurate reading over the entire speed range. Of course, if you rely on that reading you will lose the 'margin of safety' that has probably saved you from being caught in a radar trap several times already. If you don't already have a tachometer, or if you mistrust the one fitted in your car, you can also obtain reliable rpm data from the OBD-II system.

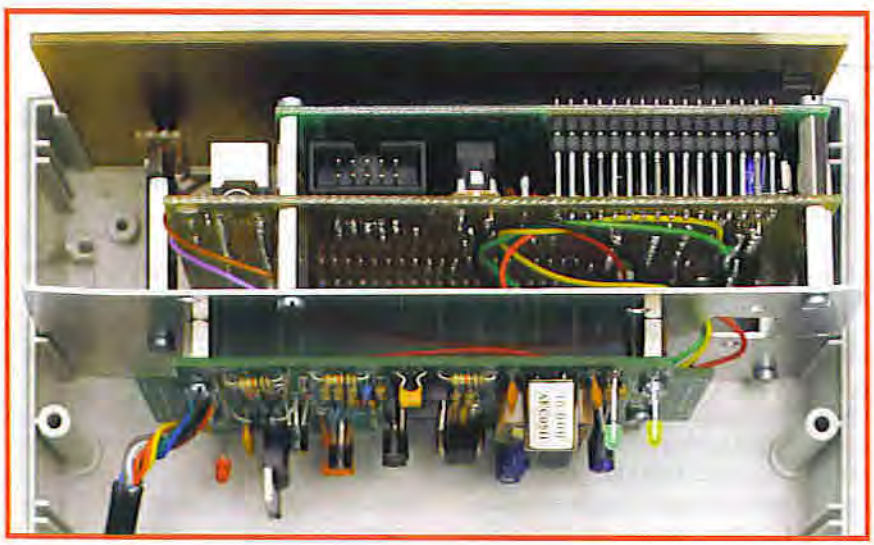
The exact coolant temperature is another thing that is doubtless interesting. Unfortunately, there's no uniform specification for the OBD-II interface with regard to outputting the water temperature or the oil temperature. The oil temperature is more commonly output with diesel vehicles than with petrol vehicles, which usually output the water temperature. You can figure out where the sensor is fitted by

Figure 2. Prototype of the stand-alone OBD analyser.

Table 1. OBD-2 Analyser response to a request to provide the PIDs available in the vehicle.

Byte	Meaning
06	Reply ID
02	Mode 2 response (report readings)
0A	Number of following bytes (10)
48	Protocol information
6B	Protocol information
10	ECU address
41	40 + requested service (1)
00	Requested PID (0)
98	First data byte (MSB)
3F	Second data byte
80	Third data byte
11	Fourth data byte (LSB)
6C	Checksum

Figure 3. Assembly of the boards shown in our prototype.



observing the time behaviour of the temperature reading provided by the OBD system. If the temperature increases linearly after a cold start, it represents the coolant temperature. If instead the indicated value does not increase until the engine has been running for a while, and then increases rapidly to around 90 °C, it comes from an oil-temperature sensor. The oil temperature is important with regard to the load capacity of the engine, and it takes a lot longer to return to the 'green' zone than the water temperature. That means an oil temperature display can certainly help extend the service life of your engine.

Software

The software for the microcontroller on the Mini Mega Board is available on the *Elektor Electronics* website in the downloads for this article in the form of a ready-to-use hex file, which you only have to download into flash memory. The program has been compiled for an ATmega16 with an external 8-MHz crystal. The software was tested with chip version 2600 of the mOByDiC microcontroller in the OBD analyser. However, future versions shouldn't cause any changes in communications between the OBD analyser and the Mini Mega Board, so we don't anticipate any problems. If necessary, information about any relevant changes will be provided in the *Elektor Electronics* website forum and the Mailbox or Corrections & Updates section of the magazine.

For readers who not only want to build and use the stand-alone analyser, but also want to know how the software works, here's a brief explanation. Simple commands can be used to request the microcontroller of the OBD-2 Analyser to establish a connection to the vehicle and supply data blocks. These commands are described in the data sheet for the mOByDiC microcontroller. The communication process essentially consists of exchanging request and response bytes. The commands are very similar to those for the well-known ELM OBD ICs, so a glance at the (significantly more informative) data sheets for those devices can be helpful.

If you want to find out which data is supported by a particular vehicle, you should request the parameter identifiers (PIDs) by sending the byte string 02 01 00 (hexadecimal values). That particular series of bytes means that

you want to read data (02), you are working in Mode 1 (request readings), and you want to read out PID0. In response, you will receive (among other things) four data bytes for the first 32 supported PIDs. Many vehicles can also supply additional parameters, but they are not supported by the display unit in its present form.

After this, you can send the byte sequence 02 01 followed by a PID number to request the data block for the corresponding PID. The response will be something resembling what is shown in **Table 1**. The checksum calculation is quite simple: the byte values starting with the third byte onward are added, and the sum is then ANDed with FF to eliminate everything except the two least-significant hex digits.

The meanings of the individual bytes and the calculations necessary to generate the displayed readings are described for all the supported protocols in the ISO 15031-5 standard and its US counterpart SAE J1979. However, if you're not willing to spend £ 100 or so for your own copy, you can obtain more information from the well-known www.obd-2.de website, which is run by the author of the first OBD article in *Elektor Electronics* (October 2002).

Display configuration

The readings shown on the display depend on two factors. The first factor is which PIDs are available from vehicle in question, and the second factor is which of the available readings the user selects for the display configuration.

When the stand-alone analyser is switched on, it automatically determines which PIDs are supported by the vehicle and stores them in the EEPROM of the ATMega. If the analyser is connected to a different vehicle, it will automatically recognise any change in the available PIDs. In both cases, the unit will ask you to configure the display for the readings you want to have displayed (**Figure 4**). You can also enter the configuration mode whenever you wish by pressing and holding the PA0 button.

The display can show up to eight readings in short form (**Figure 5**) or four readings in long form (**Figure 6**). For each line, you can select either one reading in long form or two readings in short form. A blinking cursor indicates the position that is currently being

Step by Step

1. Before you start, you have to consider where and how you want to fit the two boards. One option is to fit them into an enclosure, as we did for the prototype shown in the photos. However, you might be able to find a suitable place for them in the car (measure carefully!), so all you need is a frame or front panel to cover the boards. In that regard, you should bear in mind that the OBD cable is relatively thick, and for cosmetic reasons it should probably be concealed from sight.

Figure 2 shows the construction of our prototype unit. The enclosure has a transparent acrylic sheet as a front panel. We painted it on the inside using spray paint. The opening for the display was masked off before painting. That's an easy way to produce a perfect display window without drilling, sawing or routing.

2. The two boards are joined together using a mounting plate (aluminium sheet or piece of circuit board). The mounting plate is located between the two boards. The Mini ATMega Board is placed at the front , and the OBD analyser board is placed at the rear. The mounting plate fits into the guide slots in the enclosure. With the enclosure we used for the prototype, 15-mm and 10-mm standoffs produced exactly the right spacing for the board assembly.

As an alternative, the OBD-2 Analyser board could be fitted horizontally in the enclosure. However, the vertical arrangement we used for the prototype has the advantage that it is easier to connect the OBD cable. If you use a straight D-sub connector for K2 instead of an angle connector, the cable can be plugged in directly. Of course, you can also omit K2 and solder the OBD-II cable directly to the board. In that case, you will have to cut off the D-sub connector at the end of the OBD-II cable, but you may have to do that anyhow if the OBD cable is not long enough. If the OBD vehicle connector is located somewhere other than near the steering wheel, such as under the seat, the cable will usually be too short. Then it's a good idea to use a different cable of sufficient length and fit the OBD-II plug at one end. The other end can be fitted with a 9-way D-sub connector or soldered directly to the OBD analyser board.

3. Only four connections are necessary between the two boards. Pins 2, 3 and 5 (ground) of K1 on the OBD-2 Analyser board must be connected to the same pins of K4 on the ATmega board. You should use stranded wire for this instead of solid wire to avoid a risk of breakage. The fourth connection is required to route the +12-V supply voltage to the ATmega board. If you omit K4 (power supply connector) on the ATmega board, you will have a connection point for +12 V that is connected to the anode of D2 via a circuit board track. On the OBD-2 board, +12 V is present at the anode of D3. You can thus connect the anode of D3 on the OBD board to the anode of D2 on the ATmega board.

Connect the display configuration pushbutton switch between PA0 (microcontroller pin 40) and +5 V.

Figure 4. Display contents after switch-on in the car.

Figure 5. Display screen showing four readings.

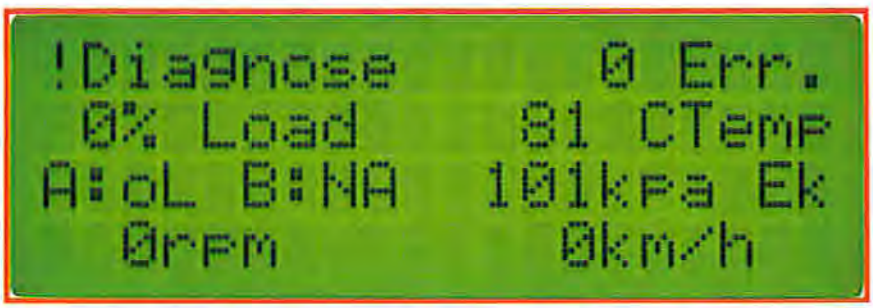


Figure 6. Up to eight readings can be displayed simultaneously.

Important Tips

- If the existing OBD-2 cable is too short and you cannot find nine-conductor screened cable to make a replacement cable, 8-conductor network cable (CAT5, preferably screened) is a readily available alternative. The missing ninth conductor (with respect to the OBD cable) is actually unnecessary, because you can use a single ground connection instead of two connections. Refer to the construction instructions for the OBD-2 Analyser in the July/August 2005 issue of Elektor Electronics for cable wiring details.
- If you already fitted the 9-way D-sub connector (K1) on the OBD analyser board, that doesn't have to present a problem for joining it to the ATmega board. Simply leave the connector in place and solder the three leads to the bottom of the ATmega board.
- If you already fitted the 9-way D-sub socket (K2) on the OBD analyser board, you shouldn't try to unsolder it intact, because the through-hole plating will usually not survive such an exercise. A better solution is to cut off the pins and then unsolder the pin remnants individually (hold the pin with pliers, heat the solder joint until the solder melts, and them pull the pin out).
- There is a new version of the OBD-2 software. Information about possible upgrades will be published on www.elektor-electronics.co.uk as soon as the details are known.

configured. If the cursor is at the start of a line, you can select the long form or the short form for displaying a reading. Pressing the button causes the next available reading or next display option to be shown. The display position is blanked after you have cycled through all the available PIDs, and pressing the button again causes the first reading option (protocol and available PIDs in hexadecimal notation) to be displayed. If you leave the button

What's in a car?

The question about which parameters you can read out from your car is best answered by your car. You can be sure of the answer after reading out the supported PIDs via the OBD-2 connector. After that, you can read out measured values for the PIDs supported by the ECU. Consult the author's website

www.blafusel.de/misc/obd2_pid.php

for specific information about he PIDs.

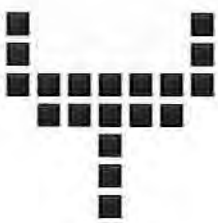
That website also provides another brilliantly simple feature: type the PID code read out by the stand-alone analyser into the search field to view full list of the supported functions. For example, the meaning of PID 983F8011 is shown in the following table.

PID	Sensor
1	System tests status
4	Calculated load value
5	Engine coolant temp
11	Intake manifold pressure
12	Engine RPM
13	Vehicle speed
14	Ignition timing advance
15	Air intake temperature
16	Air flow rate from MAF
17	Absolute throttle position
28	OBD standard
32	More PIDs

unpressed for a couple of seconds, the cursor will jump to the next display position. If you previously selected a long-form display, it will jump directly to the next line.
The configuration session is ended when the last available position has been configured. Only short-form outputs can be configured in the second half of each line.

Functions

As the stand-alone analyser is designed to be used as a digital add-on instrument for cars, its trouble diagnosis capabilities are limited. Storing text descriptions of trouble codes would vastly exceed the memory capacity of the ATmega16. Consequently, you will still have to use a laptop computer with diagnostic software to read and clear trouble codes.
PID 2 is also not supported. That PID indicates which trouble codes caused trouble data to be stored in the engine control unit. However, the ATmega software does recognise any trouble indications that may occur if they can be read out in Mode 7. That actually includes all continually monitored systems. However, the fact that no trouble is indicated does not necessarily mean that no trouble codes have been stored. The actual trouble codes must be read using other OBD service modes, depending on the manufacturer.
The blinking spanner symbol



alternating with an inverted exclamation mark and 'Diagnosis' on the display indicates that a trouble code has been detected. You can then use the diagnostic software on your laptop to read out the trouble code and clear the trouble memory.
Of course, it's also possible to configure the unit to display PID1. If PID1 is supported by the engine control unit, it contains the number of pending exhaust-related trouble codes that caused the engine-trouble warning symbol (MIL, or 'malfunction indicator lamp') to be illuminated in the vehicle cockpit.

Construction information for autonomous analyser

Component population changes to ATmega board:
Not required: R1, K4, K6, S1, D1, JP1, JP3 and JP4 (do not fit), JP2 = wire link

Additionally required:
S3 = pushbutton (1 make contact) between PA0 and +5 V
Case, e.g. Bopla Unimas U160, size 160/133/75 mm
Programmed ATmega Controller, order code 050176-42 (HEX file contained in free download **050176-81.zip** from www.elektor-electronics.co.uk)
Configuration bits for ATmega: All bits unprogrammed ('1') except BOOTSZ0, BOOTSZ1, BODEN and SUT1.

Component population changes to OBD-2 Analyser board:
Do not fit K1; use straight pins version for K2, or do not mount it.

For kits and parts for this project,
see Elektor SHOP pages or www.elektor-electronics.co.uk

DIY ideas

A microcontroller system (such as the Mini Mega Board) connected to an OBD-2 Analyser naturally lends itself to a wide variety of further applications, including DIY projects. For instance, you could develop a data logging function using a standard SD memory card so the data could subsequently be read out and analysed on your home PC. If you add GPS data storage to that, you have a true digital 'black box' in your car, which might be too much of a good thing in terms of monitoring.

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Links

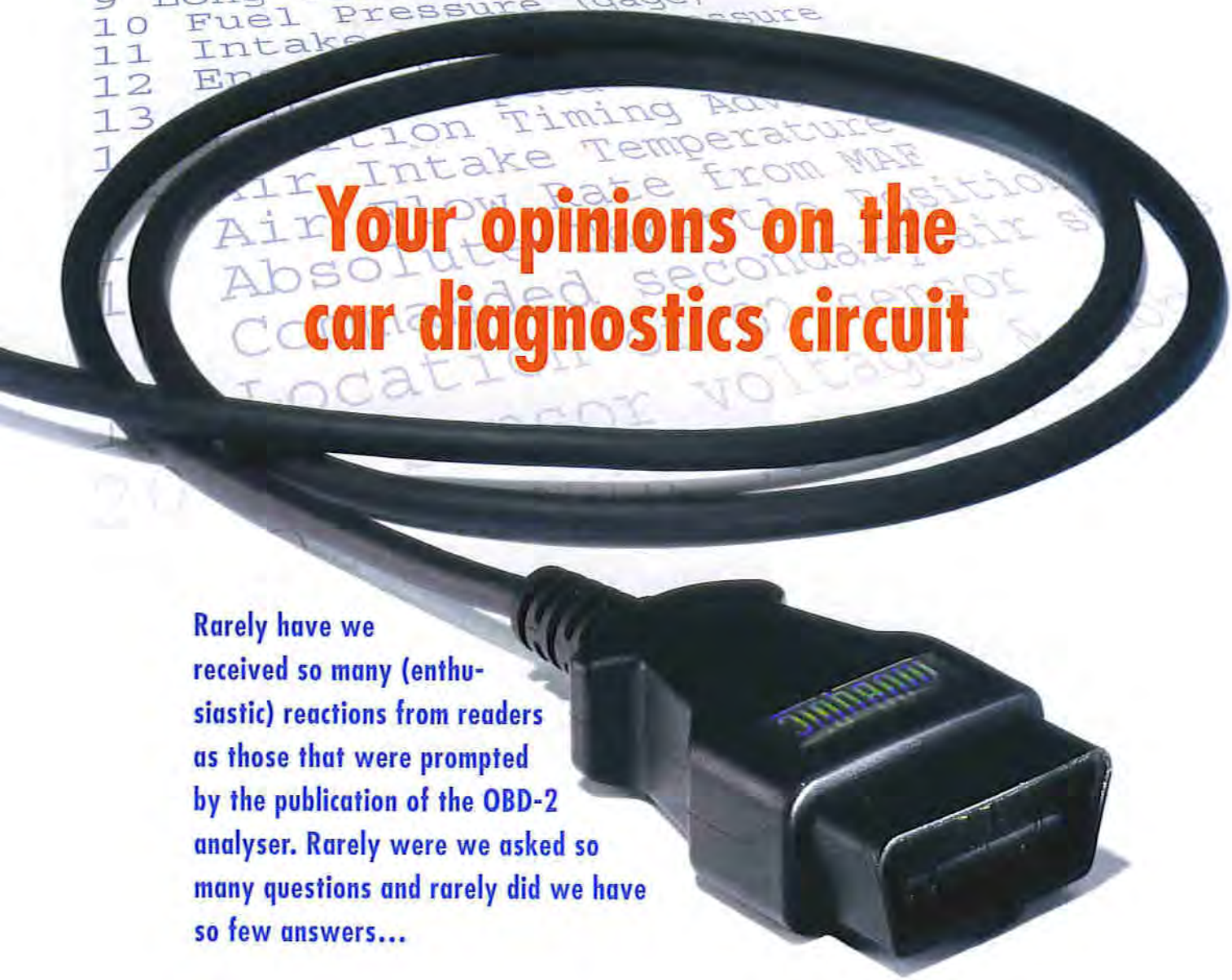
www.elektor-electronics.co.uk (OBD forum)
www.blafusel.de/misc/obd2_scanned.php (vehicle list; the Elektor Electronics OBD-2 Analyser is shown there as 'mOByDic interface')
www.ozenelektronik.com/upload/data/oe/moby2600.pdf (mOByDiC 2600 data sheet)
www.blafusel.de/misc/obd2_pid.php (PID calculation)
www.obd-2.de/tech_prog.html (Gerhard Müller's reading calculations for individual PIDs)
www.iso.org (ISO – International Organization for Standardization)
www.sae.org (SAE – Society of Automotive Engineers)

An ATmega by any other name...

As mentioned in the article, the Mini ATMega Board can be fitted with the ATmega16 (which has 16 KB of program memory) or the ATmega32 (which has 32 KB). The only difference between the two microcontrollers thus appears to be the size of the flash memory. At least, that's what we thought when we loaded code compiled for an ATmega16 into an ATmega32. When nothing at all worked and we were at our wit's end trying to figure out why, an attentive colleague pointed out that we had the wrong type of microcontroller. Now you know, so you don't have to try it for yourself.

OBD-2 in Elek

Your opinions on the car diagnostics circuit



Rarely have we received so many (enthusiastic) reactions from readers as those that were prompted by the publication of the OBD-2 analyser. Rarely were we asked so many questions and rarely did we have so few answers...

Karel Walraven

In the Double Summer Issue (the July/August issue) of 2005 we published an article concerning a DIY car analyser device, the OBD-2 Analyser.

With the aid of this circuit and a (laptop) computer it is possible to read information from your car such as temperature, speed, engine rev speed and instantaneous power. In addition, the screen also shows fault codes as soon as something goes wrong with your precious possession, so that you're no longer completely dependent on your mechanic.

Thousands of readers have built this circuit and it was unavoidable that we at the editorial offices were going to be inundated with questions. The most common question was obviously: I have such and such a car and will the circuit work with my car? To get some clarification we asked you to share your experiences on the forum on our website and we received a massive response. At the moment we are sorting through all the responses so that it will be easier for you to get a quick overview. The most important issues we discuss here.

The reports of models that were successfully read started to stream in.

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Hurray!

It appears that our car is our most precious possession, we cherish it and with every small deviation from normal driving behaviour or sound we are concerned. It is then not surprising that you as technically interested people are so happy with a circuit that allows you to diagnose possible defects. The comments on this topic varied from "Hurray, at last!" to "What a good idea".

Without doubt, the most common question was: "For which cars is the OBD-2 tester suitable?" In the original article we naturally mentioned that in principle petrol cars from 2001 and diesels from 2003 are fitted with an EOBD-interface. However, it appears to be a little sneakier than that. A few old hands in the trade butted into this discussion and the answer is: "New petrol cars from 2001 and new diesel models from 2003. If a model was already in production before that year, then it does NOT need to conform to the OBD-2 standard. And of course there are always the stubborn manufacturers who will do different if they can get away with it..."
The pinch is therefore the word 'new'. This does not mean new from the factory but a new model or an upgraded model. So it is quite possible that the car with petrol engine that you bought in 2002 is not compatible!

"The PC communicates with my Fiat Stilo from 2003, but the measurement results make no sense at all."

ues that make no sense: "The PC communicates with my Fiat Stilo from 2003, but the measurement results make no sense at all. For example, water temperature 215. I have read on another site (Özen Elektronik) that Fiats from 2003 and earlier speak their own language and they were going to make a program that would work with this. Does anyone know any more of this? I'm keen to find a good working program, because I have been struggling with this car from the beginning and really would like to read everything back. Fiat have been dragging the chain and are now saying that the warranty is over."
The company Özen does indeed have special chips for certain makes, including Fiat, Ford and Mazda. It is however best to go directly to the website for Özen Elektronik and to have a look around and, if necessary, to contact them.

It is not all gold that glitters...

We cannot ignore that a number of readers were disappointed with the design and had hoped for more. Your official car dealership has diagnostic equipment from the factory that costs thousands of Euros and provides a practically complete insight in all aspects of your car. We will be very honest here: Our OBD-2 analyser cannot compete with this, its capabilities are considerably more modest. But this is offset by a price tag that is also considerably more modest. Only those parameters (plus a few extras that differ for each car) that the manufacturer is required to make available according to European law, are displayed by our analyser. In particular with cars from earlier than 2000 it is sometimes disappointing how much (read: how little) can be read. "Not completely OBD-2 compliant. I can scan sensor values, but no DTCs are found. Unfortunately I do not know if there are no DTCs or if they cannot be read..."

In addition there were a large number of readers who wanted to use the OBD-2 circuit for engine tuning. Unfortunately it is not suitable for this. This is the domain of specialists! Consider that it is much easier to ruin your engine than it is to get more power from it!
Cars from the Fiat group often provide measurement val-

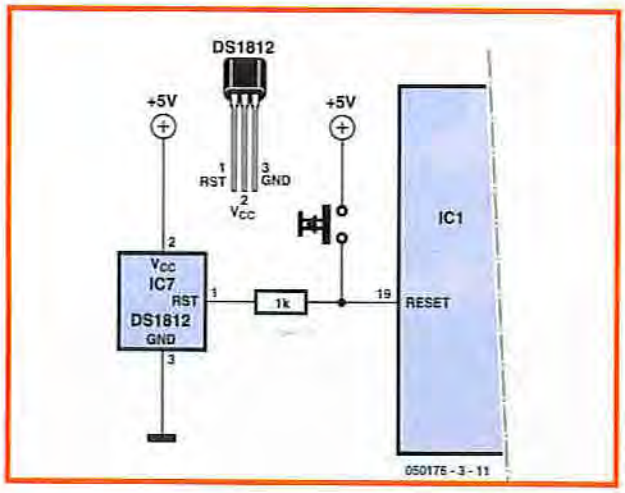

Figure 1. In this way a reset button can be added to the circuit.

A few readers with non-European cars tried to connect to the WDS (Worldwide Diagnostics System) bus, but without positive results: "I was wondering if the OBD-2 kit will allow me change or write to the ECU using WDS?" But the answer from the forum was unanimous: "WDS requires separate PC software with its own interface. This will absolutely not work via OBD-2."

Good service!

From chipping come chips. A few circuits did not work and after checking them it appeared that the program was not burned properly in the microprocessor. We promptly replaced those and in general people were quite happy with that, particularly when everything was resolved quickly.

Reset perils

The early-bird buyers were confronted with start-up problems: a few components were missing here and there. This resulted in a drastic review of our internal buying procedures, after which the problem was solved. In addition it appeared that the microprocessor in the circuit required a relatively long reset-pulse in order to start reliably. That is why initially both C7 and the ZSH560 needed to be fitted. We had to replace the reset generator with a pin-compatible, more readily available type. C7 does not have to be fitted with the new type, a DS18212, because this already provides a long reset-pulse by itself.

The reports of models that were successfully read started to stream in. For a brief period there was some doubt over the jumper because it was not mentioned in the article. "We use this jumper when downloading the firmware. Leave it open for normal use. While the flash memory will not be erased if the jumper is in place, the chip will not run either."
In the meantime, owners of cars from the Volkswagen group had a few difficulties. They were plagued by start-up problems. But in the shortest possible time the answer was available in the forum: At power on the **red LED** has to light up. The moment the microprocessor starts to communicate the **yellow LED** will blink irregularly. All protocols are now tried one after the other. As soon as a valid protocol has been found the **green LED** lights up and the yellow LED will flash every now and then to indicate that communication is taking place. If no valid protocol has been found, then the yellow LED will light every 3 seconds. The search for the protocol is done only once after each reset. If the electronics in the car is switched on later via the ignition key so that the protocol is not available early enough, then the OBD-2 analyser will wait indefinitely. There are a few remedies for this: Briefly unplug the OBD cable so that the microprocessor is reset after which the cable can be plugged back in, add a reset switch on the circuit board, or and on/off switch in the +12-V connection between the car and the analyser. In **Figure 1** you can see that adding a reset pushbutton is a straightforward job.

Who has succeeded in mounting the assembled PCB in its enclosure?

Other pitfalls

When working on a car, a laptop is obviously much more practical than a large PC with all its individual parts. However, laptops often have only USB connections and there was quickly the realisation that some types of USB/RS232 converters were not compatible enough. If the conversion from RS232 to USB is too slow then it is possible that the OBD-2 analyser does not find a valid protocol. In any case, the converters from the company Özen Elektronik work well and all converters with FTDI chips work without problems.

About the construction

"Who has succeeded in fitting the assembled PCB in its enclosure without removing the front?" a reader asked. The answer came from both the *Elektor Electronics* lab as well as from a reader: "I have done it differently. Place the PCB on the upside-down lid and place the enclosure on top, so that the holes line up. Then mark the width of the connectors. After that, place the enclosure with the edge on the lid and mark the height of the connectors. Cut out or file away the marked parts. When you place the PCB on the lid and the enclosure over the top and screw them together, the PCB is then held in place by the connectors. Sliding or rattling is then not a problem."

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Suitable programs

In the forum the following programs have been mentioned that appear to work well with the OBD-2 hardware:

- MCI 1.2b
- Mobytester plus
- Scanmaster
- Digimoto lite
- OBD2Spy
- VitalScan

All these programs can be found at http://www.ozenelektronik.com. You have to log in and then select Download/Mobydic.