



CAN and LIN bus systems



MATRIX
CP0607

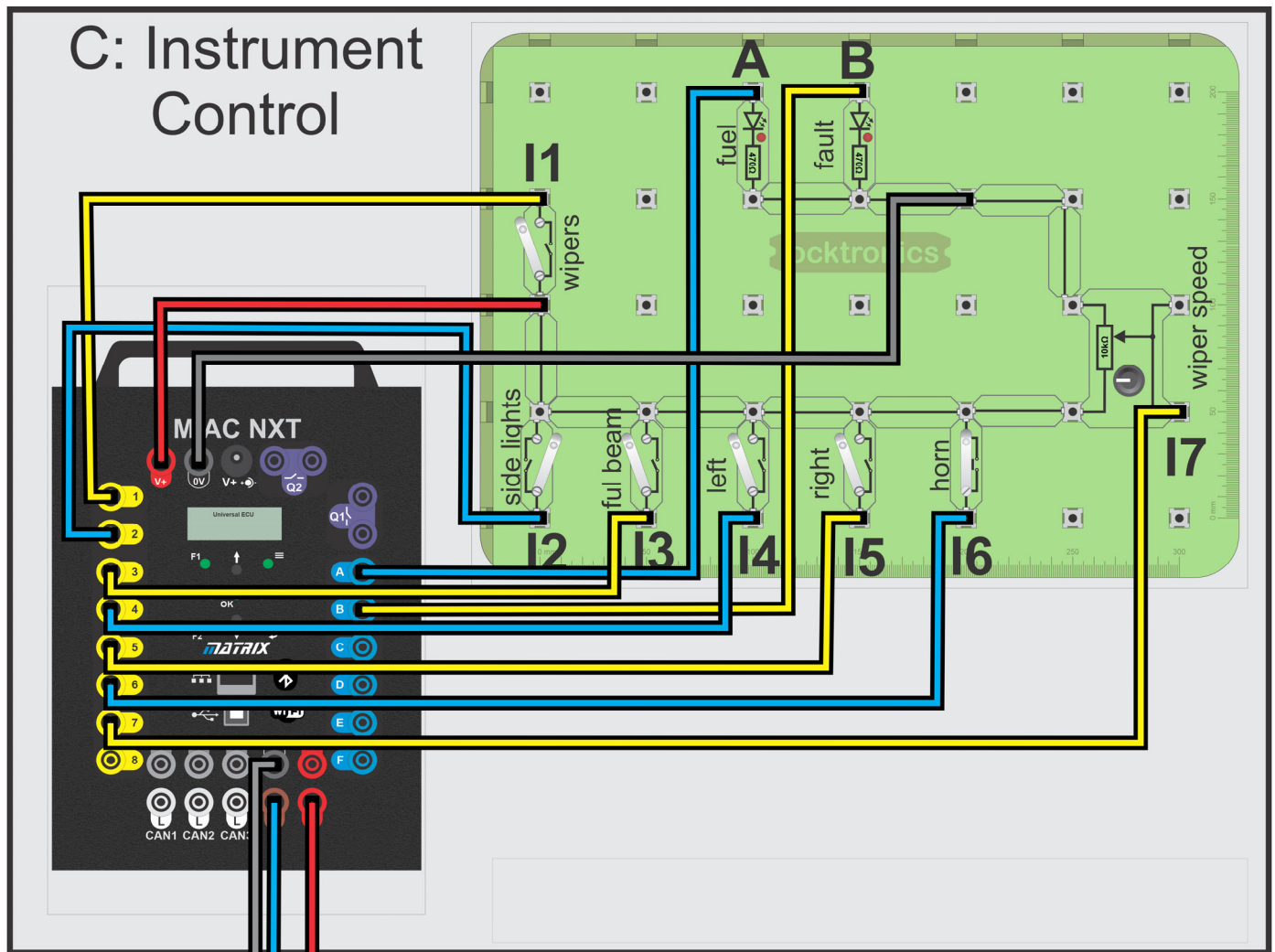
www.matrixtsl.com

Copyright © 2021 Matrix Technology Solutions Limited

Worksheet 1 - Building the Instrument Control node	3
Worksheet 2 - Building the Body control Front node	4
Worksheet 3 - Building the Engine Control node	5
Worksheet 4 - Building the Powertrain Control node	6
Worksheet 5 - Building the Body Control rear node	7
Worksheet 6 - Building the Power and Fuses node	8
Worksheet 7 - Wiring up the Gateway and OBDII node	9
Worksheet 8 - Wiring it all up	10
Worksheet 9 - OBDII scanners and fault codes	11
Worksheet 10 - Circuit design for fault detection	13
Worksheet 11 - Diagnosing CAN faults with a multimeter	15
Worksheet 12 - Diagnosing CAN faults with a scope	18
Worksheet 13 - More complex CAN faults	20
Worksheet 14 - LIN bus faults	22
Expanding the system with real sensors and actuators	23
Notes for the instructor	39

Worksheet 1

Building the Instrument Control node

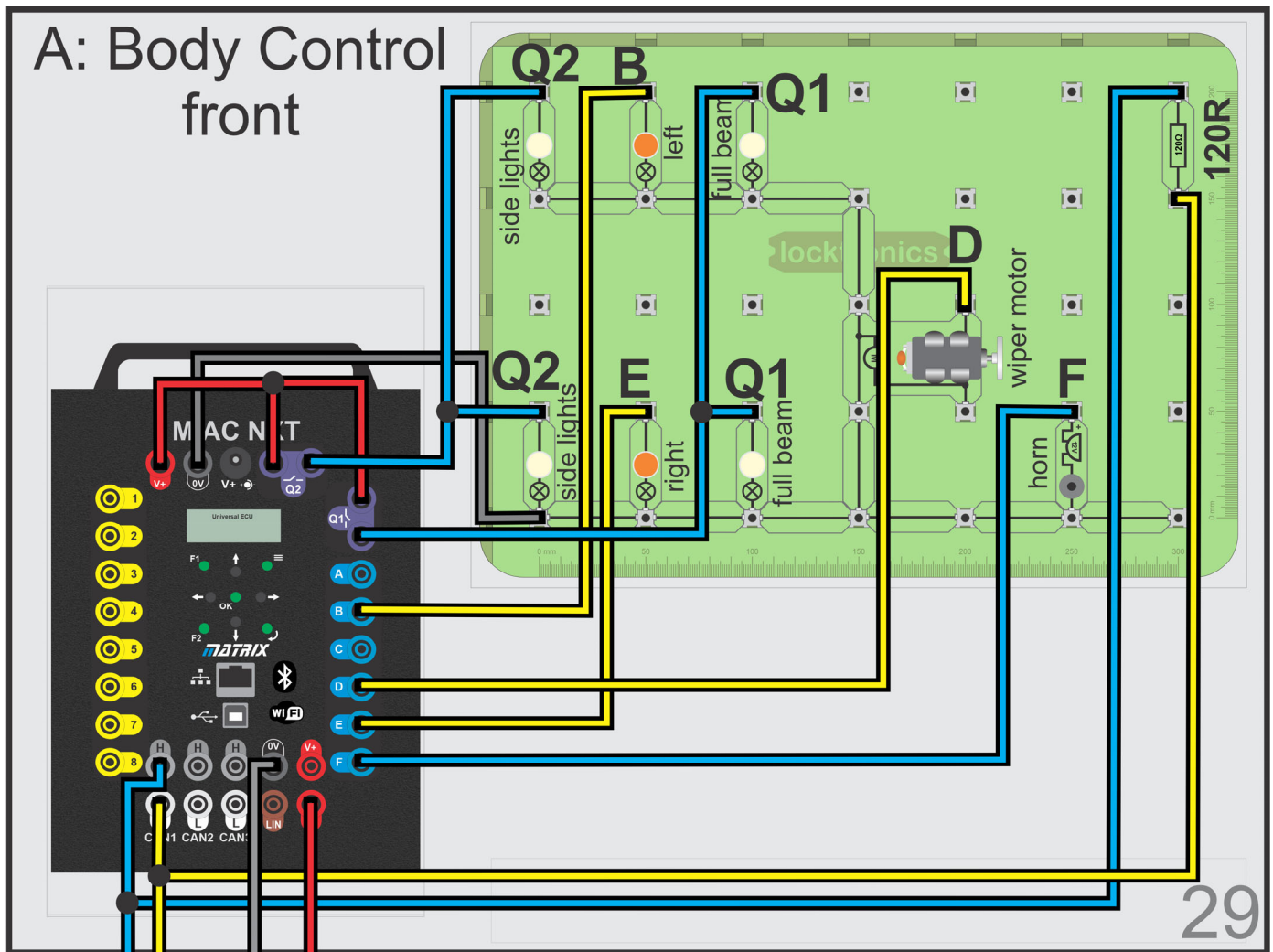


Over to you:

1. Wire up the circuit as shown in the diagram above.
2. Connect 12V to the MIAC ECU.
3. The LCD shows you options for 4 seconds and then reverts to the MIAC's previous programme choice. After power up use the UP/Down switches to choose the Instrument Control node, then press and hold the F1 switch to put the MIAC in self-test mode.
4. Test each switch and potentiometer and make sure the display shows the status change.
5. Remove power from the MIAC to reset it then reapply power.
6. Use the UP/Down switches to choose the Instrument Control node and wait: after a few seconds the MIAC will become the Instrument Control ECU.

Worksheet 2

Building the Body control Front node

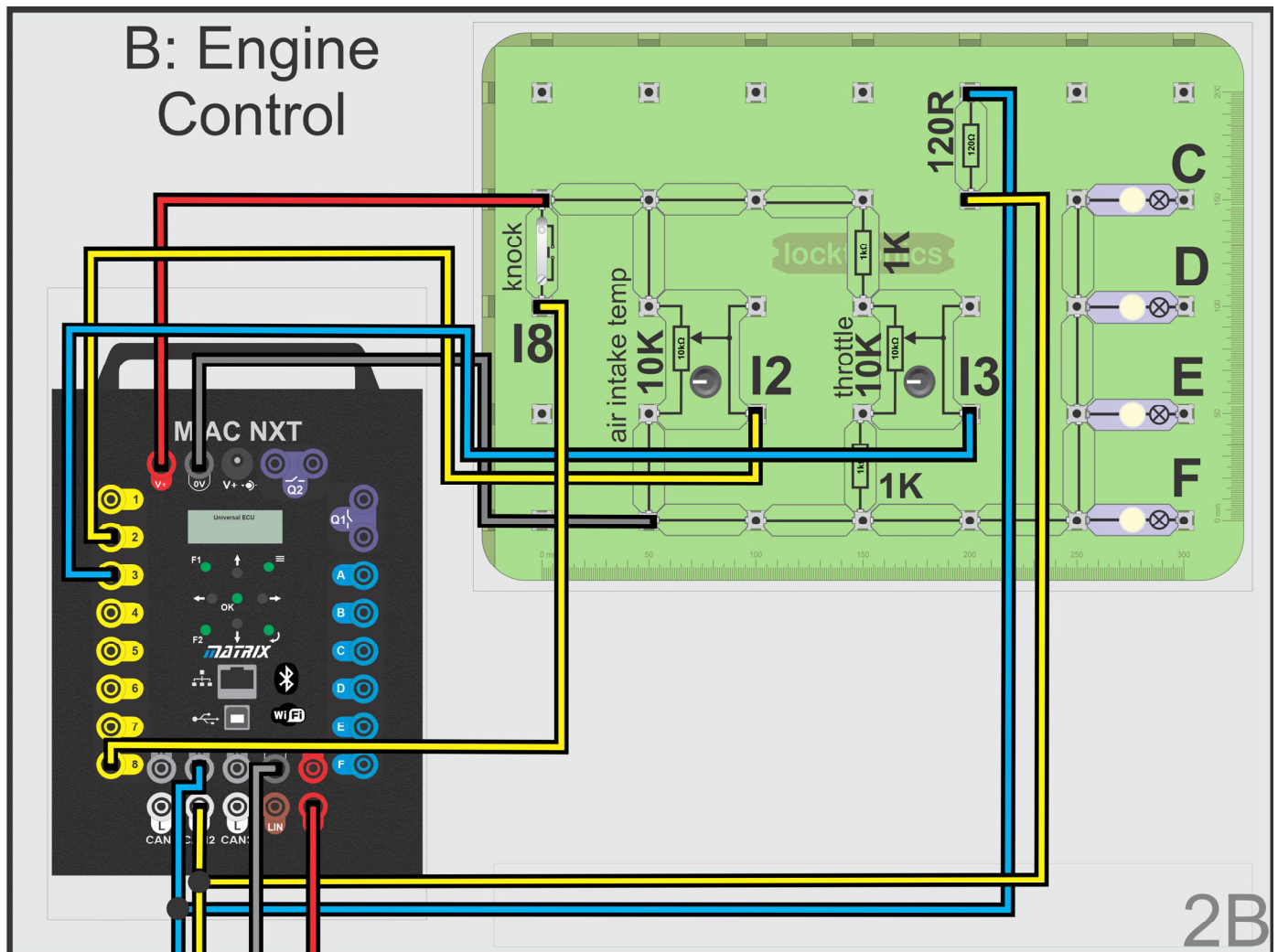


Over to you:

1. Wire up the circuit as shown in the diagram above.
2. Connect 12V to the MIAC ECU.
3. The LCD shows you options for 4 seconds and then reverts to the MIAC's previous programme choice. After power up use the up and down arrows to select 'Body Control Front' then press and hold the F1 switch to put the MIAC in self test mode.
4. Each of the bulbs and the motor should come on in turn. This allows you to check that your wiring is OK.
5. Remove power from the MIAC to reset it then reapply power.
6. Use the UP/Down switches to choose the Body Control front and wait: after a few seconds the MIAC will become the Body Control front ECU.

Worksheet 3

Building the Engine Control node



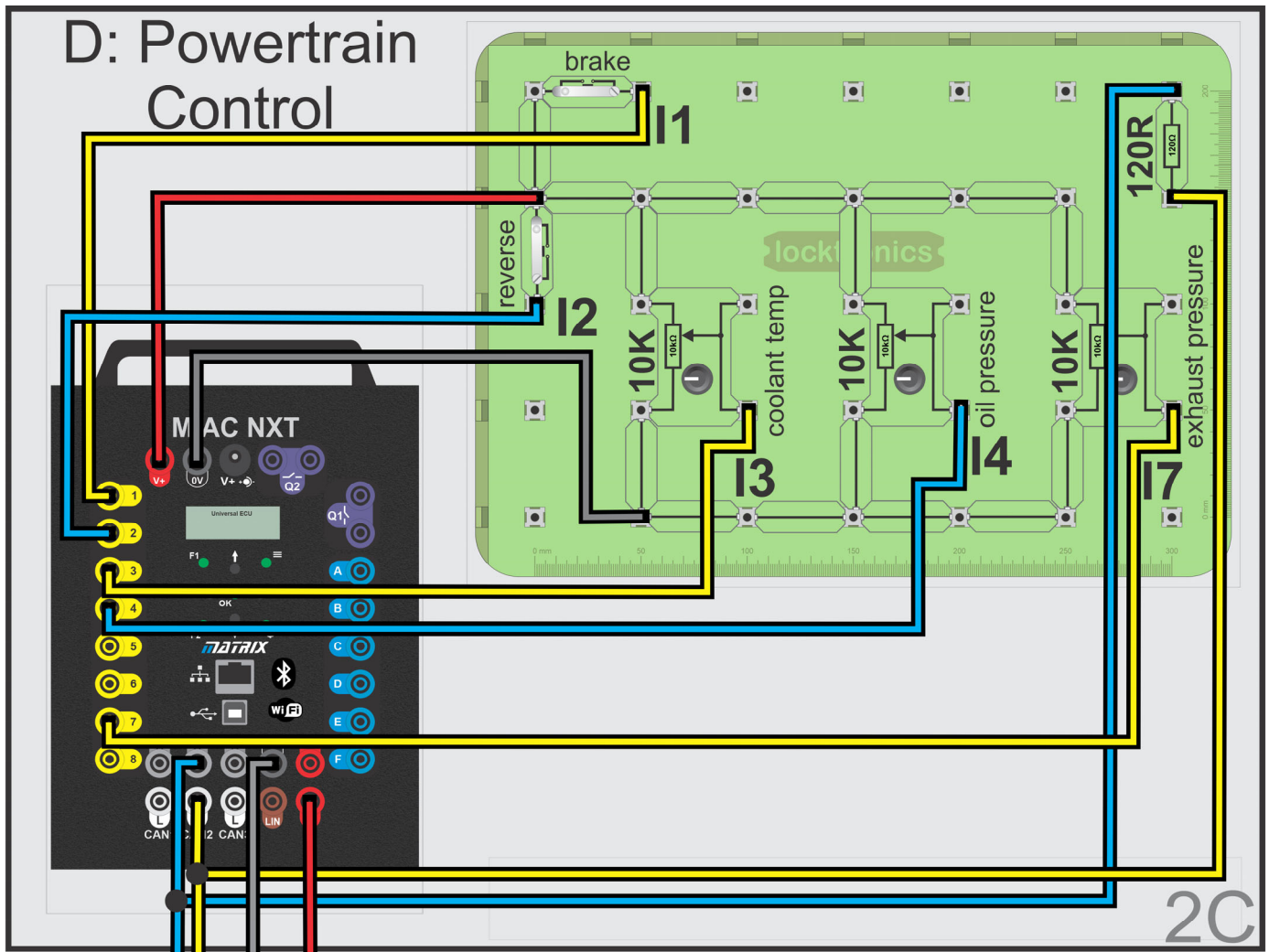
Over to you:

1. Wire up the circuit as shown in the diagram above.
2. Connect 12V to the MIAC ECU.
3. The LCD shows you options for 4 seconds and then reverts to the MIAC's previous programme choice. After power up use the up and down arrows to select 'Engine Control' then press and hold the F1 switch to put the MIAC in self-test mode.
4. Test each switch and potentiometer and make sure the display shows the status change.
5. Remove power from the MIAC to reset it then reapply power.
6. Use the UP/Down switches to choose Engine Control and wait: after a few seconds the MIAC will become the Engine Control ECU.

Note that A,B,C,D lamps mimic injection valves when the CAM crank actuator is used.

Worksheet 4

Building the Powertrain Control node

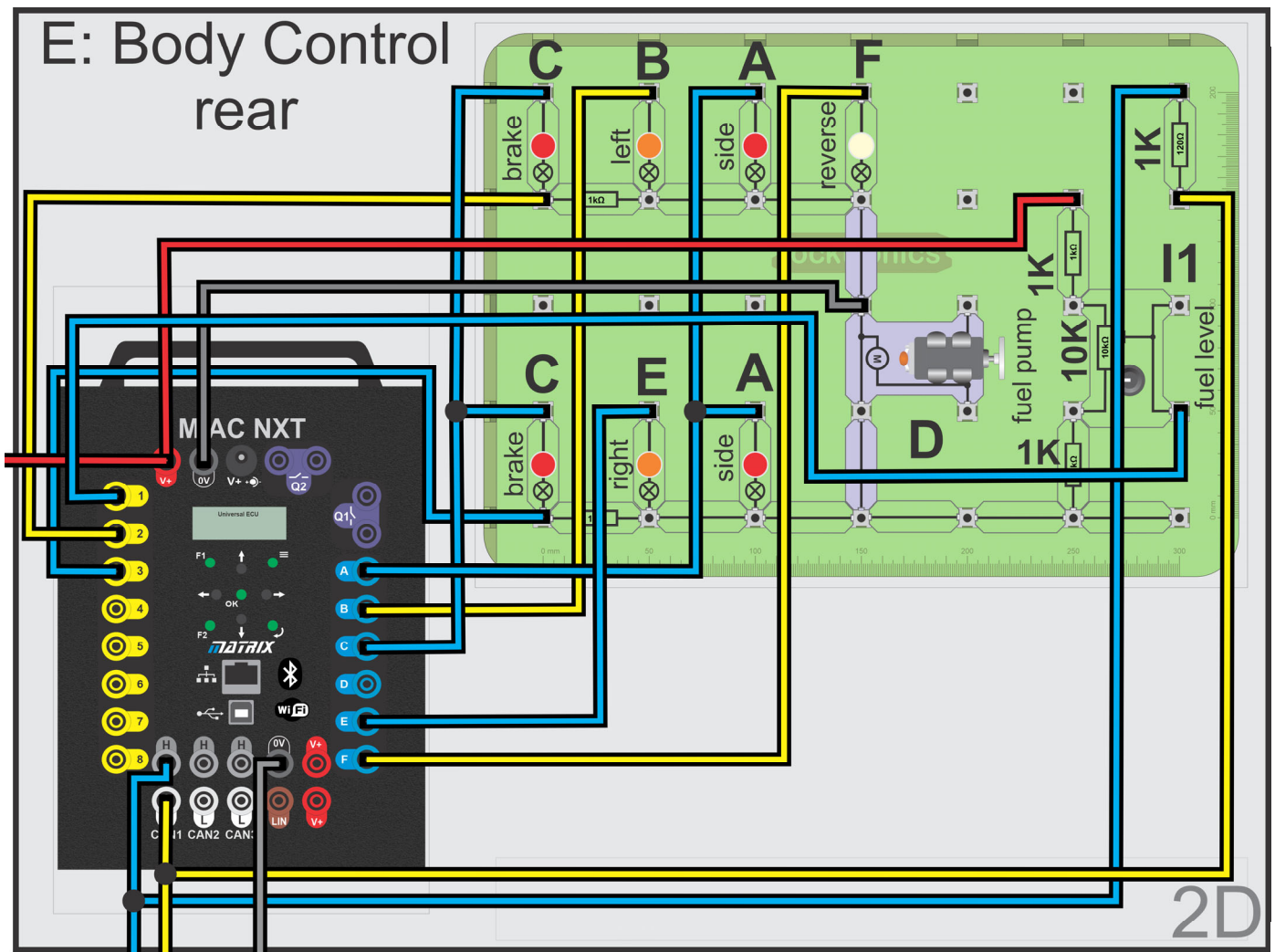


Over to you:

1. Wire up the circuit as shown in the diagram above.
2. Connect 12V to the MIAC ECU.
3. The LCD shows you options for 4 seconds and then reverts to the MIAC's previous programme choice. After power up use the up and down arrows to select 'Powertrain Control' then press and hold the F1 switch to put the MIAC in self-test mode.
4. Test each switch and potentiometer and make sure the display shows the status change.
5. Remove power from the MIAC to reset it then reapply power.
6. Use the UP/Down switches to choose Powertrain Control and wait: after a few seconds the MIAC will become the Powertrain Control ECU.

Worksheet 5

Building the Body Control rear node



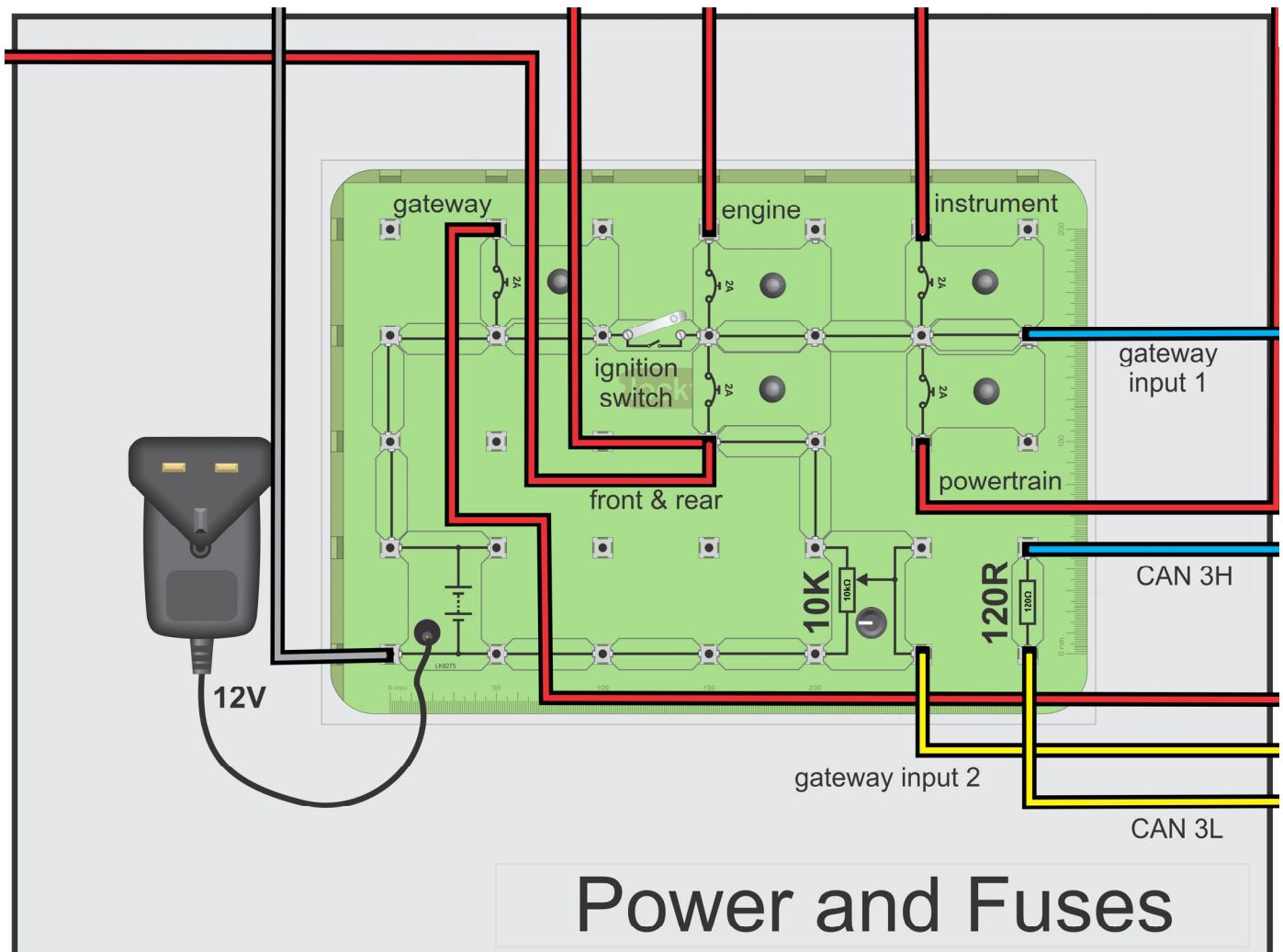
Over to you:

1. Wire up the circuit as shown in the diagram above.
2. Connect 12V to the MIAC ECU.
3. The LCD shows you options for 4 seconds and then reverts to the MIAC's previous programme choice. After power up use the up and down arrows to select 'Body Control rear' then press and hold the F1 switch to put the MIAC in self-test mode.
4. Each of the bulbs and the motor should come on in turn. This allows you to check that your wiring is OK.
5. Remove power from the MIAC to reset it then reapply power.
6. Use the UP/Down switches to choose Body Control rear and wait: after a few seconds the MIAC will become the Body Control rear ECU.

Note - the fuel pump motor shown in purple is for use with the Sensors and Actuators on brackets.

Worksheet 6

Building the Power and Fuse panel

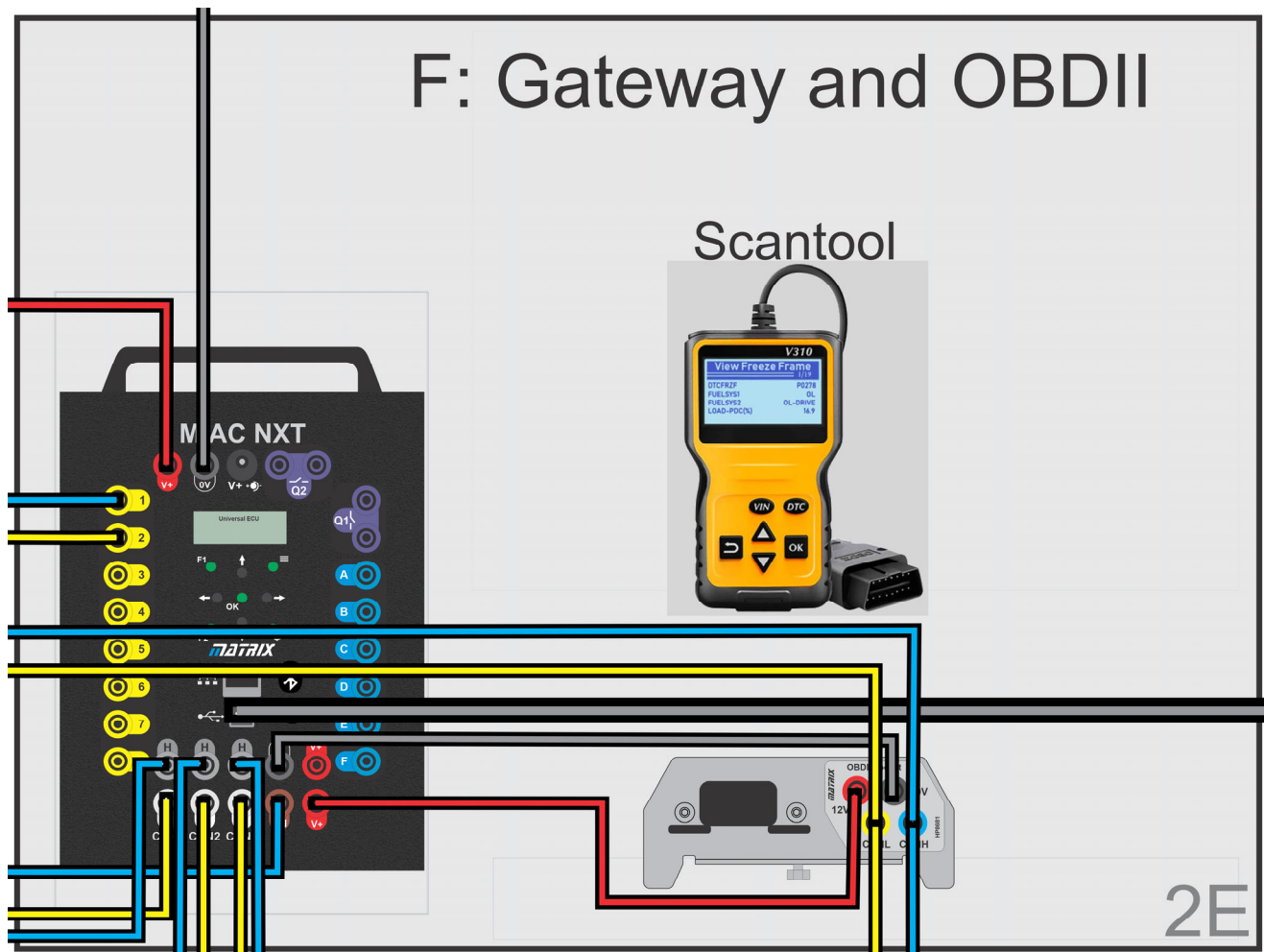


Over to you:

1. Wire up the circuit as shown in the diagram above.
2. Connect the 12V power supply to the circuit.
3. There is no self-test for this part of the circuit.
4. The potentiometer feeds the Gateway input 1. This is the system voltage monitoring input. When it falls below 12V an error is issued.
5. Set the potentiometer to fully anticlockwise: 12V.
6. Note that the Gateway power is always wired to 12V, its always on. Power for the other ECUs is wired through the ignition switch.
7. Gateway input 1 is wired to the ignition switch output. This allows the Gateway to know when power is turned on.
8. The potentiometer is used to mimic low battery voltage and is wired to Gateway input 2.

Worksheet 7

Building the Gateway and OBDII node

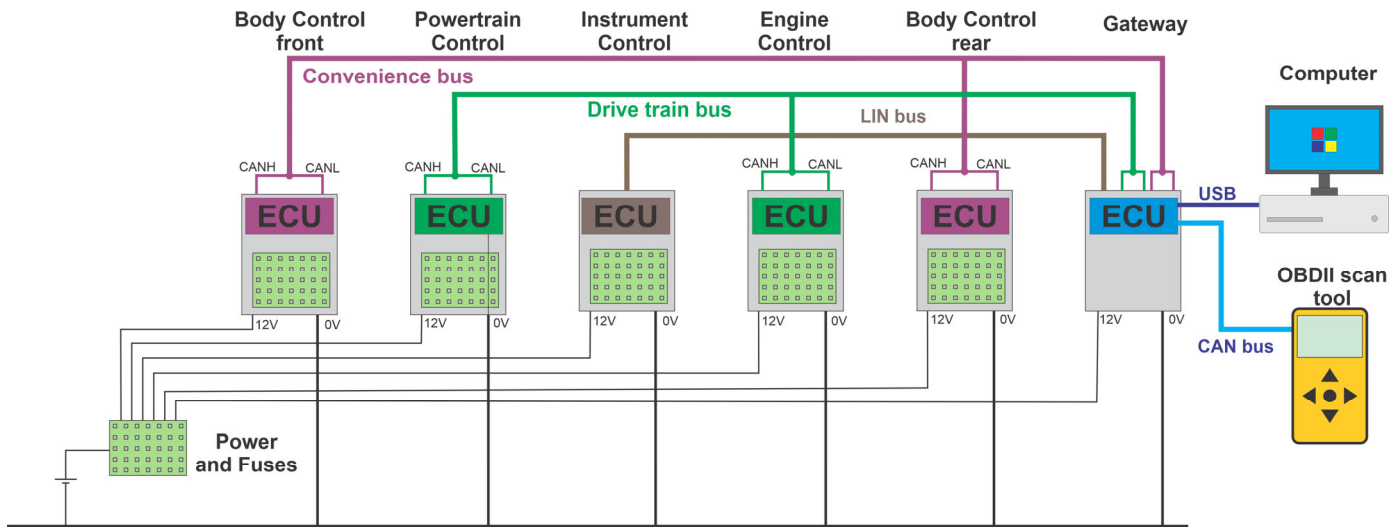


Over to you:

1. Add the OBDII bracket to the system and connect CANH and CANL to CAN3 on the Gateway MIAC.
2. Connect the 12V power supply to the MIAC ECU.
3. You will see the start screen and then a menu option.
4. Choose 'CAN bus' system.
5. Use the Up and Down arrows to select 'Gateway' and press 'OK'.
6. The Gateway is now ready.
7. Connect the OBDII socket on the bracket to the MIAC as shown.
8. Add the OBDII scan tool to the system using the OBDII socket.
9. Wire up inputs 1 and 2 on the gateway to the fuse panel.
10. Wire up the termination resistor on the fuse panel to CAN 3.

Worksheet 8

Wiring it all up



Over to you:

1. The diagram above shows the top level block diagram. You can see the full circuit of the Basic CAN system in the reference section, on the separate PDF file supplied, and on the poster supplied.
2. Connect each ECU and Locktronics board to 0V.
3. Connect each ECU to the appropriate output on the Fuse panel.
4. Wire up the Drivetrain LIN bus - a single wire - between the Gateway LIN socket and the LIN socket on the Instrument Control ECU.
5. Wire CAN 1 High and Low on the Body Control Front system in parallel with CAN 1 High and Low on the Body Control rear and with CAN 1 High and Low on the Gateway. This is the Convenience CAN bus. Connect the two 120 ohm resistors at each end of the CAN bus in parallel.
6. Wire CAN 2 High and Low on the Powertrain Control to the CAN 2 High and Low on the Engine Control and to CAN 2 High and Low on the Gateway. This is the Drivetrain CAN bus. Connect two 120 ohm resistors at each end of the bus in parallel.
7. Turn the ignition switch on. The displays on all MIACs should come on.
8. Use the MIAC keypad Up and Down switches to select the appropriate node on each MIAC. See MIAC menu system in the Reference section for details.
9. You should now have a fully-functioning CAN / LIN system. You can test it using switches on the Instrument Control and make sure the relevant lights and indicators come on.
10. If your system is not working, check your wiring.

Worksheet 9

OBDII scanners and fault codes



On-board diagnostic scan tools connect to the OBD II socket in a car, usually under the steering wheel.

The OBDII communications bus is a CAN bus, connected only to the Gateway. This reduces the risk of CAN bus contamination by a rogue scan tool and also limits the number of messages sent to the scan tool device.

The specification for OBDII is well established and our CAN bus solution works with most modern scan tools.



Over to you:

With the CAN bus system up and running:

1. Remove the Body Control rear from the CAN bus system by simply unplugging the two wires CANH and CANL into the Body Control rear MIAC. Leave the CAN wires plugged into the 120 ohm termination resistor.
2. The system periodically checks that each node is present. It will notice that Body Control rear is missing and will flag up a fault.
3. Your scan tool can be used to ask for details of faults on the system. You may need to refer to the scan tool manual to find out how to do this. Use the scan tool to interrogate the system to find out what the fault code is. _____
4. Put the CANH and CANL connections back into the Body Control rear sockets.
5. Use the scan tool to reset the fault code.
6. Next remove the 12V power connector to the Body Control rear MIAC.
7. Use the scan tool to find out what the fault code is. _____
8. Put the 12V connection back into the Body Control rear 12V connector.
9. Use the scan tool to reset the fault code.
10. Next remove the 0V power connector and power up the system again.
11. Use the scan tool to find out what the fault code is. _____
12. Put the 0V connection back into the Body Control rear 12V connector.

So what?

All three faults create the same fault code.

Fault codes often give you an idea of where there is a problem, but don't necessarily tell you exactly what the problem is.

Worksheet 9

OBDII scanners and fault codes



Over to you:

1. For each of the Engine Control, Instrument Control, Powertrain Control, and Body Control front nodes remove 12V and use the scan tool to find out what error codes are given.

Engine Control	_____
Instrument Control	_____
Powertrain Control	_____
Body Control front	_____

So what?

- There are separate fault codes in the system for each ECU missing or not functioning.

Over to you:

1. Repeat the fault for the Powertrain. Don't reset the fault with the scan tool
2. Remove power from the system
3. Power the system up. Is the fault light on the Instrument Control panel still lit?

So what?

Removing power or resetting the system does not always reset the fault. In a situation where the system has been unreliable the fault remains so that the driver is encouraged to take the vehicle into the workshop to get it serviced.

Over to you:

1. Use the scan tool to find the Vehicle Identification Number: _____
2. On the fuse panel there is a potentiometer. In practice an ECU will operate on a range of voltages - probably to less than 10V. However when the battery voltage falls below, say, 11V then the system should give a warning to the driver. This potentiometer allows you to mimic the situation where the battery voltage falls below an acceptable threshold.
3. Alter the wiper of the potentiometer so that the voltage falls to, say, 10V.
4. Use the scan tool to find the fault code. _____

Worksheet 10

Circuit design for fault detection



Over to you:

1. Restore the system so that it is working properly and the fault light is off. Use the scan tool to reset the fault if necessary.
2. Locate the fuel level circuit on the Body Control rear node, shown in the image here.
3. Use a multimeter to measure the output voltage of this circuit at maximum and minimum settings of the potentiometer.

Max: _____

Min: _____

4. Remove the top resistor in the potential divider chain. This means that the voltage at the output of the circuit falls to 0V

5. A fault will be registered by the ECU.

Use the scan tool to get the DTC: _____

6. Replace the resistor. Use the scan tool to reset the fault.

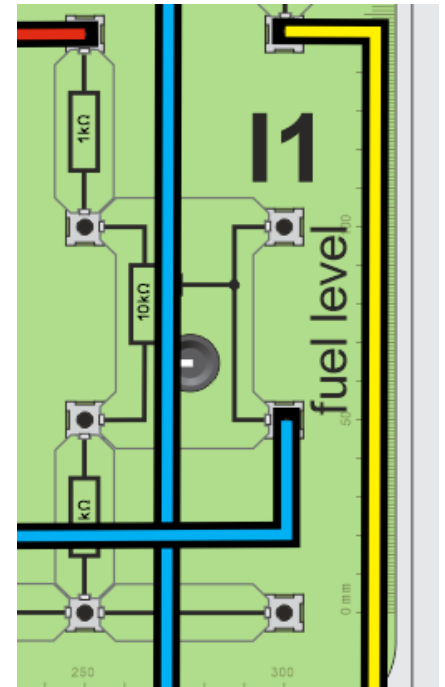
7. Make a table of possible faults with the fuel sensor and the DTC reading as follows:

5V connection open circuit _____

0V connection open circuit _____

Output short to 0V _____

Output short to +5V _____

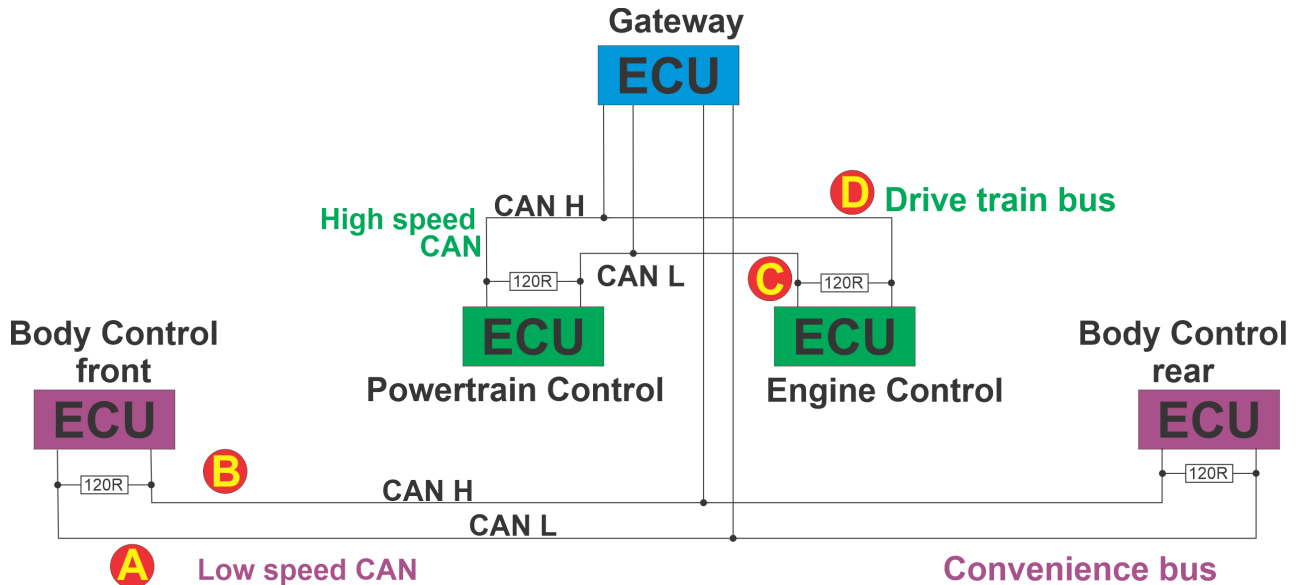


So what?

- System designers can devise circuits and ECU configurations that allow built-in fault-finding in vehicles
- DTC codes sometimes pinpoint the problem exactly or can give you a rough guide to where the problem lies. DTC codes will often need some interpretation and further investigation.

Worksheet 11

Diagnosing CAN faults with a multimeter



Over to you:

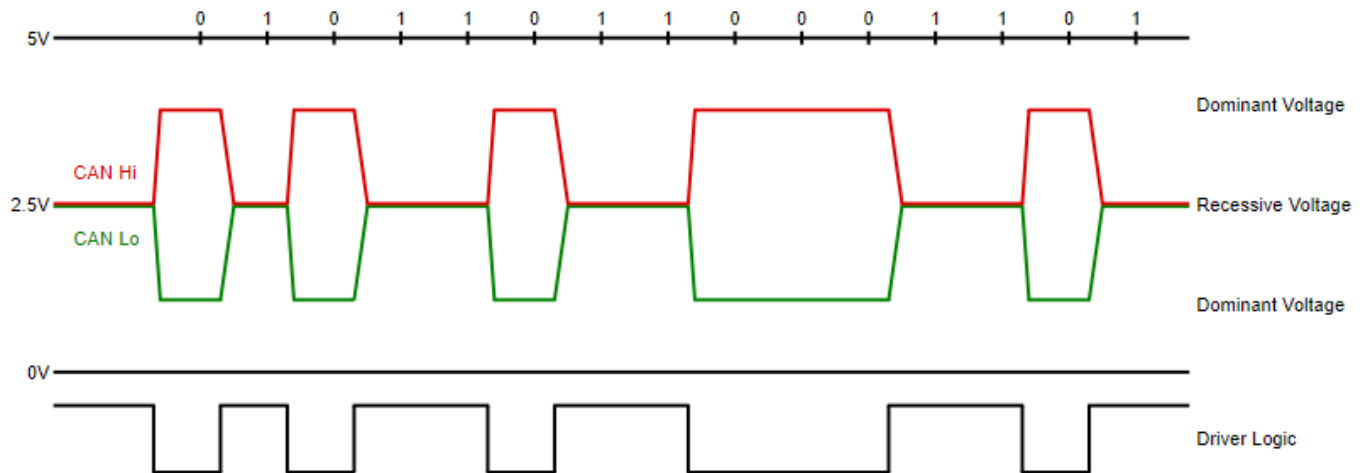
1. Make sure that the power to the system is turned off.
2. The diagram above shows you the schematic of the two CAN buses in the system. With your multimeter on the resistance setting, put the probes at points **A** and **B** - across the Convenience CAN bus.
What is the reading: _____ ohms
3. Remove the CAN bus connection to the Body Control front ECU and termination resistor.
What is the reading on the multimeter now? _____ ohms
4. Replace the CAN bus connections
5. Remove the Convenience CAN bus connections to the Gateway.
What is the reading on the multimeter now? _____ phms
6. Restore the connection to the Gateway ECU.
7. Now short-circuit the CAN H and CAN L connections on the Body Control front ECU.
What is the reading on the multimeter now? _____ ohms

So what?

- A resistance of zero ohms between CAN H and CAN L is a pretty good indicator that there is a short-circuit between the two wires at some point in the system
- In most systems the 120 ohm termination resistors are inside the ECUs. A resistance of 60ohms is not a guarantee that all nodes in the system are connected. It is an indication that the first and last ECUs on a CAN bus are well connected. If a single ECU is missing then the resistance test will not necessarily reveal it. It depends on how the ECUs are wired.

Worksheet 11

Diagnosing CAN faults with a multimeter



The above image (taken from Wikipedia) shows the ideal CAN bus voltage waveform. You can see that the voltage on CANH is somewhere between 2.5V and 4V and the voltage on CANL is somewhere between 1V and 2.5V.

Over to you:

1. Power up and start the system. Clear any faults with a scan tool.
2. With the multimeter negative probe on 0V, make the following voltage measurements:
 - CAN L on the Convenience bus: _____ V
 - CAN H on the Convenience bus: _____ V
 - CAN L on the Drivetrain bus: _____ V
 - CAN H on the Drivetrain bus: _____ V

So what?

CAN signals are based on around 2.5V.

CAN H pulses between 2.5V and 5V so the quiescent voltage on CAN H is just above 2.5V.

CAN L pulses between 2.5V and 0V so the quiescent voltage on CAN L is just below 2.5V.

Over to you:

1. Power up and start the system. Clear any faults with a scan tool.
2. With the multimeter negative probe on 0V, short-circuit CAN L on the Convenience bus to 0V. Make the following voltage measurements:
 - CAN L on the Convenience bus: _____ V
 - CAN H on the Convenience bus: _____ V

Worksheet 11

Diagnosing CAN faults with a multimeter



So what?

If there is a short-circuit to 0V, it occurs in the connection with lower of the two voltages.

Over to you:

1. Power up and start the system. Clear any faults with a scan tool.
2. With the multimeter negative probe on 0V, short-circuit CAN L on the Convenience bus to 12V. Make the following voltage measurements:

- CAN L on the Convenience bus: _____ V
- CAN H on the Convenience bus: _____ V

So what?

If there is a short-circuit to 12V, it occurs in the connection with the lower of the two voltages.

Over to you:

1. Repeat these exercises with the high speed Drive train CAN bus.
2. Is it any different?

Over to you:

On the Rear-body-control MIAC:

1. short-circuit the CANL line to 0V. Does the CAN bus still work? _____
2. short-circuit the CANL line to 12V. Does the CAN bus still work? _____
3. short-circuit the CANH line to 0V. Does the CAN bus still work? _____
4. short-circuit the CANH line to 12V. Does the CAN bus still work? _____

So what?

- The CAN bus detects the difference in voltage between CANL and CANH using analogue circuitry and passes this to a digital circuit to get the final CAN signal. This means that it is quite fault tolerant:

Short-circuit CANL to 0V and the CAN bus still works

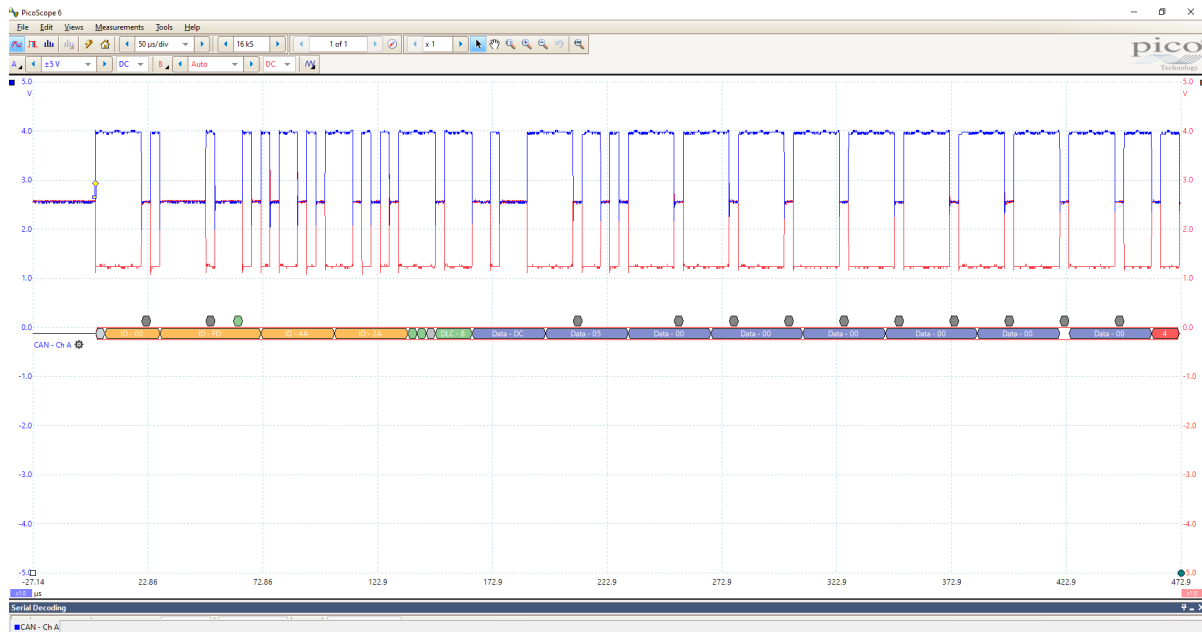
Short-circuit CANL to +V and the CAN bus stops working

Short-circuit CANH to +V and the CAN bus still works

Short-circuit CANH to 0V and the CAN bus stops working.

Worksheet 12

Diagnosing CAN faults with a scope



Over to you:

1. Power up and start the system. Clear any faults with a scan tool.
2. Connect an oscilloscope to the Body Control rear MIAC, with channel **A** on CANH and channel **B** on CANL. Connect the oscilloscope ground to 0V.
3. Use the following oscilloscope settings: 100 μ s / division, range: +/-5V, single trigger, trigger voltage: channel **A** at around 3V. You should get a trace like the one above.
4. Practise triggering the oscilloscope. Make sure that you understand the trigger settings on both Channel **A** - CANH - and Channel **B** - CANL.
5. If the oscilloscope allows, try decoding the CAN bus signal. On a Picoscope you do this using: TOOLS...DECODING...CREATE...CAN...Channel A...250Kbaud (for the low speed convenience bus or 500kbaud for the high speed Drive train bus).

So what?

- CAN bus messages are frequent and fast. Understanding how to trigger an oscilloscope to see them is important
- If you can get a clear trace on an oscilloscope, like the one above, then it is likely that your CAN bus electronics are working properly.
- Oscilloscopes are great for seeing an individual waveform. This gives you some degree of certainty that the CAN bus is connected properly. But there are so many CAN bus messages on the bus that using a scope for diagnostics is very limited.

Worksheet 12

Diagnosing CAN faults with a scope



Over to you:

1. Short-circuit CANL to ground.

How is each signal affected? Does the bus still work?

2. Remove the short-circuit. Short-circuit CANL to +12V.

How is each signal affected? Does the bus still work?

3. Remove the short-circuit. Short-circuit CANL to CANH.

How is each signal affected? Does the bus still work?

So what?

- An oscilloscope is a good tool for giving you information on short-circuits on a CAN bus as you can easily see the shift in voltage levels that a short-circuit causes.

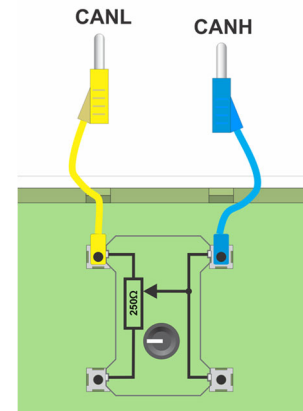
Worksheet 13

More complex CAN faults



The CAN bus is remarkably tolerant to partial short-circuits between the two lines of the bus and between any one line and power and ground.

In this investigation, you will see just how tolerant it is but that sometimes a multimeter is not enough to diagnose a fault - you need to use an oscilloscope as well.



Over to you:

1. Place a 250 ohm potentiometer in an empty space on one of the Locktronics boards, on the BodyControl front node, for example.
2. Connect it across the CANH and CANL lines of the Convenience CAN bus.
3. Turn the potentiometer fully clockwise to its maximum resistance - i.e. around 260 ohms.
4. Use an oscilloscope, with one input on CANH, the other on CANL and one of the ground terminals connected to 0V to allow you to display the CAN signals.
5. Make a sketch of the CANH and CANL signals on the graph paper on the next page and make a note of the significant voltages for CANH and CANL.
6. Take the potentiometer out of circuit and set its resistance first to 30 ohms and then 10 ohms, using a multimeter. For each case, sketch the CANH and CANL signals on the graph paper on the next page and make a note of significant voltages.

So what?

- A multimeter is a great way of checking the CAN bus: most of the time it will identify a fault if there is one.
- A multimeter does not guarantee that there are no faults on the CAN bus. It does not reveal a partial fault.
- An oscilloscope is a really good tool for checking the health of the CAN bus.

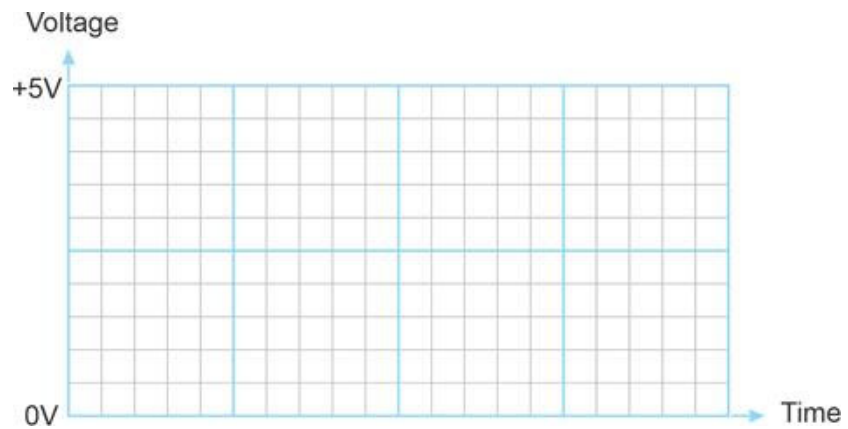
Worksheet 13

More complex CAN faults



Case 1 - 260 ohms

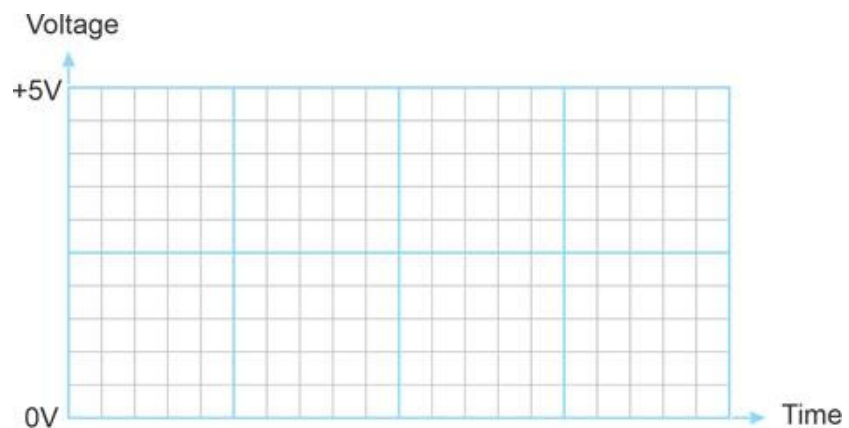
Oscillogram:



Multimeter voltage on CAN H: _____ Multimeter voltage on CANL _____

Case 2 - 30 ohms

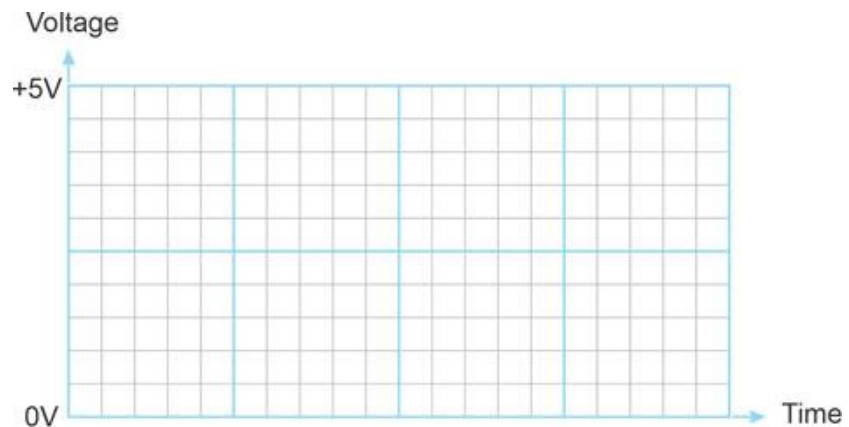
Oscillogram:



Multimeter voltage on
H: _____ Multimeter voltage on CANL _____ CAN

Case 3 - 10 ohms

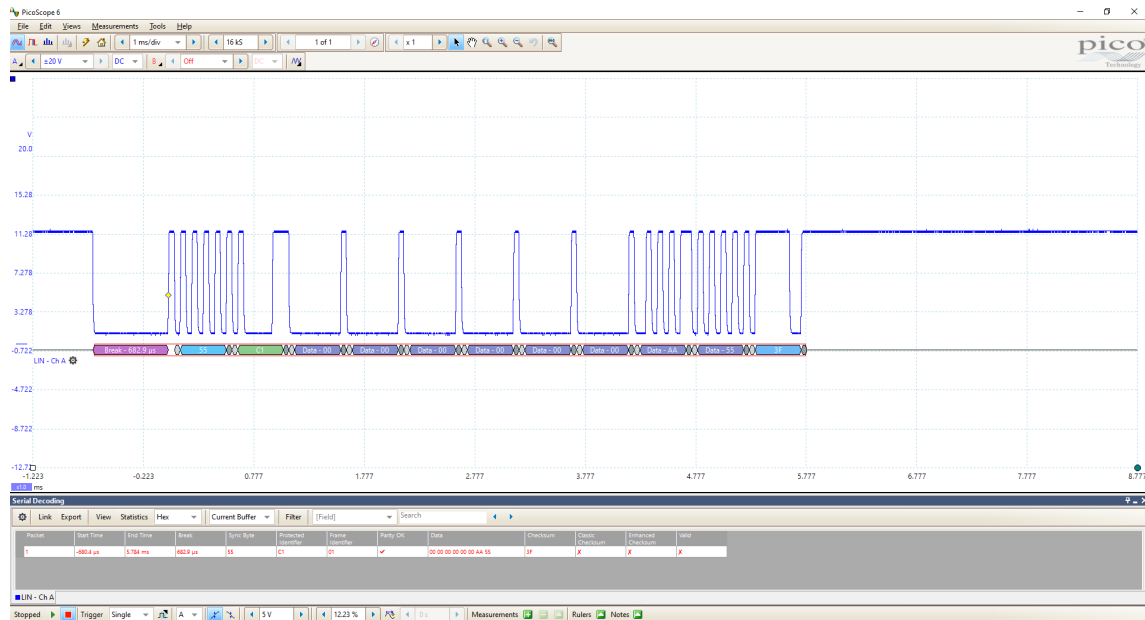
Oscillogram:



Multimeter voltage on CAN H: _____ Multimeter voltage on CANL _____

Worksheet 14

Diagnosing LIN bus faults



Over to you:

The LIN bus is simple, consisting of a single wire, plus the +12V and 0V power connections.

1. Using a multimeter with its ground lead connected to 0V and positive lead connected to +12V, measure the supply voltage. _____
2. Now measure the voltage at the LIN bus terminal on the Instrument panel. _____

3. Is this multimeter reading constant? _____

So what?

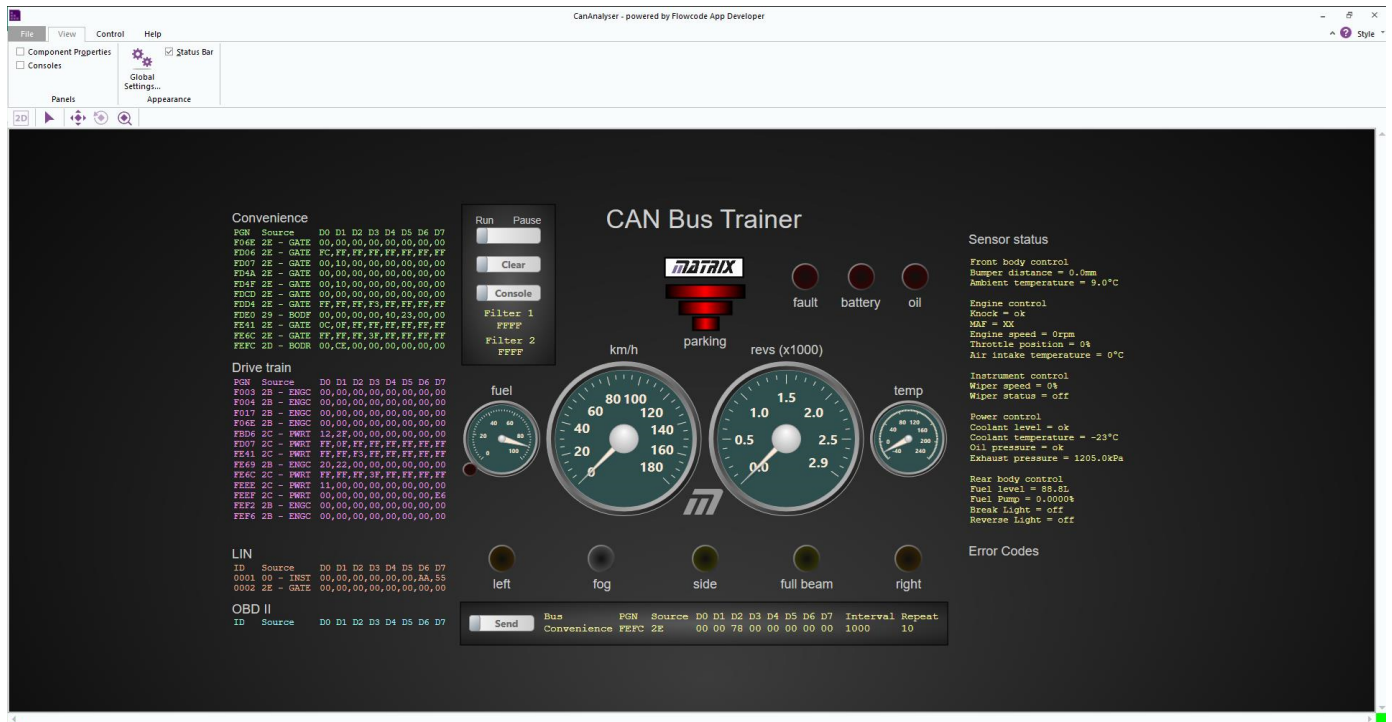
The LIN bus sits at +12V. When there is a message on it, it goes to 0V in short pulses. This brings the average voltage below 12V.

Over to you:

1. Short-circuit the bus to 0V.
What happens to the voltage on the LIN bus connector? _____
2. Short-circuit the bus to +12V.
What happens to the voltage on the LIN bus connector? _____
3. Disconnect one end of the LIN bus.
What happens to the voltage on the disconnected LIN bus? _____
4. Using settings of: time base 1ms/div, +/-20V, make sure you can trigger the oscilloscope.

Expanding the system

Adding diagnostics



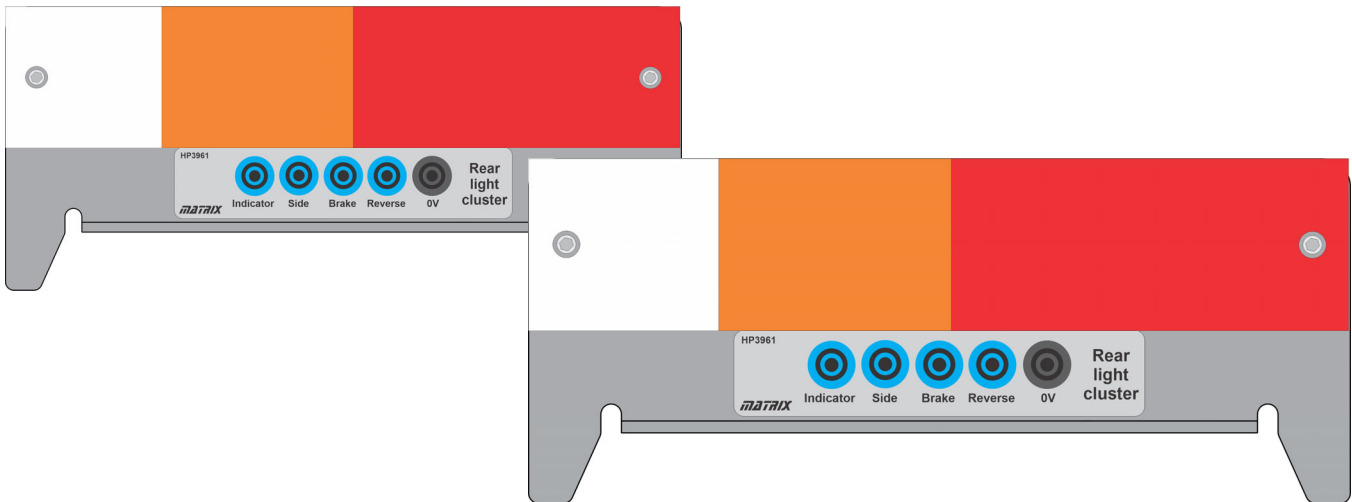
Over to you:

1. Using a standard USB cable connect the Gateway MIAC to your PC.
2. No drivers are needed for the MIAC
3. Open the "Open CANAnalyser.bat" application. See the CAN and LIN bus reference document for information on how to find this program.
4. Press the GO button on the top left hand side of the screen.
5. The on screen instruments should now reflect what is happening in the CAN bus.
6. Make sure that you are familiar with the information in the document 'CAN and LIN bus system reference'. This contains information on how to use the diagnostic software.
7. This diagnostic software will allow you to see the effects of some of the sensors more clearly.

Expanding the system



Rear light clusters



Component name: Rear light cluster.

About this component:

These can be placed in parallel with all existing lamps on the Body Control rear ECU.

ECU connection: Body Control rear

Connections - left cluster:

- 'Indicator' to MIAC output E
- 'Side' to MIAC output A
- 'Brake' to MIAC output C
- 'Reverse' to MIAC output F
- '0V' to MIAC 0V

Connections - right cluster:

- 'Indicator' to MIAC output B
- 'Side' to MIAC output A
- 'Brake' to MIAC output C
- 'Reverse' to MIAC output F
- '0V' to MIAC 0V

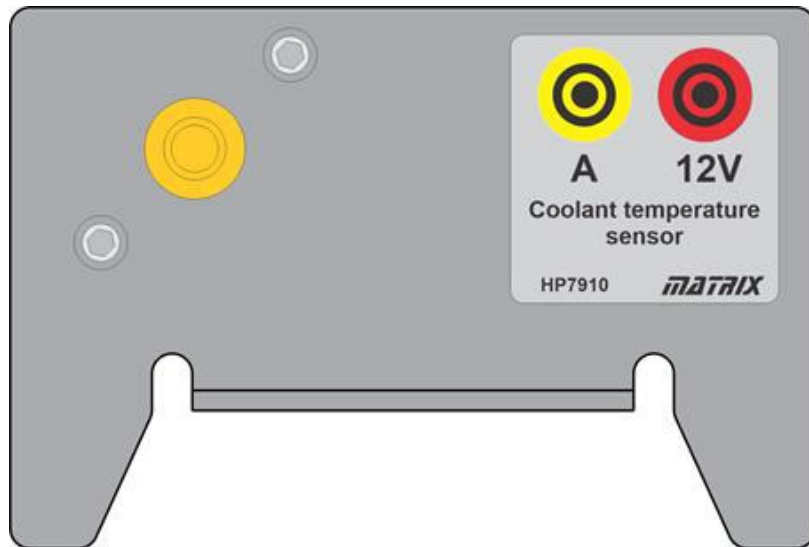
Testing:

Lights should be controlled by the switches on the Instrument Control and Powertrain Control panels.

Expanding the system



Coolant temperature sensor



Component name: Coolant temperature sensor

About this component:

You can replace the 10K potentiometer mimicking the fuel sensor with this real automotive temperature sensor. (You must take the 10k potentiometer out of circuit.)

ECU connection: Powertrain Control

Connections:

- 'A' to MIAC input I3
- '12V' to MIAC 12V

Testing:

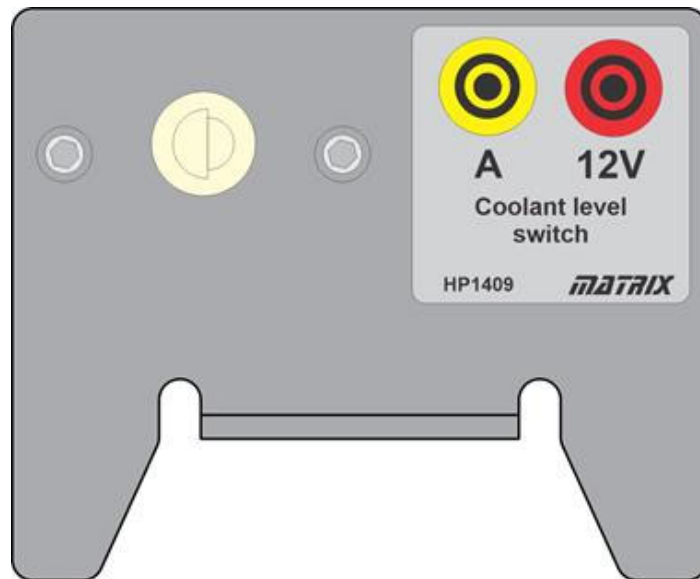
- Connect a multimeter to measure the voltage on input I3.
- Warm the sensor gently and observe the effect on the voltage at I3.
- Observe the behaviour of the 'Fault' LED.

You can see the temperature reading from the sensor on the diagnostic software.

Expanding the system



Coolant level switch



Component name: Coolant level switch

About this component:

Connecting the coolant level switch gives additional functionality to the Powertrain Control ECU. The sensor contains a magnet and a reed relay.

ECU connection: Powertrain Control

Connections:

- 'A' to MIAC input I5
- '12V' to MIAC 12V

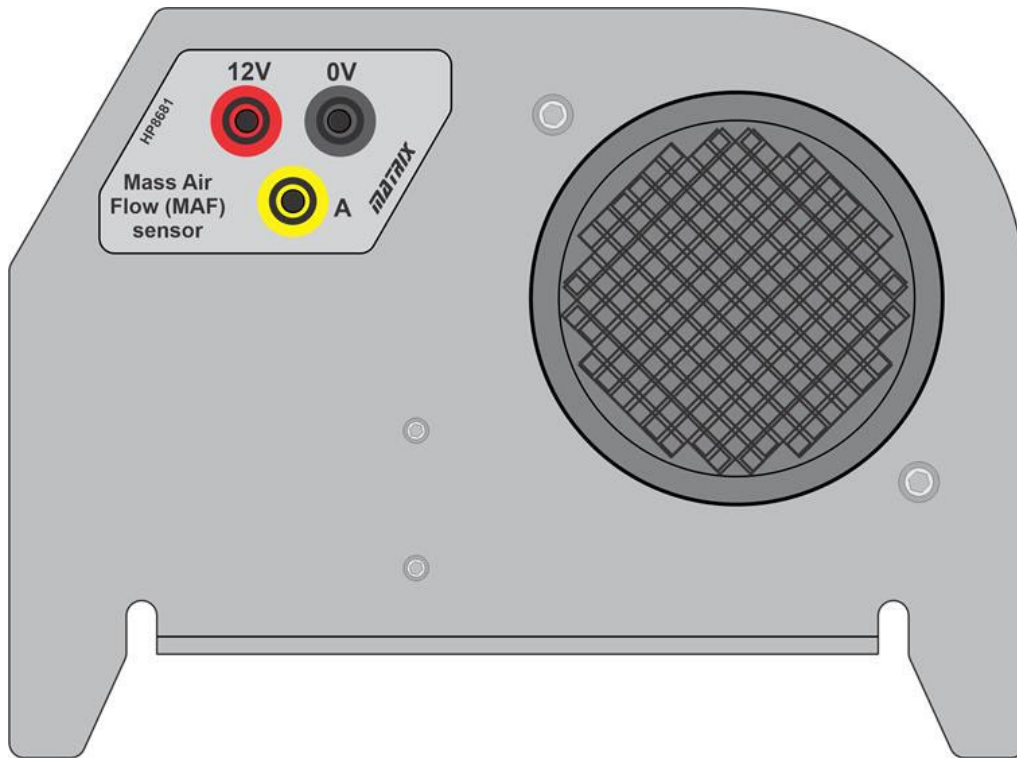
Testing:

- Connect a multimeter to measure the resistance between 12V and A
- Vary the position of the switch and note the reading on the multimeter

You can see the status of the coolant level switch on the diagnostic software.

Expanding the system

MAF sensor



Component name: Mass Air Flow Sensor - MAF

About this component:

The MAF sensor gives a pulse-width-modulated (PWM) output where the width of the pulse shortens as the airflow increases.

ECU connection: Engine Control

Connections:

- 'A' to MIAC input I6
- '12V' to MIAC 12V
- '0V' to MIAC 0V

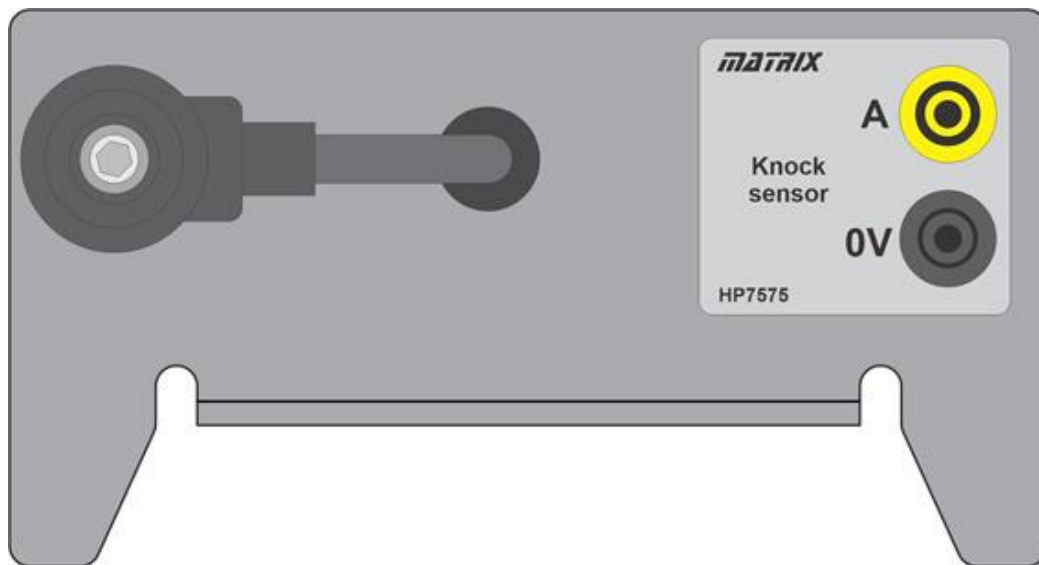
Testing:

- Connect an oscilloscope to examine the signal on input I3.
(Picoscope settings: +/-10V per div / 10ms/div timebase / trigger 3V)
- Measure the mark:space ratio of the resulting PWM signal.
- Blow air (from a hair drier) through the MAF sensor.
- Observe the behaviour of the CRO trace and recalculate the mark:space ratio.

Expanding the system



Knock sensor



Component name: Knock sensor

About this component:

The knock sensor is a simple sensor that detects short, large vibrations in the engine. Low frequency vibrations of the engine are filtered out.

When the knock sensor is triggered a vehicle engine management system adjusts the timing and power of the ignition signal. On our software you will see the word "error" appear.

Note that you will need to use a hard metallic object on the retaining bolt - plastic will not trigger the sensor. You will need to give it quite a hard hit!

ECU connection: Engine Control

Connections:

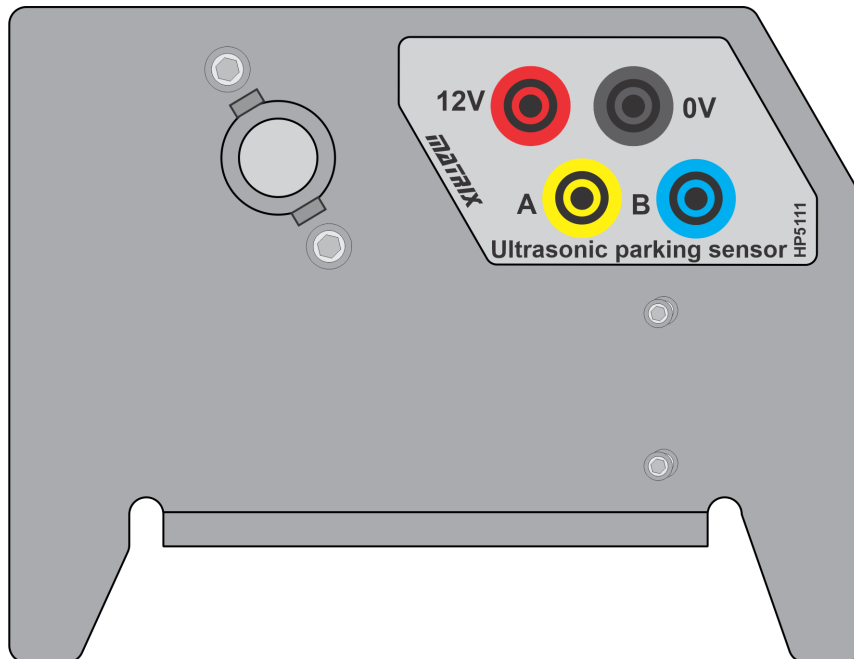
- 'A' to MIAC input I4
- '12V' to MIAC 12V
- '0V' to MIAC 0V

You can see the status of the Knock sensors on the diagnostic software.

Expanding the system



Ultrasonic parking sensor



Component name: Ultrasonic parking sensor

About this component: This parking sensor works on ultrasonic sound technology: a burst of high frequency sound (inaudible to humans) is sent from the sensor at regular intervals. The sound reflects off an object and is received by the sensor. The time difference between sending the sound and receiving the echo is measured and the distance from the object calculated.

ECU connection: Body Control front

Connections:

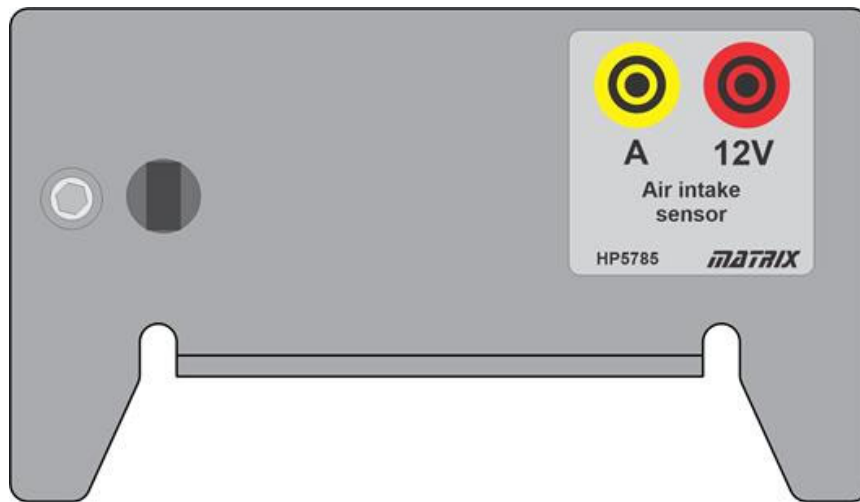
- 12V to 12V
- 0V to 0V
- A to I2
- B to output A

You can see the status of the Ultrasonic parking sensor on the diagnostic software: the green/red bars at the top of the screen show the distance of an object from the sensor..

Expanding the system



Air temperature sensor



Component name: Air intake sensor

About this component:

You can replace the potentiometer with this component which will give a reading of air temperature.

ECU connection: Engine Control

Connections:

- 'A' to MIAC input I2
- '12V' to MIAC 12V

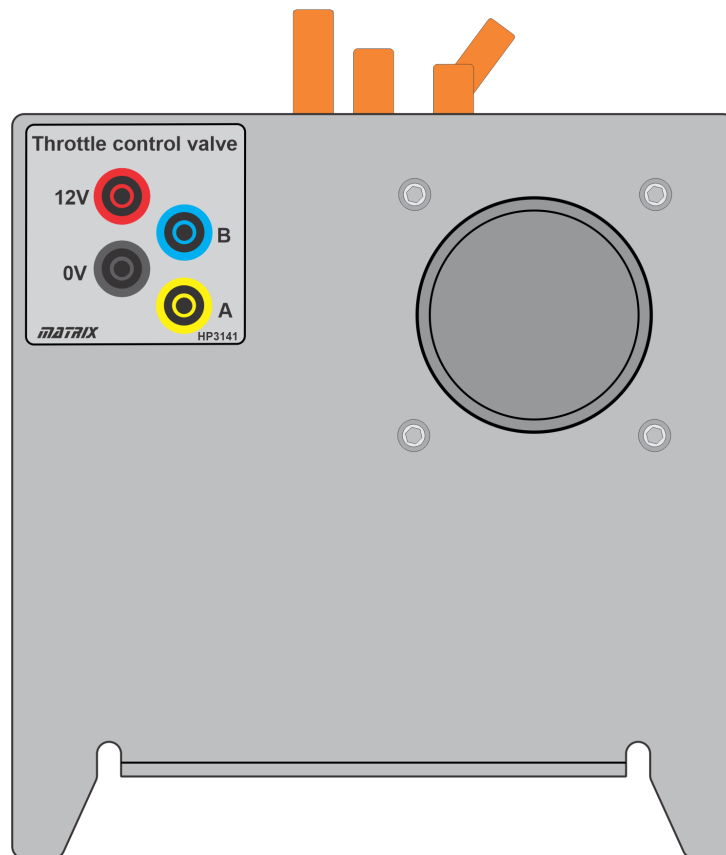
Testing:

- Warm the sensor gently and observe the effect on the voltage at I2.
- Observe the reading shown for 'Intake air temperature' on the diagnostic software

Expanding the system



Electronic throttle control valve



Component name: Electronic throttle control valve

About this component:

The Electronic control throttle valve gives additional functionality. As the throttle potentiometer - or throttle position sensor - is increased the butterfly valve will open.

Note that 12V and B connections are for future use.

ECU connection: Engine Control

Connections:

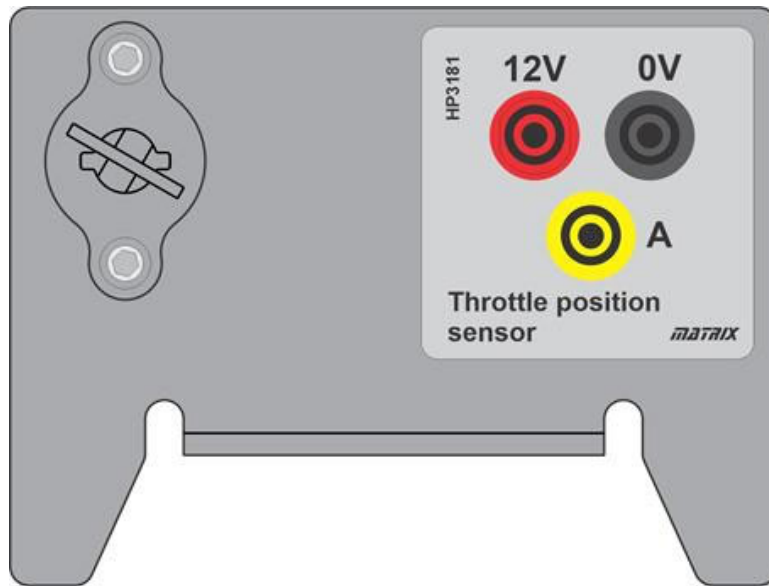
- 'A' to MIAC output A
- '0V' to MIAC 0V

When this component is connected you can also connect the bulbs on the Engine Control node to outputs C, D, E, F of the MIAC. These bulbs then show you the fuel injector signals on the four engine cylinders which are synchronised with the CAM crank sensors.

Expanding the system



Throttle position sensor



Component name: Throttle position sensor

About this component:

The throttle position sensor replaces the 10K throttle potentiometer and the two 1K resistors. The throttle position sensor varies from 0 - 10k in a fraction of a turn.

ECU connection: Engine Control

Connections:

- 'A' to MIAC input I3
- '12V' to MIAC 12V
- '0V' to MIAC 0V

Testing:

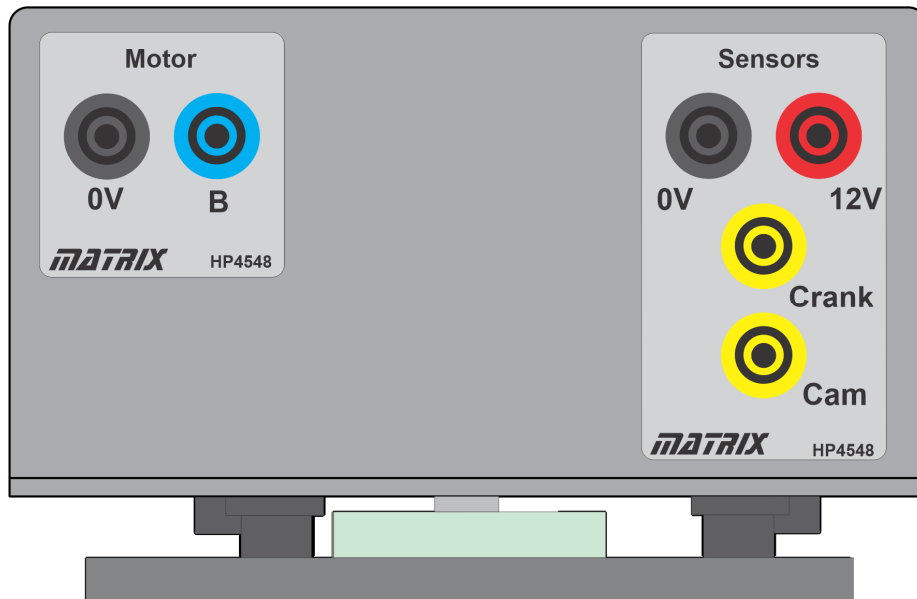
- Rotate the sensor and observe the effect on the diagnostic software.

When the CAM crank sensors are connected this will increase the speed of the motor and will cause the butterfly valve to open.

Expanding the system



Cam crank system



Component name: Cam Crank system

About this component:

The Cam crank system includes a motor and two Hall effect sensors - one for camshaft and one for the crankshaft.

If you power just the sensors part of the circuit then you can manually rotate the CAM crank wheel to see the sensors working.

ECU connection: Engine Control

Connections:

Motor

- 'B' to MIAC output B
- '0V' to MIAC 0V

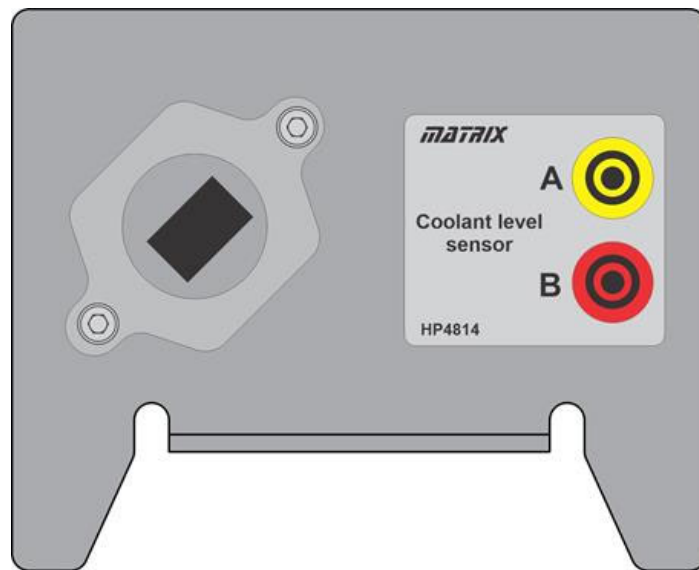
Sensors

- 'Crank' to MIAC input I7
- 'Cam' to MIAC input I1
- '12V' to MIAC 12V

Expanding the system



Coolant level sensor



Component name: Coolant level sensor

About this component:

This coolant level sensor is an alternative to the coolant level switch. You can insert it into a cup of water or use a damp cloth to change the reading.

ECU connection: Powertrain Control

Connections:

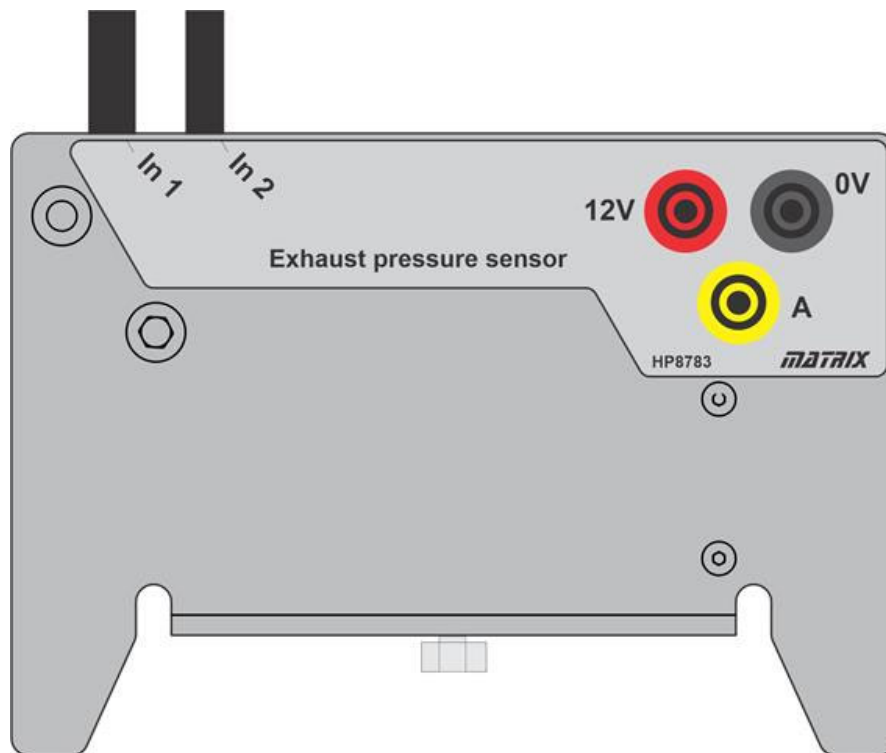
- A to input B
- B to 12V

You can see the status of the Coolant level sensor on the diagnostic software

Expanding the system



Exhaust pressure sensor



Component name: Exhaust pressure sensor

About this component:

The exhaust pressure sensor shows the difference in pressure on the two inputs.

ECU connection: Powertrain Control

Connections:

- A to input B
- B to 12V

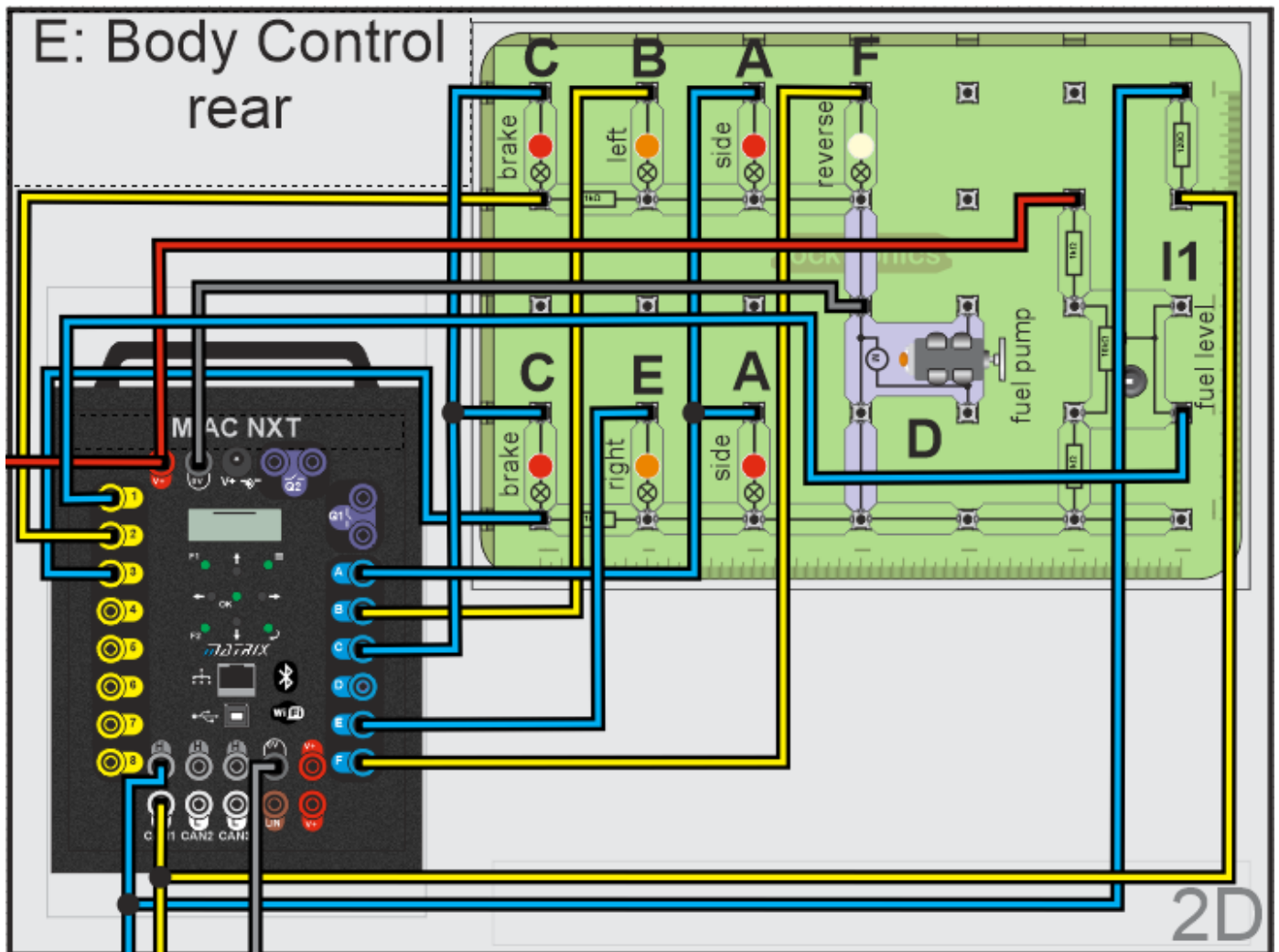
You can use the pipette and tubing supplied with the kit to alter the pressure on one of the inputs. You can see the results on the diagnostic software.

When the CAM crank system is fitted the Powertrain Control ECU will power four 'injectors': simply bulbs in this case that light when the injector outputs are on. The timing of these lamps relates to the timing of the camshaft and shows the injector pulses.

Copyright 2023 Matrix TSL

Expanding the system

Fuel pump



You can add a fuel pump to the Body Control rear as shown by the purple components in the diagram above. Connect the motor to output D of the MIAC.

The fuel pump will come on for 4 seconds on startup.

Introduction

This course gives an introduction to the use of CAN and LIN buses in automotive applications. It is a practical course designed to teach students the basics of CAN and LIN bus connections and voltages and how to debug faults in CAN and LIN systems.

Prior Knowledge

Students need an understanding of electricity in a vehicular context.

Learning Objectives

On successful completion of this course the pupil will have learned:

- Using multimeters and oscilloscopes
- CAN bus system construction and topology
- Fault-finding on CAN bus with a multimeter
- Fault-finding on CAN bus with an oscilloscope
- ECU construction
- ECU input and output characteristics
- ECU circuits
- CAN bus termination
- Use of scan tools in querying CAN bus systems
- Use of fault codes to diagnose and reset faults
- How ECUs provide fault information
- Use of multiple buses in vehicles
- LIN bus systems and topology
- Debugging faults in LIN bus systems
- Triggering an oscilloscope with CAN bus messages
- Decoding CAN bus messages with an oscilloscope

Notes for the Instructor



Worksheet	Notes
	At this initial stage, it is good to get each member of the team to build a node so that they understand the basic construction of the node and the wiring between vehicle parts and the ECU.
1 The Instrument Control node	In this worksheet, students build the Instrument Control node and use the self-test function of the MIAC to ensure that all of the Locktronics parts are
2 The Body Control Front node	In this worksheet, students build the Body Control front node and use the self-test function of the MIAC to ensure that all of the Locktronics parts are
3 The Engine Control node	In this worksheet, students build the Engine control front node and use the self-test function of the MIAC to ensure that all of the Locktronics parts are connected properly.
4 The Powertrain Control node	In this worksheet, students build the Powertrain Control node and use the self-test function of the MIAC to ensure that all of the Locktronics parts are connected properly.
5 The Body Control-rear node	In this worksheet, students build the Body Control rear node and use the self-test function of the MIAC to ensure that all of the Locktronics parts are connected properly.
6 The Power and Fuse panel	In this worksheet, students build the Power and fuse panel.
7 The Gateway and OBDII socket	In this worksheet, students wire up the Gateway and the OBDII socket. At this point, all parts of the system are now wired up. It is time to connect them together to form the CAN bus. Students should look at the system block diagram, which shows how each node is connected to the CAN bus. There are a lot of wires in the system, but overall the connection schematic is not complex. Most of the wiring is local to the particular node. Between nodes, each needs power, ground and the CAN or LIN bus connection.

Notes for the Instructor



Worksheet	Notes
8 OBDII scan and fault codes	The system is compatible with any OBDII scanner. There is no OBDII scan tool supplied with your CAN bus kit. The scanner plugs into the OBDII socket. This worksheet shows students how the scan tool is used to show fault information. The difficulty here is that scan tools give you a guide to where the fault is but don't give you an exact diagnosis. Becoming comfortable with the process of using a scan tool to detect errors is a key exercise. The system also has a Vehicle Identification Number (VIN) and you can use
9 Circuit de- sign for fault	This worksheet shows how vehicle designers build fault detection into the circuitry of the ECU and the vehicle circuit.
10 Diagnosing CAN faults with a multi- meter	A lot of faults - but not all - can be detected with a multimeter by just examining the voltage on the CAN bus. This worksheet goes over that process and the system allows students to get comfortable with the voltages and how they change with different faults. The CAN bus is rugged and the MIACs will not be broken by shorting CAN lines to 12V or 0V. Students can practice at their will. Students can also practice removing termination resistors to see the effects on the voltages.
11 Diagnosing CAN faults with a scope	This worksheet allows students to look at the CAN bus signals with an oscilloscope. Once students are familiar with how the CANH and CANL signals should look on an oscilloscope then often a scope trace can give valuable information on what a fault might be.
12 More com- plex CAN faults	This worksheet shows students why a multimeter alone is not enough to diagnose a fault - you need an oscilloscope in your tool kit too.
13 LIN bus faults	This worksheet allows students to use a multimeter and an oscilloscope to examine the LIN bus and the faults that appear on it.

Appendix 4

Bill Of Materials



The Basic CAN bus can be set up with the following parts;

CAN bus II		
2	HP2045	Shallow tray
5	HP2666	Adjustable DC power supply
1	HP2876	12V Power supply
1	HP2705	Poster
7	HP4039	Tray Lid
4	HP5540	Deep tray
5	HP7750	Daughter tray foam cutout
1	HP8681	OBDII bracket
4	HP9564	62mm daughter tray
1	LK3246	Buzzer, 12V, 15mA
6	LK5202	Resistor, 1k, 1/4W, 5% (DIN)
6	LK5206	Resistor, 120R, 1/4W, 5% (DIN)
1	LK5208	250 ohm potentiometer
8	LK5214	Potentiometer, 10K ohm (DIN)
72	LK5250	Connecting Link
17	LK5291	Lampholder, MES
10	LK5603	Red 4mm to 4mm lead, 500mm
10	LK5604	Black 4mm to 4mm lead, 500mm
32	LK5607	Blue 4mm to 4mm lead, 500mm
30	LK5609	Yellow 4mm to 4mm lead, 500mm
2	LK6207	Switch, push to make, metal strip
8	LK6209	Switch, on/off, metal strip
6	LK6574	Red 4mm to 4mm lead, 2m
2	LK6635	LED, red
2	LK6706	Motor, 12V
4	LK6749	12V LED bulb red
4	LK6822	12V LED bulb orange
13	LK6841	12V LED bulb white
1	LK8275	Power supply carrier with battery symbol
6	LK8623	Circuit breaker
6	LK8900	7 x 5 metric baseboard with 4mm pillars
6	MI5550	MIAC NXT
6	LK8654	Black 4mm to 4mm lead, 2m
4	LK7466	Blue 4mm to 4mm lead, 2m
4	LK7155	Yellow 4mm to 4mm lead, 2m
1	COM5825	UK head for HP2876
1	COM5826	EU head for HP2876
1	COM5827	USA head for HP2876

11 02 24

The CAN bus system can also be extended to work with the following real car parts on brackets:

1	HP4548	Cam and crank(Hall Effect) sensor
1	HP5111	Ultrasonic parking sensor
1	HP5785	Intake Air Temperature (Thermistor) sensor
1	HP3181	Throttle position sensor
1	HP7575	Knock Sensor
1	HP0713	Mass Air Flow Sensor
1	HP1409	Coolant level (magnetic reed) switch
1	HP7910	Coolant temperature (Thermistor) sensor
1	HP8738	Exhaust (differential) pressure sensor
2	HP3961	rear light cluster
1	HP3141	throttle valve
1	COM00170	Pipette filler
1	COM4177	4mm diameter tubing, 300mm

Version control



Frist release 13 01 23

Second release 13 04 23

Minor amends 26 04 23

Reformatting to new style 02 08 23

29 09 23 Changes to text on page 8. Image changed on page 8.

21 11 23 made early images clearer and put resistor values on Locktronics layouts

11 03 24 Small Bom changes on page 42