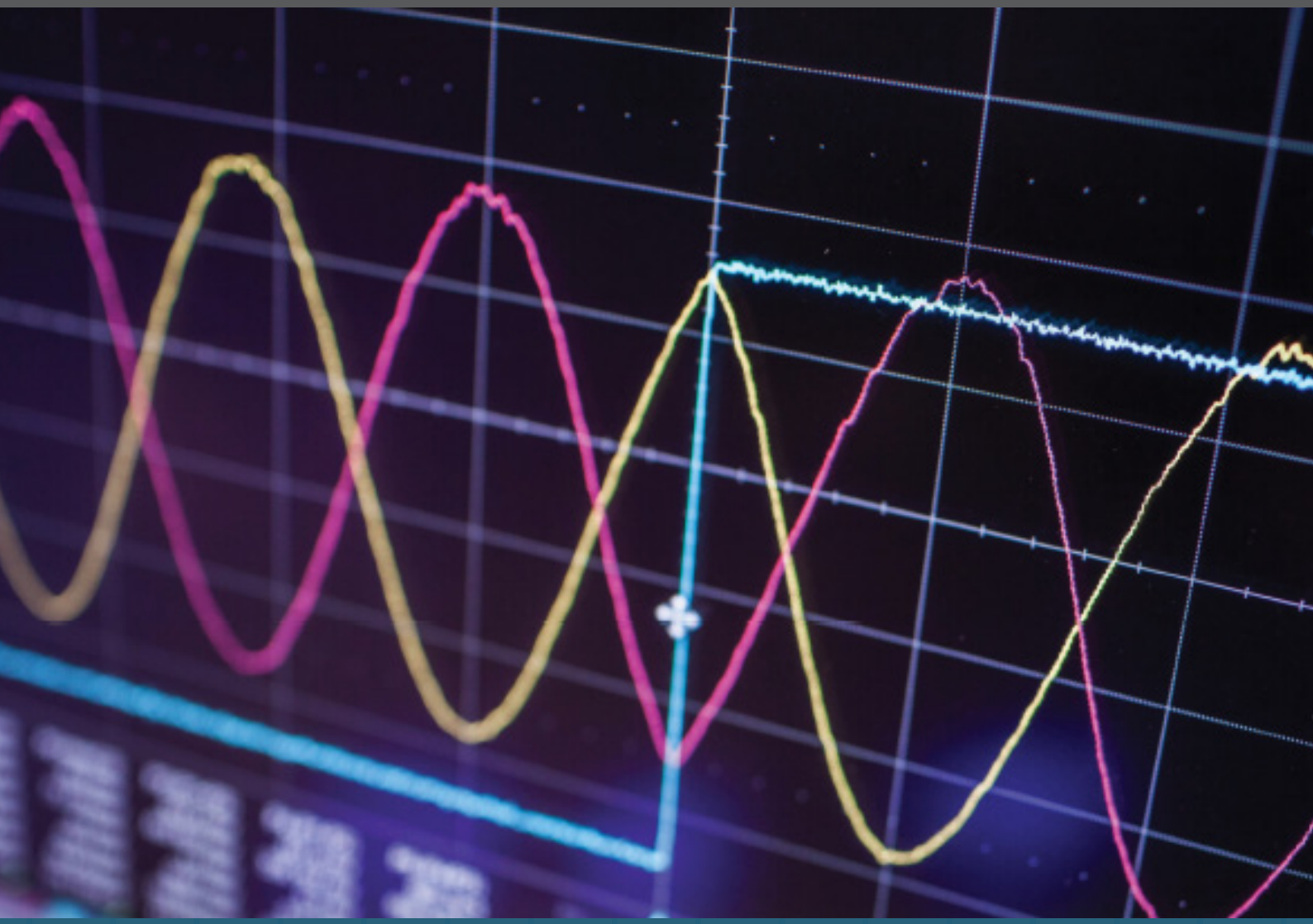

AUTOMOTIVE OSCILLOSCOPE USE

CP5950

Inspiring The Next Generation Of Engineers

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Contents

WORKSHEETS

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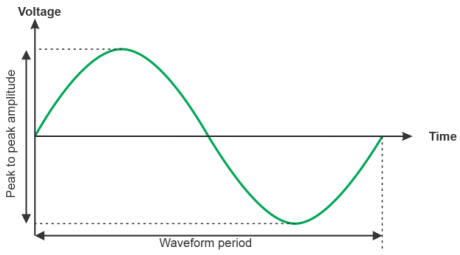
Worksheet 1 - Simple Analogue Signals

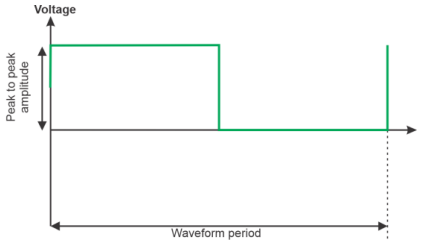
Multimeters and clamp meters are great for showing us static values of voltage and current in a vehicle. But when we are trying to diagnose problems in systems that have signals that are changing quickly then an oscilloscope is needed to capture those signals and display them.

The difficulty here is that to capture the signals you need to understand how to 'trigger' the oscilloscope. This is not always straightforward.

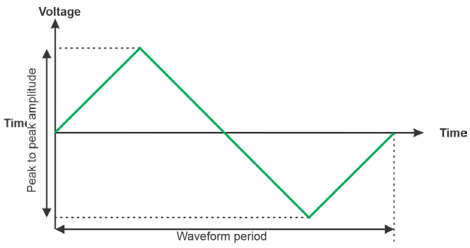
The photograph shows a Fluke handheld oscilloscope.



Sine wave



Square wave



Triangle wave

Over to you:

- Power up the Oscilloscope trainer. Read the section on 'Using the oscilloscope trainer' in the Reference section to familiarise yourself with how the trainer works and its outputs.
- Use the Trace Up and trace down buttons (on the left of the display) to select the Generic Sine wave.
- Read the manual on your oscilloscope. Understand how to adjust the time base, the trigger level, and the trigger settings. Put it on Auto trigger for now.
- Use the secondary up down buttons to set the unit to the highest output frequency. Set up the oscilloscope so that it shows a nice stable trace.
- Sketch the waveform on the space in the student handout and mark the 0V line in bold
- Fill in the square boxes against the vertical and horizontal graticules
- In the student handout fill in the tables for oscilloscope settings and waveform information.
- Use the Trace Up and trace down buttons (on the left of the display) to select the Generic Triangle wave and use the secondary buttons to choose the lowest frequency. Sketch the waveform again and fill in the table.

So What?

- On nicely regular repeating waveforms the Oscilloscope is easy to trigger. Setting the trigger on Auto is probably going to give you the information you need.
- This is harder on irregular waveforms.

Our (very) rough guide on triggering an oscilloscope for automotive is:

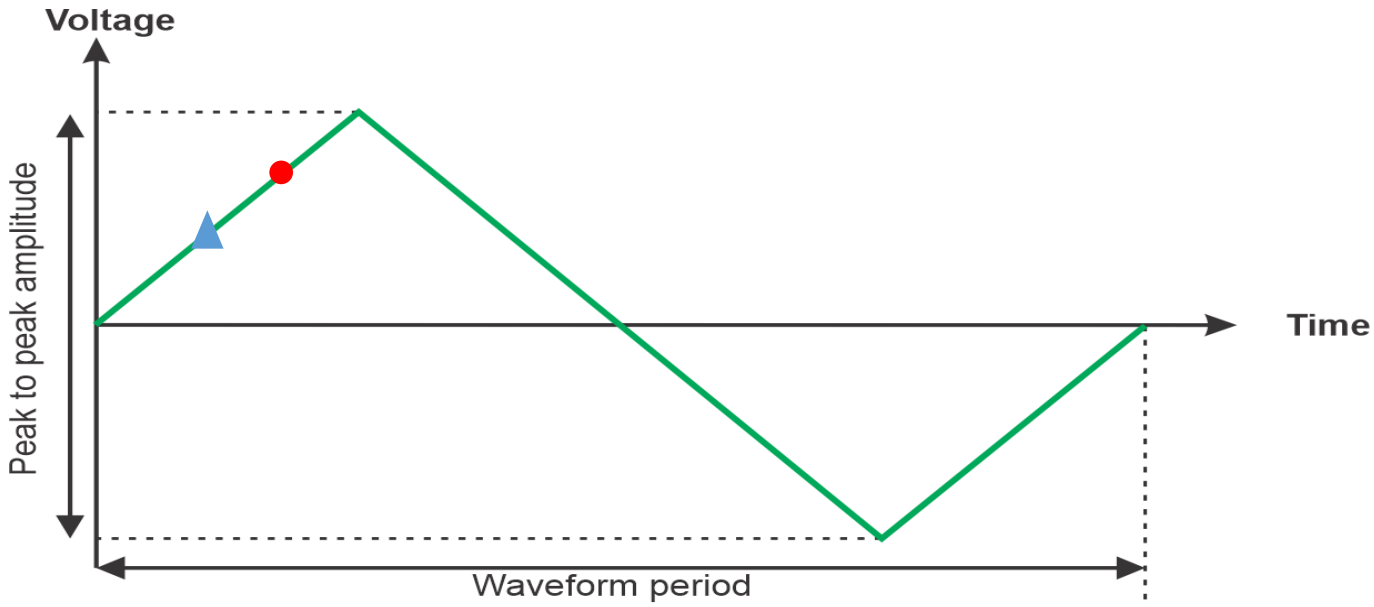
1. Don’t use auto trigger
2. Don’t use auto ranging
3. Set to continuous run and get 0v traces on screen before applying signal inputs
4. Set vertical voltage range to the maximum expected from the input signals
5. Connect the input signals
6. Adjust the vertical resolution if necessary (if the peak goes off screen, or to expand the view)
7. Set the trigger level to just below the signal trace voltage peak (assuming a positive input signal)
8. Set trigger mode, if no trigger occurs, adjust the trigger level slightly until it does
9. Adjust the timebase to bring the signal feature into view

WORKSHEETS

Worksheet 2 - Manual Trigger

The trigger level on an oscilloscope sets the voltage at which the scan of the oscilloscope trace starts. Triggering an oscilloscope can be a multistage process: put it on Auto trigger, find out the peak to peak values of the oscilloscope, determine which part of the waveform you want to see, put the trigger on manual and fine tune.

Photograph shows a Pico oscilloscope connected to a laptop.

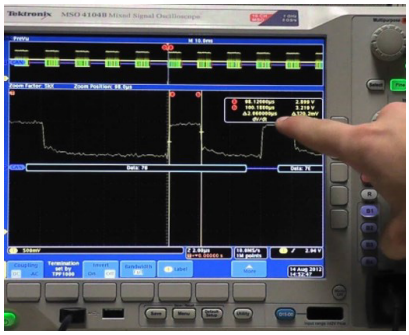


Over to you:

- Use the Trace Up and trace down buttons to select the triangle wave output.
- Switch the trigger to Manual.
- Alter the trigger level so that the left hand of the waveform starts at different points in the triangle waveform cycle. Referring to the diagram above get the trigger to activate at the small blue triangle and the small red dot.
- Answer the questions in the student handbook

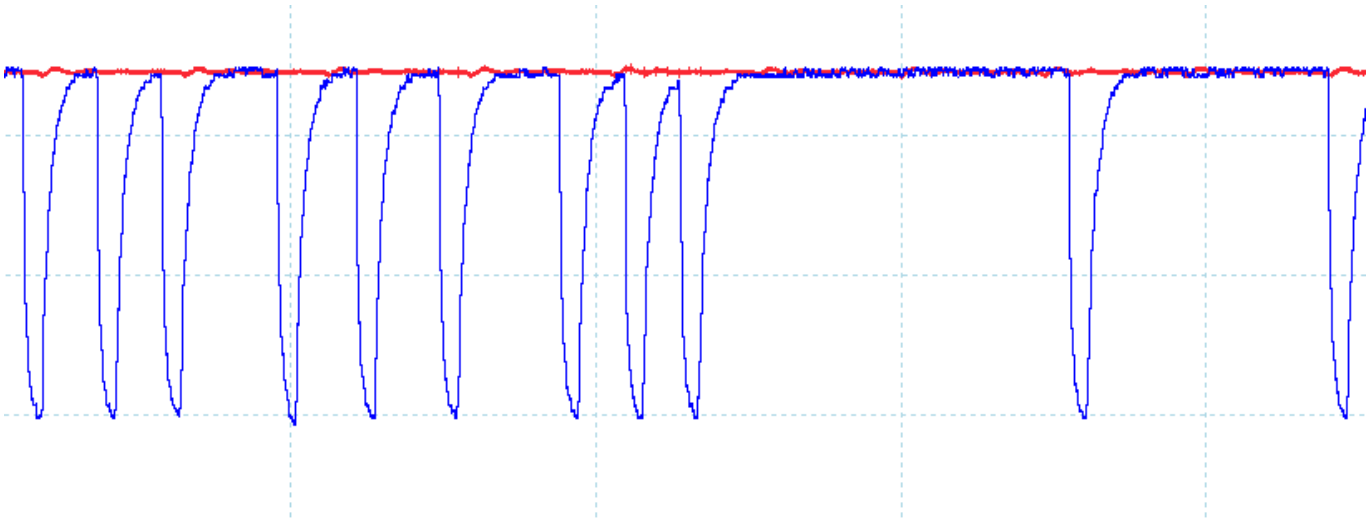
WORKSHEETS

Worksheet 3 - Irregular Waveforms



Most of the signals in a petrol or diesel car are periodic - they are repetitive and driven by the engine cycle. But some modern automotive signals are repetitive but irregular and are harder to capture. Some signals are not repetitive with the engine cycle but are driven by events in the vehicle - like a CAN bus signal.

The photograph shows an oscilloscope showing a SENT bus signal.



The waveforms you have looked at so far have been regular - they repeat over a certain period. Some waveforms - particularly digital signals - are irregular and harder to see using an oscilloscope.

Over to you:

- Use the Trace Up and trace down buttons to select the Exhaust pressure waveform
- Switch your oscilloscope trigger to 'auto'. What happens? Could you take measurements from this?
- Adjust the trigger voltage so that it is in the middle of the trace
- Switch your oscilloscope trigger to 'Single'. Capture a single trace. It should look something like the above.

So What?

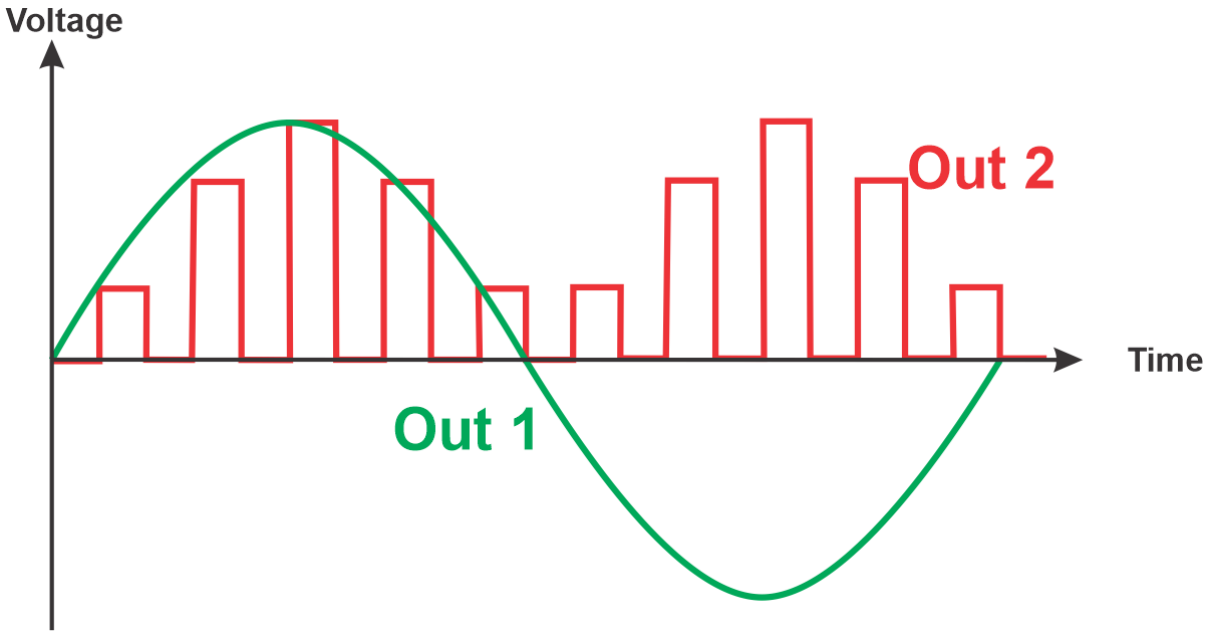
- At a first glance it looks like the Exhaust pressure sensor waveform is not repetitive. But it does repeat although the pattern is a strange one.

WORKSHEETS

Worksheet 4 - Two Channel Waveforms

Nearly all oscilloscopes allow you to measure two waveforms at once. This is really useful where the timing of two signals in relation to each other is critical or where it is difficult to trigger on a waveform of interest: you can trigger on one waveform and look at the information in another.

The photograph shows a current clamp in a vehicle.



Over to you:

- Use the Trace Up and trace down buttons to select the Dual trace waveform.
- Put channel A of your oscilloscope onto Out 2.
- Try to trigger the waveform using the Auto trigger and the Single trigger modes.

So What?

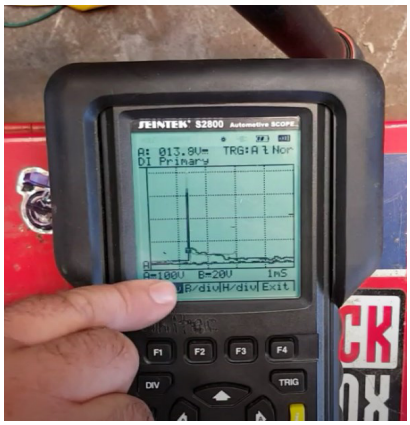
When waveforms are not repeating regularly at the timebase you are interested in they can be very hard to see with an oscilloscope.

Over to you:

- Put channel A of your oscilloscope onto Out 2.
- Put channel B of your oscilloscope onto Out 1.
- Trigger your oscilloscope to Channel A to Auto trigger.
- Now trigger on Channel B.
- Answer the questions in the handout.

WORKSHEETS

Worksheet 5 - PWM Waveforms



Pulse Width Modulation is used in all motor control circuits as a way of controlling the power to a motor. The ratio of power on to power off is pulsed many times a second to allow us to control the average power supplied to a motor. This give us speed control of the motor.

Photograph shows a handheld oscilloscope showing a secondary ignition signal.

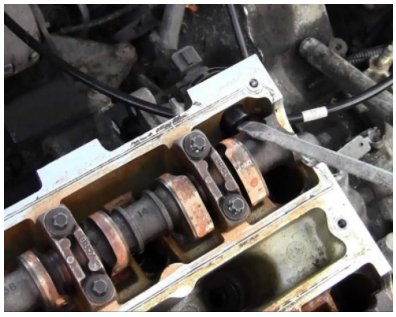
The photograph shows a handheld oscilloscope being used to diagnose motor faults.

Over to you:

- Use the Trace Up and trace down buttons to select the PWM signal.
- Put channel A of your oscilloscope onto Out 1
- Select an appropriate trigger mode
- Use the sub selection up and down buttons to vary the PWM percentage output between 30 % and 70 %.
- Use the oscilloscope to measure the time the pulse is high and the time the pulse is low.
- Prove mathematically that the percentage of power is 30% and 70% for the two settings using the timings from the oscilloscope trace.
- Follow the instructions in the Student handout.

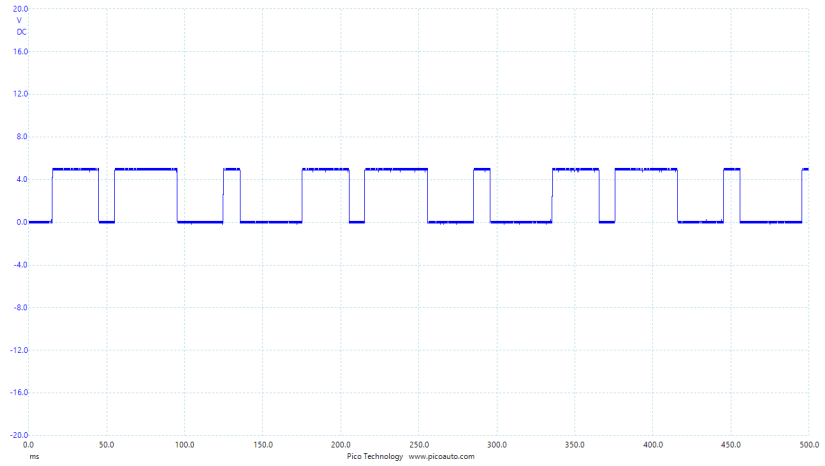
WORKSHEETS

Worksheet 6 - Camshaft Sensor



The camshaft sensors is usually a three wire Hall effect sensor that measures the presence of steel under the sensor head. It allows the ECU to understand the angle the camshaft is at and is vital for the timing of fuel injection and ignition.

The photograph shows a Camshaft sensor.



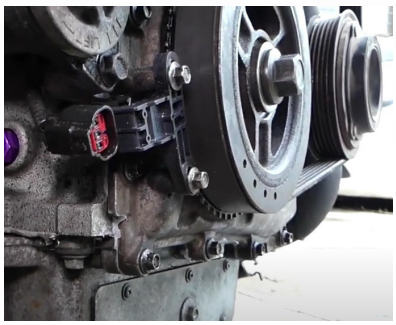
This image shows the camshaft waveform for a VW Passat.

Over to you:

- Use the Trace Up and trace down buttons to select the Camshaft waveform
- Put channel A of your oscilloscope onto Out 1
- Set up the oscilloscope so that the waveform is stable on the screen
- Follow the instructions in the Student handout.

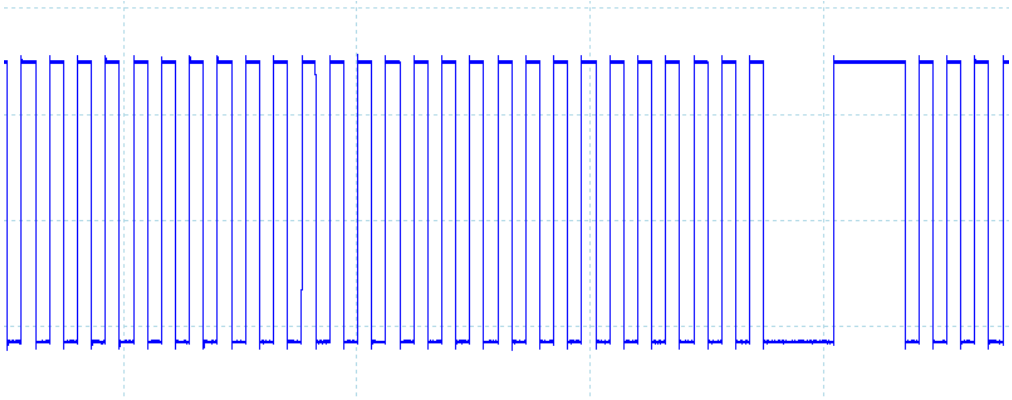
WORKSHEETS

Worksheet 7 - Crankshaft Sensor



Like the camshaft sensor the crankshaft sensors is usually a three wire Hall effect sensor that measures the presence of steel under the sensor head. It allows the ECU to understand the angle the camshaft is at and is vital for the timing of fuel injection and ignition.

The photograph shows a crankshaft sensor. (in red plastic connector removed)



This image shows the crankshaft waveform for a VW Passat.

Over to you:

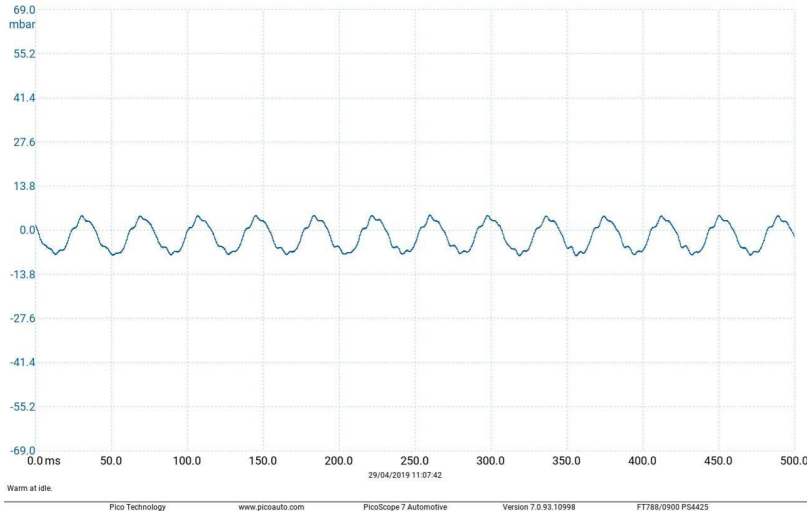
- Use the Trace Up and trace down buttons to select the Crankshaft waveform
- Put channel A of your oscilloscope onto Out 1
- Set up the oscilloscope so that the waveform is stable on the screen
- Follow the instructions in the Student handout.

WORKSHEETS

Worksheet 8 - Exhaust Pressure Sensor

The exhaust pressure sensor measures the difference in pressure across the particulate filter in diesel cars. This allows the ECU to estimate the amount of soot in the filter.

Image shows exhaust pressure sensor for Nissan / Vauxhall / Renault cars.



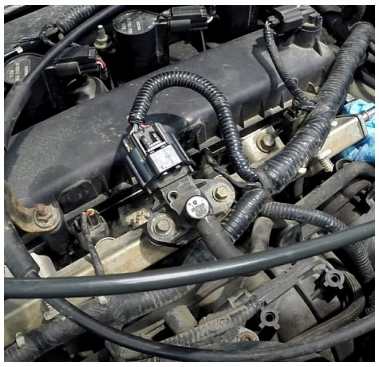
This image shows an exhaust pressure waveform.

Courtesy Pico Technology Limited

Over to you:

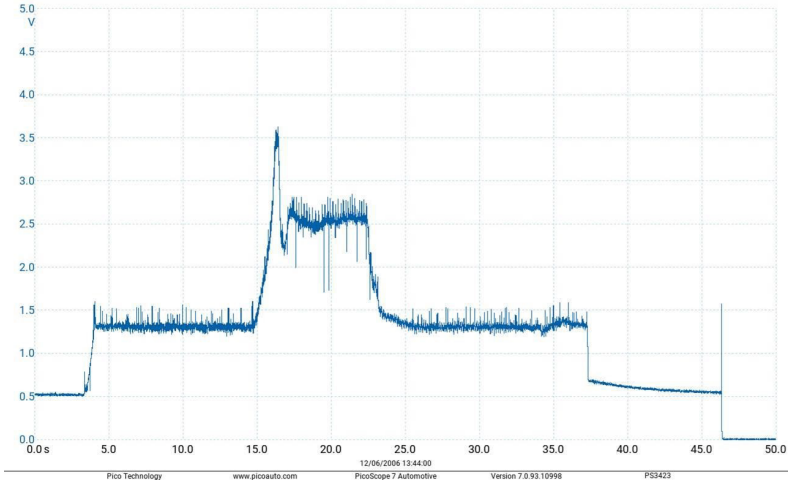
- Use the Trace Up and trace down buttons to select the Exhaust pressure waveform
- Put channel A of your oscilloscope onto Out 1
- Set up the oscilloscope so that the waveform is stable on the screen
- Follow the instructions in the Student handout.

Worksheet 9 - Fuel Pressure Sensor



The fuel pressure sensor is used to monitor the pressure of the fuel in the fuel rail after the fuel pump. Regulating pressure is important in ensuring that the right amount of fuel is delivered to the cylinders by the ECU.

The photograph shows a fuel pressure sensor on the top of the crank case.



This image shows an exhaust pressure waveform.

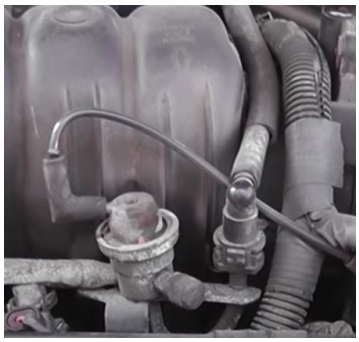
Courtesy Pico Technology Limited

Over to you:

- Use the Trace Up and trace down buttons to select Fuel pressure waveform
- Put channel A of your oscilloscope onto Out 1
- Set up the oscilloscope so that the waveform is stable on the screen
- Follow the instructions in the Student handout.

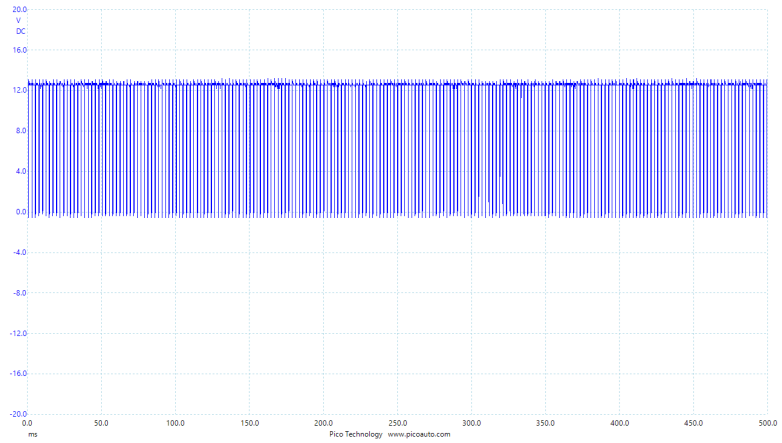
WORKSHEETS

Worksheet 10 - Fuel Pressure Regulator Drive



The fuel pressure regulator is a valve that is used to ensure that the pressure in the fuel rail is correct. The ECU takes in the reading from the fuel pressure sensor and controls the aperture of the valve with the regulator waveform. In conjunction with the fuel pressure sensor and the fuel pump the ECU controls the rate of fuel flow into the engine.

The photograph shows a fuel pressure regulator on an engine.



This image shows the fuel pressure regulator waveform for a VW Passat.

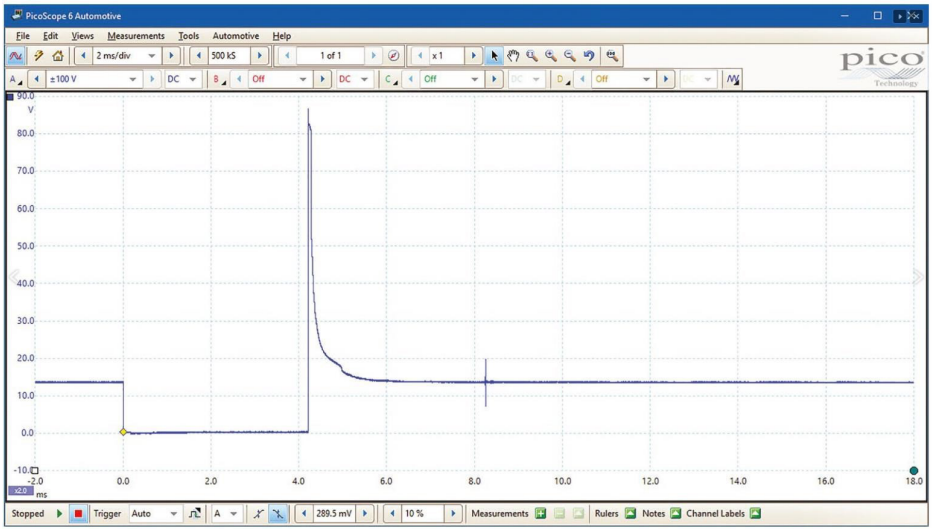
Over to you:

- Use the Trace Up and trace down buttons to select the Fuel pressure waveform
- Put channel A of your oscilloscope onto Out 1
- Set up the oscilloscope so that the waveform is stable on the screen
- Follow the instructions in the Student handout.

Worksheet 11 - Injector Current

Injectors control the amount of fuel pumped into the cylinder. If the waveform is too short, too long, or weak then the incorrect amount of fuel will be delivered to the cylinder. An oscilloscope with a current clamp is a great way to monitor the fuel delivered to each cylinder.

The photograph shows fuel injectors on an engine.



This image shows an injector voltage waveform

Over to you:

- Use the Up and Down buttons to select the injector waveform
- Put channel A of your oscilloscope onto Out 1
- Connect a current clamp to the oscilloscope
- Set up the oscilloscope so that the waveform is stable on the screen
- Follow the instructions in the Student handout.

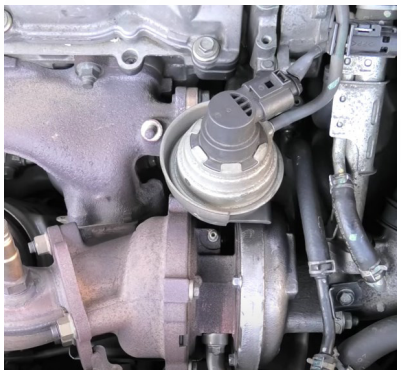
The Mass Air Flow sensor is used to measure the rate of air entering the engine. The ECU needs this information so that it can deliver the correct fuel mass to the cylinder.

The photograph shows a MAF sensor on an engine.

Over to you

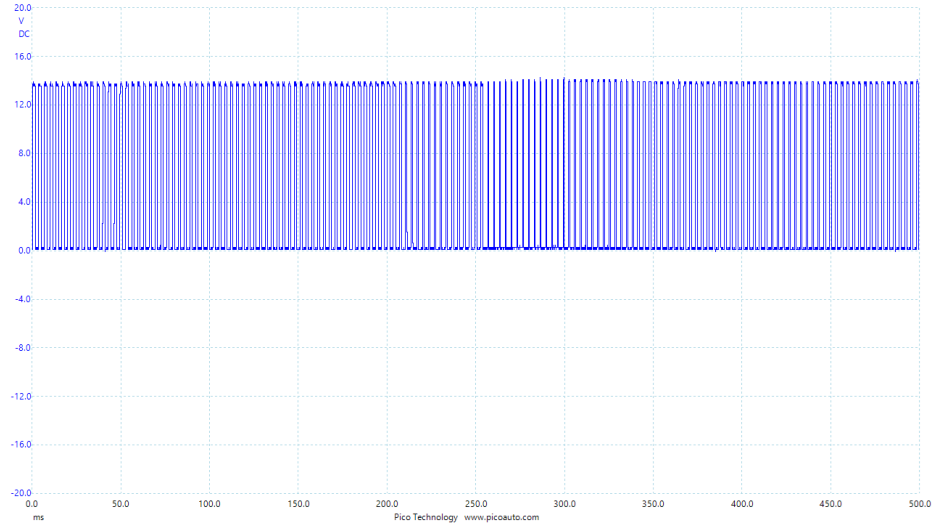
- Use the Up and Down buttons to select the MAF waveform.
- Put channel A of your oscilloscope onto Out 1
- Set up the oscilloscope so that the waveform is stable on the screen
- Follow the instructions in the Student handout.

Worksheet 13 - Turbo Actuator Drive



The turbo actuator acts as a pressure relief valve that controls the boost output of your turbo, diverting excess exhaust gases away from the turbine wheel. This controls the speed of the turbine, preventing it from over-speeding, and regulating the speed of the compressor.

The photograph shows a turbo actuator on an engine.



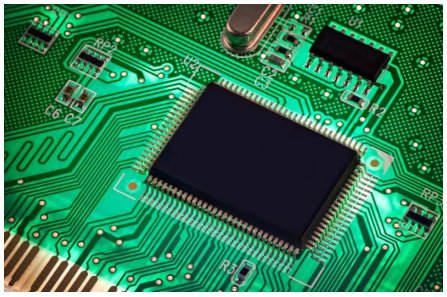
This image shows an turbo actuator drive waveform for a VW Passat.

Over to you

- Use the Up and Down buttons to select the turbo waveform.
- Put channel A of your oscilloscope onto Out 1
- Set up the oscilloscope so that the waveform is stable on the screen
- Follow the instructions in the Student handout.

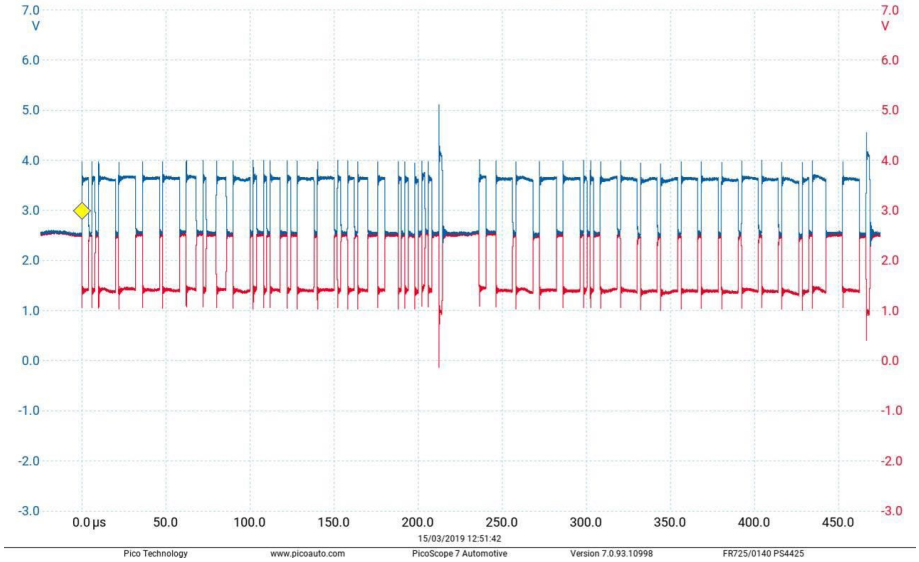
WORKSHEETS

Worksheet 14 - CAN Bus Signals



The CAN bus is the standard communication system used in virtually all vehicles. It is probably the hardest bus to understand. All you can do is capture the signal, ensure that the voltages are correct and if you have a smart automotive oscilloscope you can decide the CAN bus signal to get a raw message - although the oscilloscope will not tell you what that message means.

The photograph shows an ECU in a car.



This image shows a CAN bus waveform.

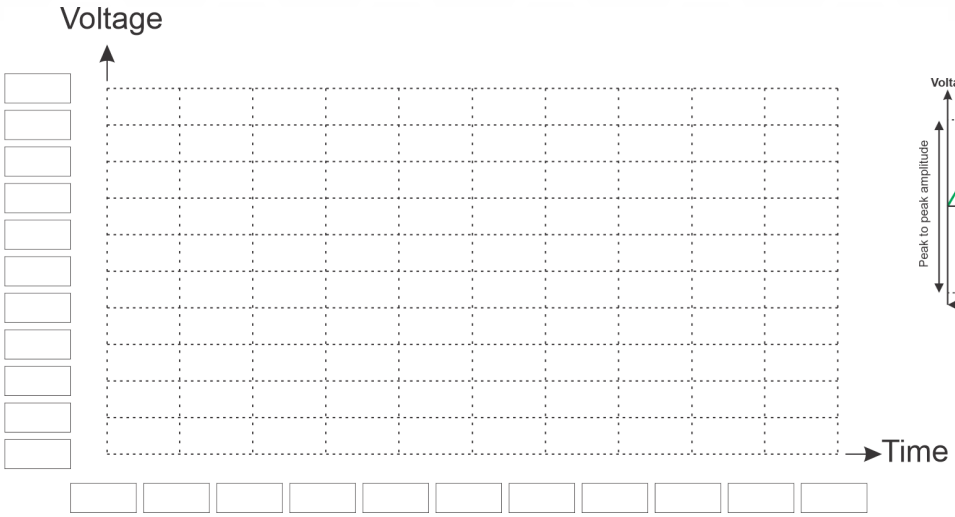
Courtesy Pico Technology Limited

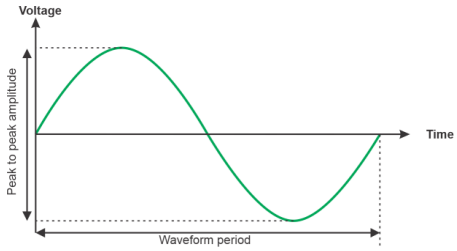
Over to you

- The 250kbaud CAN bus signals are on CAN H and CAN L for all settings of the Oscilloscope trainer.
- Put channel A of your oscilloscope onto CAN H, and put channel B of your oscilloscope onto CAN L.
- You will see a CAN bus message repeated at set intervals
- Set up the oscilloscope so that the waveform is captured on the screen
- Follow the instructions in the Student handout.

STUDENT HANDOUT

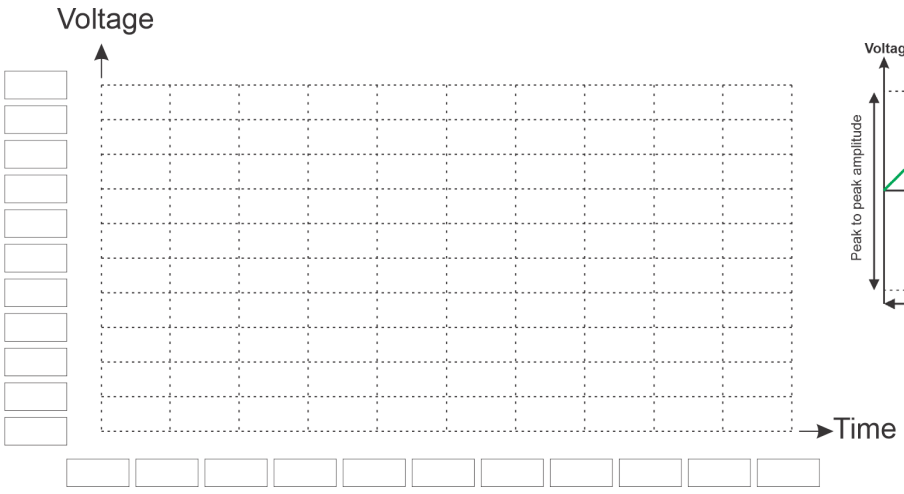
Worksheet 1 - Simple Analogue Signals

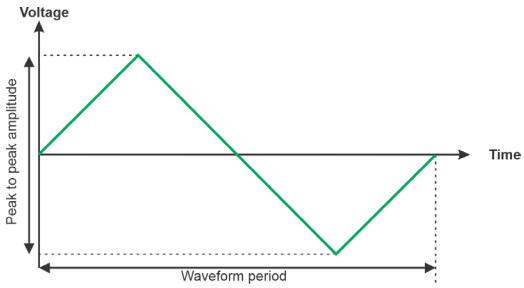




Setting	Measurement
Time per divison	s
Voltage per person	V
Trigger mode	Auto

Setting	Measurement
Period	s
Peak to peak voltage	V





Setting	Measurement
Time per divison	s
Voltage per person	V
Trigger mode	Auto

Setting	Measurement
Period	s
Peak to peak voltage	V

Worksheet 2 - Manual Trigger

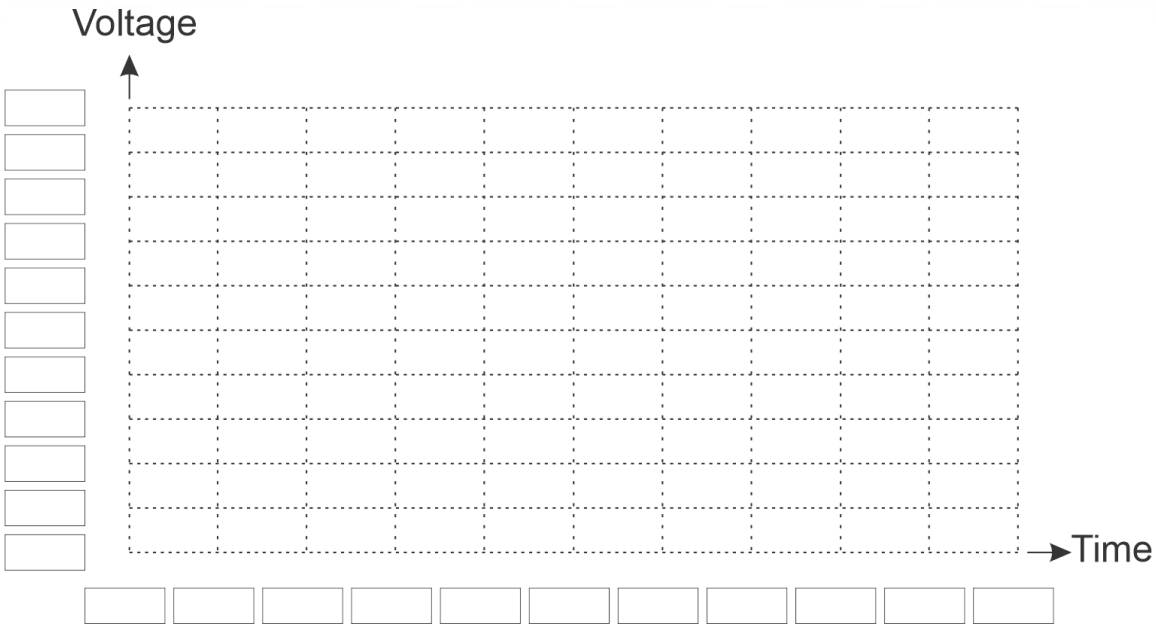
What happens when the trigger level is higher than the peak voltage of the waveform?

What happens when the trigger level is lower than the peak voltage of the waveform?

The inputs to the oscilloscope can be AC coupled or DC coupled. What difference does this make to how you see the trace?

(You may need to refer to the oscilloscope handbook to understand how to change the settings.)

Worksheet 3 - Non Repeating Waveforms



Over to you

- Set the timebase to 500us.
- Capture a complete cycle of the waveform. The signal is repetitive.
- Zoom in in time until you have just one complete cycle on your display
- Sketch the waveform on the oscillogram above.

Using your oscilloscope measure the width of each of the pulses (the time from when the waveform goes high to when it goes high again) in the waveform and enter the information below:

Pulse 1 _____
Pulse 2 _____
Pulse 3 _____
Pulse 4 _____
Pulse 5 _____
Pulse 6 _____
Pulse 7 _____
Pulse 8 _____
Pulse 9 _____
Pulse 10 _____
Pulse 11 _____

Worksheet 4 - Two Channel Waveforms

Over to you

Why will the oscilloscope show a static waveform when triggered on channel A and not on Channel B?

_____

_____

_____

Worksheet 5 - Pulse Width Modulation

Fill in the table to show how the settings you used to trigger the oscilloscope:

Setting	Measurement
On time at 30%	s
Off time at 30%	s
Ratio of On to Off	%
On time at 70%	s
Off time at 70%	s
Ratio of On to Off	%

Worksheet 6 - Camshaft Sensor

Fill in the table to show how the settings you used to trigger the oscilloscope:

Setting	Measurement
Time per division	s
Voltage per division	V
Trigger mode	
Trigger channel	
Trigger direction	
Trigger threshold	V

Worksheet 7 - Crankshaft Sensor

Fill in the table to show how the settings you used to trigger the oscilloscope:

Setting	Measurement
Time per division	s
Voltage per division	V
Trigger mode	
Trigger channel	
Trigger direction	
Trigger threshold	V

Over to you

- Now select the waveform Camshaft and Crankshaft.
- Connect Out 1 to Channel A and Out 2 to Channel B.
- You can now see the camshaft and the crankshaft sensors together. Experiment with triggering the pair of waveforms on each channel. Which channel presents the easiest way to view the waveform?

Worksheet 8 - Exhaust Pressure Sensor

Fill in the table to show how the settings you used to trigger the oscilloscope:

Setting	Measurement
Time per division	s
Voltage per division	V
Trigger mode	
Trigger channel	
Trigger direction	
Trigger threshold	V

Worksheet 9 - Fuel Pressure Sensor

Fill in the table to show how the settings you used to trigger the oscilloscope:

Setting	Measurement
Time per division	s
Voltage per division	V
Trigger mode	
Trigger channel	
Trigger direction	
Trigger threshold	V

Worksheet 10 - Fuel Pressure Regulator Drive

Fill in the table to show how the settings you used to trigger the oscilloscope:

Setting	Measurement
Time per division	s
Voltage per division	V
Trigger mode	
Trigger channel	
Trigger direction	
Trigger threshold	V

Worksheet 11 - Injector Current

Fill in the table to show how the settings you used to trigger the oscilloscope:

Setting	Measurement
Time per division	s
Voltage per division	V
Trigger mode	
Trigger channel	
Trigger direction	
Trigger threshold	V

Worksheet 12 - MAF Sensor

Fill in the table to show how the settings you used to trigger the oscilloscope:

Setting	Measurement
Time per division	s
Voltage per division	V
Trigger mode	
Trigger channel	
Trigger direction	
Trigger threshold	V

Worksheet 13 - Turbo Actuator Drive

Fill in the table to show how the settings you used to trigger the oscilloscope:

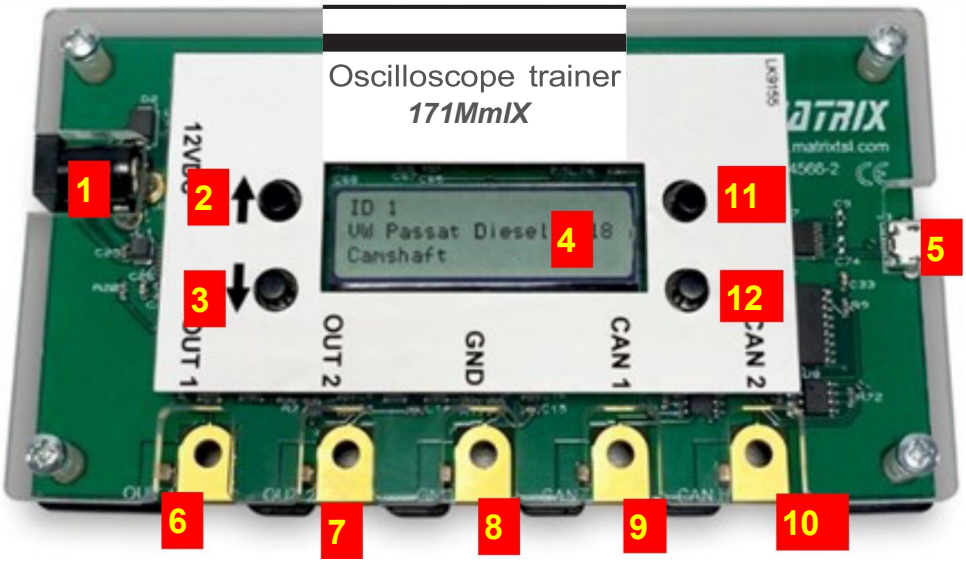
Setting	Measurement
Time per division	s
Voltage per division	V
Trigger mode	
Trigger channel	
Trigger direction	
Trigger threshold	V

Worksheet 14 - CAN Bus Waveforms

What is the data transmitted in the CAN bus waveform?

REFERENCE

Using the Oscilloscope Trainer



Connections

Referring to the above photograph the numbered items are:

1. Power jack - 12V
2. Trace up button
3. Trace down button
4. Display
5. USB socket for reprogramming
6. Out 1 terminal
7. Out 2 terminal
8. Ground terminal
9. CAN Low terminal
10. CAN high terminal
11. Sub selection up
12. Sub selection down

Using the oscilloscope trainer

1. Insert the power connector
2. Use the up and down buttons to change the waveform that is emitted from the connectors at the bottom of the waveform generator.
3. Put the Ground of the oscilloscope on the centre connector
4. Put the oscilloscope probe on the terminal you are interested in
5. Trigger oscilloscope to see the waveform.

Reprogramming the Oscilloscope Trainer

Prerequisites

- PC installed with Programmer software “STMFlashLoader Demo.exe” and USB driver. These will be supplied by Matrix
- Firmware hex file: CP5050 Osc Trainer Firmware.hex or new .hex file with your images on supplied by Matrix
- Micro USB lead
- Digital Volt Meter

Programming the LK9155 (PCB4566-2) with firmware

Connect the Oscilloscope trainer to the PC via a Micro USB cable (nb. Do not connect the 12v PSU)

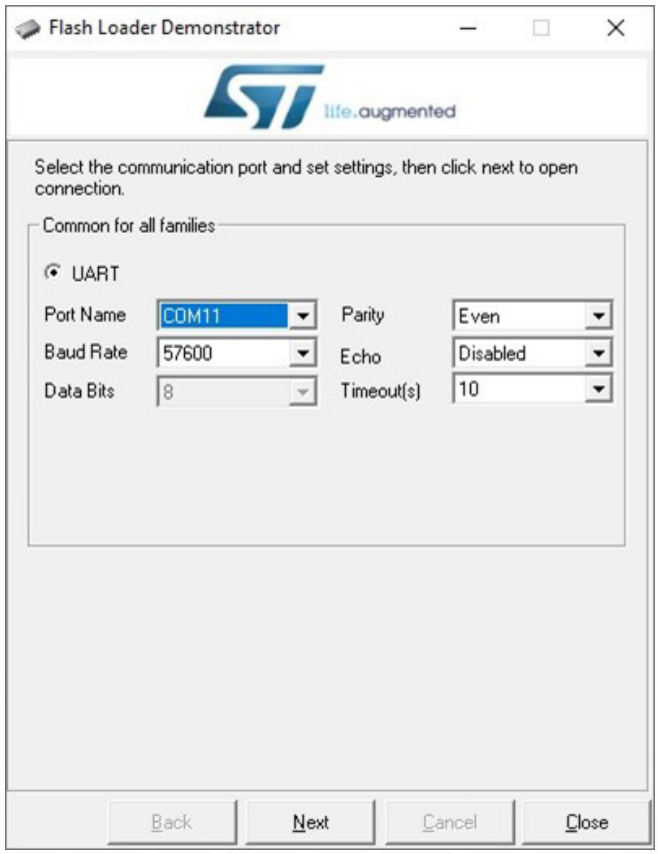
Run the PC Device Manager and check that the USB port is detected.

It is listed here as “USB Serial Port (COM11)”

In your case the COM number will likely be different, make a note of it.

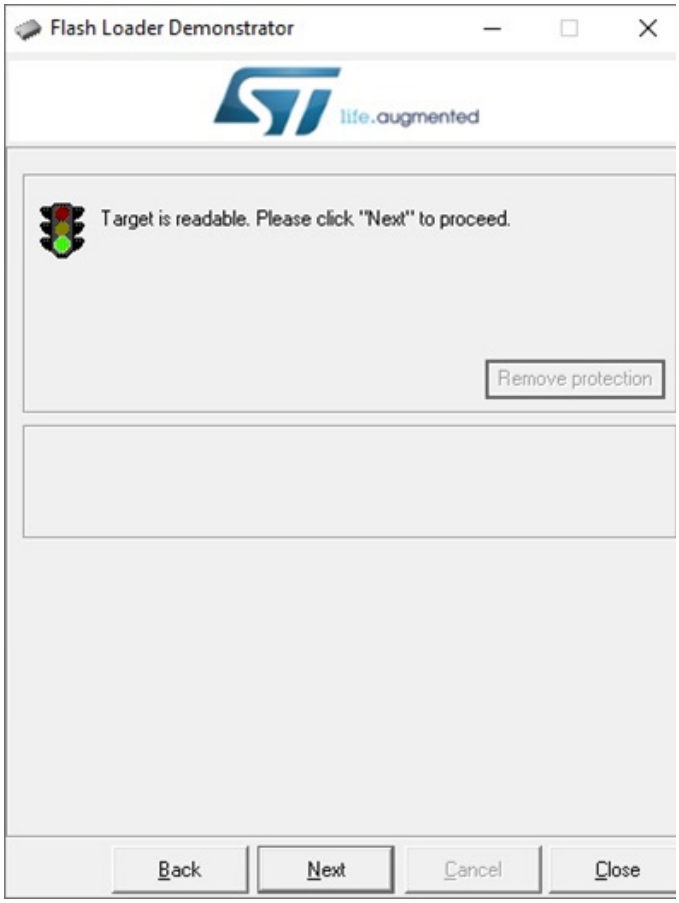
Run the “STMFlashLoader Demo.exe” (nb. It might be identified as “Demonstrator GUI”)

You will see the following screen:

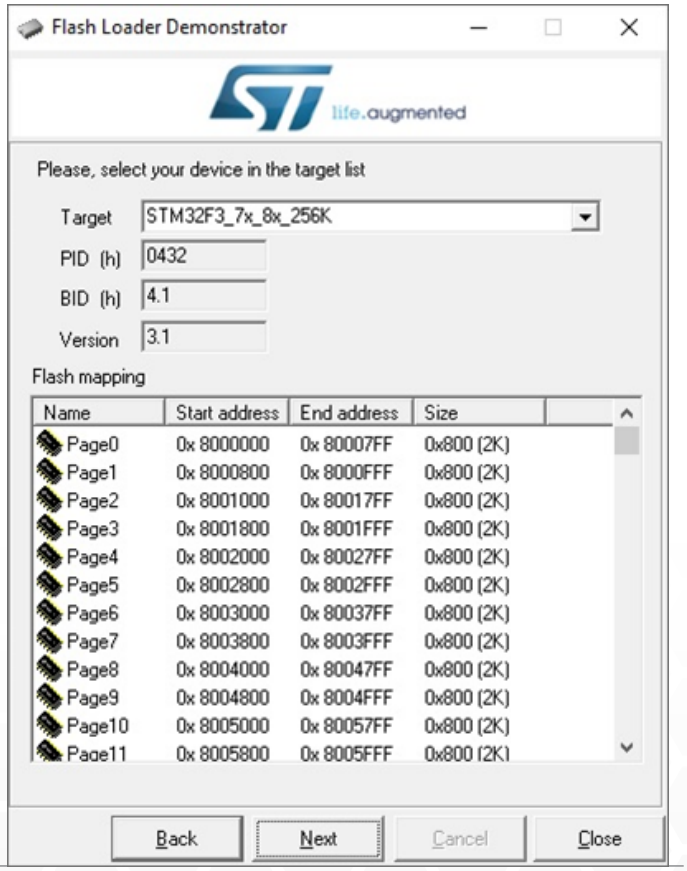


Reprogramming the Oscilloscope Trainer

The following screen should appear (some details may differ):

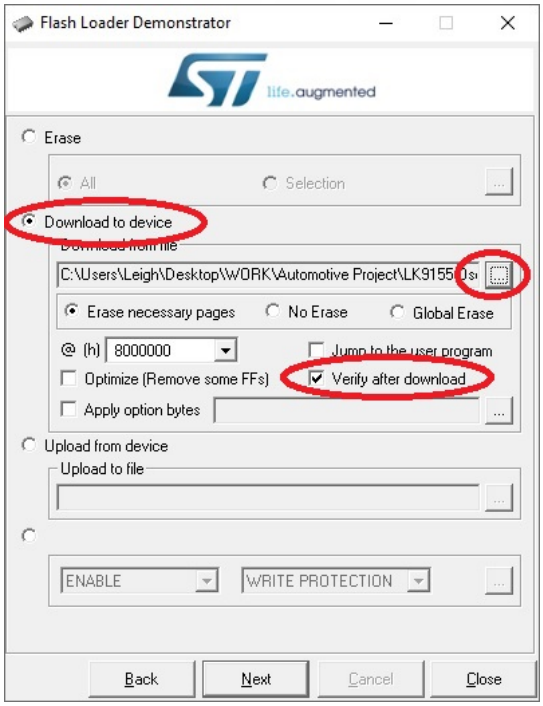


Click the “Next” button and the following screen should appear:



Reprogramming the Oscilloscope Trainer

The following screen should appear (some details may differ):

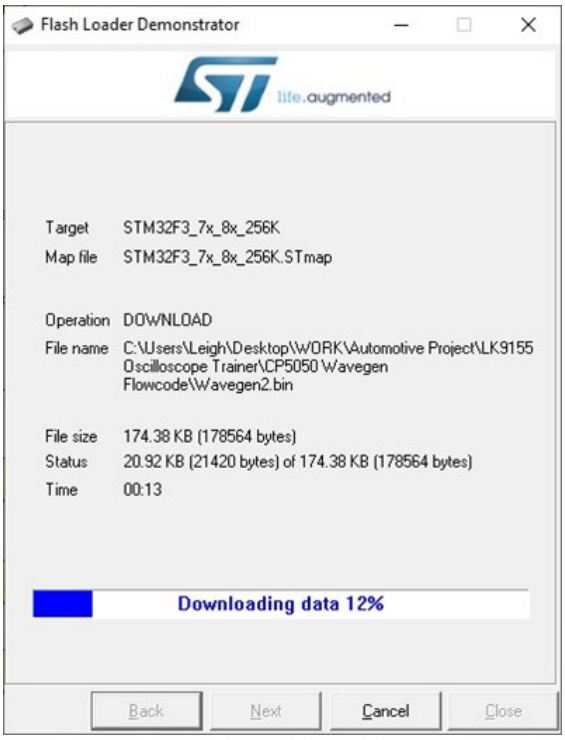


Select “Download to device”

Click the file select button and locate the firmware Hex file.

Enable “Verify after download”

Click the “Next” button



The “Downloading” screen will appear, when successfully completed, click the “Close” button.

Disconnect the USB lead from the Oscilloscope trainer.

List of Waveforms

ID	Source	Out 1	Out 2	CAN Low	CAN High
1	Generic	Sine wave (adjustable)		Y	Y
2	Generic	Triangle wave (adjustable)		Y	Y
3	Generic	PWM (adjustable)		Y	Y
4	Generic	Dual wave A (sine)	Dual wave B	Y	Y
5	VW Passat Diesel 2018	Camshaft		Y	Y
6	VW Passat Diesel 2018	Exhaust pressure		Y	Y
7	VW Passat Diesel 2018	Fuel pressure		Y	Y
8	VW Passat Diesel 2018	Fuel pressure regulator		Y	Y
9	VW Passat Diesel 2018	Injector current		Y	Y
10	VW Passat Diesel 2018	MAF		Y	Y
11	VW Passat Diesel 2018	Turbo actuator		Y	Y
12	VW Passat Diesel 2018	Crankshaft		Y	Y
13	VW Passat Diesel 2018	ABS analogue		Y	Y
14	VW Passat Diesel 2018	Camshaft	Crankshaft	Y	Y

Notes

Notes

Notes

AUTOMOTIVE OSCILLOSCOPE USE

CP5950

www.matrixtsl.com

Matrix Technology Solutions
The Factory, 33 Gibbet Street, Halifax, HX1 5BA, United Kingdom
t: +44 (0) 1422 252380 e: sales@matrixtsl.com