ENAiKOON

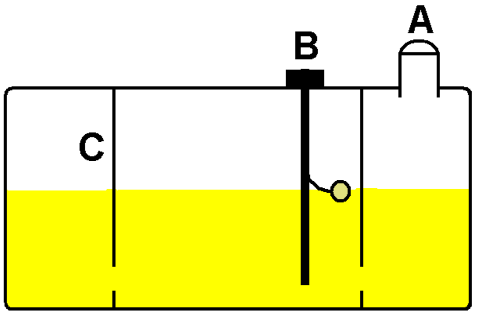
fuel-tracker sensor

8.11.2017

1 TABLE OF CONTENT

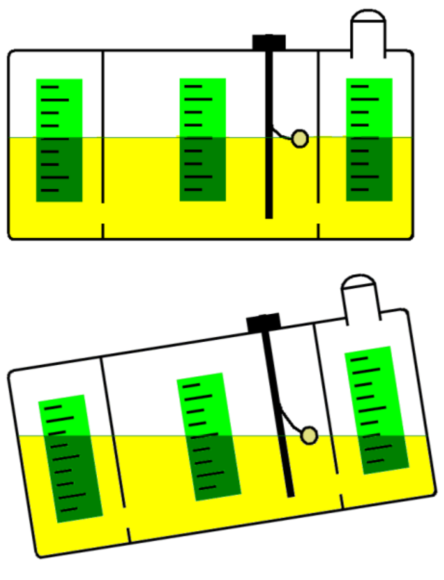
2 INTRODUCTION AND BASICS

2.1 Truck fuel tanks in general



Picture 1:
Typical fuel tank.
A is the refuelling opening.
B is the fuel pump pipe together with the existing float type fuel level sensor.
C is a compartment separator. Compartment separators prevent severe fuel sloshing that could damage the tank or cause vehicle stability issues.
Compartments are connected with holes on the compartment walls near the bottom.
Tank material is usually Aluminium or Steel.

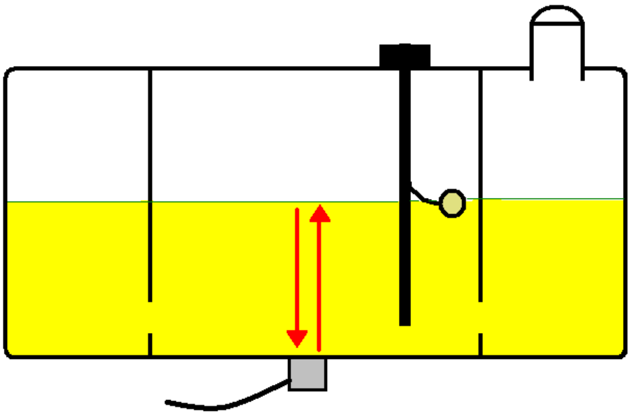
2.2 Measuring fuel level



Picture 2:
The best place to measure the fuel depth is as near as possible to the tank's geometric centre. This is because if the road has slope and the truck tilts the fuel level will have minimum change in the centre and maximum change at the edges. Also, fuel sloshing is minimal at the centre.

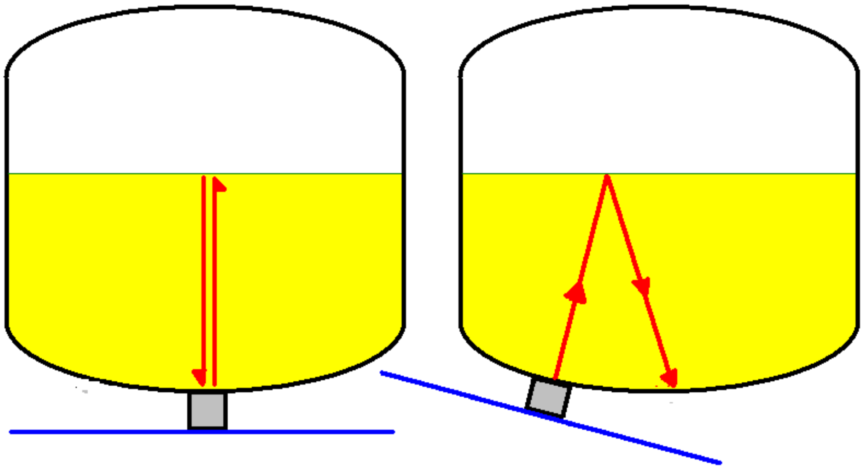
Example: What is the change of fuel depth (i.e. depth measurement error) introduced by road slope of 3 degrees when the fuel depth is measured 15 cm off the geometrical centre of a rectangular tank? Answer: The error in depth is 15 cm x $\tan 3^{o}$ = 0,79 cm.

2.3 How the ENAiKOON ultrasonic fuel-tracker sensor works



Picture 3:
An ultrasonic sensor is adhered externally on the bottom of the tank. The sensor transmits a sonar pulse that is reflected at the fuel surface and returns back (echo). The electronics measure the time of flight and deduce the fuel depth.

2.4 Important sensor placement details

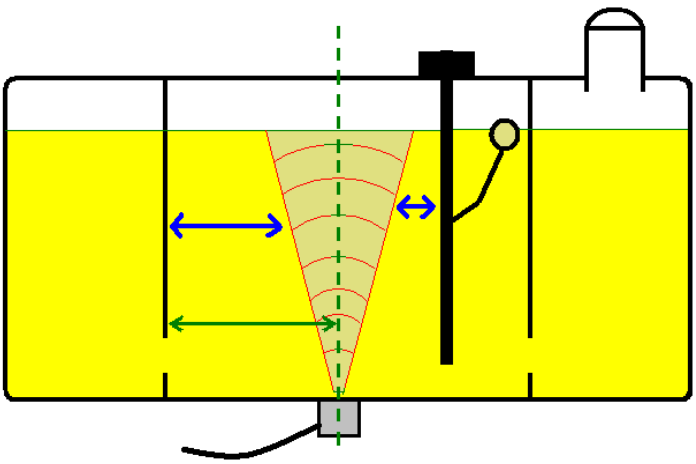


Picture 4:
Rectangular tank cross section. Left: Correct installation with the sensor's face plane parallel to the fuel surface (horizontal level). Right: Incorrect installation with the sensor's face plane not parallel to the horizontal level.

For the sensor to work the sonar pulse must return back (echo). This means that the sensor's face plane must be parallel to the fuel surface (which is the horizontal level) as seen on the left of Picture 4.

If they are not parallel, the echo will be reflected away and the sensor will not work as seen on the right of Picture 4. As the bottom of the tank is always curved to ensure tank wall strength, this means that the installer must carefully select the proper position with the help of a levelling spirit. This should be used for both directions front-back and left-right so that the sensor's face plane is parallel to the horizontal level.

The sensor is able to tolerate a small installation error to the horizontal orientation and is also able to work with the truck on a road with a slope. In these cases the fuel surface is not parallel to sensor's face plane. This is achieved by transmitting the sound in a cone of a total angle of 12 to 20 degrees. This ensures that the installation error plus the road slope can be as high as 6 to 10 degrees. 6 degrees of road slope is 10.5% slope which is ok.



Picture 5:
Ultrasonic beam cone. Total angle is 12 to 20 degrees, which means that the angle of the cone surface to its axis is 6 to 10 degrees. It is important not to have obstructions in the cone beam. Obstructions may cause false reflections (echoes) that may cause an erroneous depth reading. They also may limit the cone spreading and thus reduce the maximum road slope that the sensor can handle.

The clearance of the ultrasonic sensor axis to the nearest obstruction (green arrows in Picture 5) should be at least 11 cm (60 cm x tan 10° = 11 cm) for tanks of expected maximum fuel depth of 60 cm. This falls proportionally for smaller maximum depths and rises proportionally for higher maximum depths. The device can assist the installer to locate obstructions if the fuel level in the tank is high enough for them to be immersed.

2.5 Sensor acoustic contact to the tank bottom

For ultrasound to pass from the sensor to the metal and back, good acoustic contact must be established. There should always be a thin layer of acoustic coupling substance between the sensor and the tank bottom just like the gel in the case of medical ultrasound.

For permanent installation, two-component hard epoxy glue is recommended. It is best to use the recommended glue as other glue may cause very bad acoustic contact. The glue is applied so that it covers completely and well all the sensor face surface with effort not to create bubbles. The sensor is then pressed with much force to the installation spot to ensure that the glue layer becomes as thin as possible. Be careful that the sensor does not slip away while you are pressing. If it does clean the glue from the tank bottom and re-apply the glue on the sensor face. The DP105 glue by 3M has work life around 3 minutes (you can move the sensor around for 3 minutes), handling strength time 20 minutes (the bond is strong to handle after 20 minutes) and full cure time 1-2 days (to reach final state). All these are at 23 degrees Celsius. At higher temperatures, these times become shorter and at lower temperatures these times become longer.

For temporary installation, machine grease or a water based gel such as water based personal lubricant is suggested. Water based substances are easier to clean. Apply enough gel to cover completely and well all the sensor face surface. Press the sensor with much force to the installation spot to ensure that the gel layer becomes as thin as possible. Be careful that the sensor does not slip away while you are pressing. If it does re-apply the gel.

Tank material and thickness. Good acoustic coupling also depends on tank material and thickness. The proper sensor has to be selected to address each tank material and thickness.

Tank Material	Tank Thickness	Sensor Model
Aluminum	up to 4mm	S500AL
Steel	up to 2mm	S570IRON
Steel	5mm +/- 0,5mm	S570TOMAS

Table 1: sensor selection for tank material

3 DEVICE OVERVIEW

3.1 ENAiKOON fuel-tracker sensor - brief description

The ENAiKOON fuel-tracker sensor is a device used to monitor the fuel level in truck fuel tanks. A sensor is adhered externally to the bottom of the tank, which connects with a 6-meter cable to the electronics processing box placed near the telematics unit.

3.2 Fuel sensor features

- **Nominal fuel depth range:** 4 cm to 100 cm.
- **Nominal maximum road slope:** 6 degrees (10.5%) to 10 degrees (17.6%).
- **Accuracy:** 4mm absolute level accuracy, 1 mm relative level accuracy for standard diesel composition and at constant temperature.
- **Water layer on tank bottom:** The device can handle a water layer on the tank bottom.
- **1-Wire interface:** The fuel sensor is accessed as a 1-Wire slave similar to a DS18B20 thermometer. Through 1-Wire the user can access the measurement data, the status data, change settings and perform firmware upgrade. The 1-Wire connection of the fuel sensor is not essential for its operation. Apart from the standard commands of a DS18B20 the fuel sensor recognizes a custom ROM command for firmware upgrade. Each fuel sensor has a unique ID taken from an on-board DS18B20.
- **Temperature compensation of measurements:** The sensor head contains a temperature sensor to measure the temperature of the tank and compensate for the variation of the velocity of sound in the fuel.
- **Multiple types of sensors supported by the electronics:** The electronics automatically adapts to a variety of possible sensors with various cable lengths and PZT element diameters to expand the device's capabilities in specific situations.
- **RS232 interface:** RS232 output for measurements and data.
- **Analogue output:** 0-3 Volt 10-bit output for fuel level
(0mm at 0 Volt and 1000mm at 3Volt).
- **Remote firmware upgrade:** The entire fuel sensor firmware can be upgraded thru the 1-Wire interface. The firmware upgrade operation is done in parallel to the normal operation and in indefinite time periods and intervals. This achieves a firmware upgrade process that is virtually unnoticeable by the user. The data integrity is checked by CRC. The fuel sensor provides as 1-Wire data the last successfully written flash memory packet address, so if the process is interrupted the firmware upgrade can continue from this point instead of restarting from the start. Two or more fuel sensors that are used in the same vehicle can be reprogrammed simultaneously.

- **In-premises firmware upgrade:** The entire fuel sensor firmware can be upgraded by In-circuit programming of its MCU (microcontroller) by a connector on the PCB. In-circuit programming is done with ICD-3 or any other tool for PIC18F microcontrollers.
- **Power supply input:** Power supply of 6-31 Volts DC with protection from voltage spikes by a suppressor diode (TVS).
- **Low power operation:** The fuel sensor varies its measurement rate according to fuel level fluctuation to support low power operation. At fuel level relaxation the rate drops to a minimum and at fuel sloshing or refuelling rises up to a maximum value. CPU and all circuitry operate at a variable duty cycle to optimize and minimize power consumption.
- **Internal battery:** The fuel sensor can use an internal LiPo 3.7 Volt battery. The presence of the battery or its good state is not required for fuel sensor operation. The fuel sensor charges the battery and reports the charging process status and the battery voltage through 1-Wire. The charging is inhibited by a low temperature limit (0 degrees Celsius) and a high temperature limit (50 degrees Celsius). In the case that the fuel sensor is powered exclusively by the internal battery and its voltage drops below 3 Volts approximately the fuel sensor will shut down leaving a very small remaining current drain from the battery to prevent deep discharge. The battery is used only in the absence of an external power supply.
- **Measurement filtering:** The fuel sensor holds the completed measurements in a stack and outputs to 1-Wire a low-pass FIR filtered result similar to averaging. Software algorithms exclude or correct bad measurements.
- **LED signalling:** Three LEDs signal the device status.

3.3 Device modes and LED signalling

- **Just after power up mode.** After power up all three LEDs will flash simultaneously for about 3 seconds. After this time expires it enters one of the other modes.
- **Normal mode**. The device measures the fuel depth with a variable measurement rate and reports to 1-Wire the results. The results are filtered with low pass filtering and are temperature compensated with the fuel temperature as reported from the temperature sensor in the sensor head. At the end of each measurement, the yellow LED (middle) blinks in case the measurement was successful. If the measurement failed the Green LED (right) blinks. The Red LED (left) shows 1-Wire activity.
- **Installation mode.** This mode is entered by connecting pin 5 (INST) to pin 7 or 8 or 9 (GND). This mode is useful only during the installation of the sensor for the purpose of finding a good spot to install the sensor. In this mode the Green LED (right)

is constantly ON. The Yellow LED (middle) is ON when the installation spot gives a good signal with fuel depth over 15 cm and OFF otherwise. The Red LED still indicates 1-Wire activity although in this mode 1-Wire is not used. 1-Wire and the Analogue Output report the last depth measurement. The results are deliberately not filtered for the installer to be able to see the readings immediately. Also, the results are not temperature compensated but are calculated for the sound velocity at 18 degrees Celsius. This is because the sensor head will not have enough time to reach the tank temperature during installation and will be instead at the temperature of the installer's hands and luggage. So the reading will be slightly different from the real value but this is not important at all for the installation process.

- **Before use mode:** This mode is entered when the device is not powered at all and then the battery is connected. In this case all LEDs flash simultaneously at a much slower rate than in "Just after power-up mode". In this mode all functions are inactive (1-Wire, ultrasonic measurements, etc.) to preserve power. The point of this mode is not to go to "Normal mode" immediately after connecting the battery when you just want to put the battery in the electronics box or to reprogram the device in your premises. It is a low power mode. This mode is excited when the device's external power is activated or by going to "Installation mode" by connecting pin 5 (INST) to pin 7 or 8 or 9 (GND).

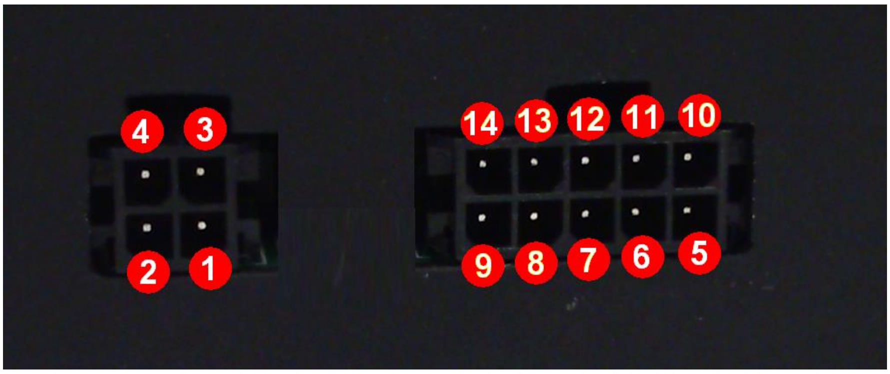
4 FUEL SENSOR DEVICE SPECIFICATIONS

4.1 Electrical characteristics

Parameter	Device Characteristics	Value	Comments
D1	Power supply	6→31Volt DC	
D2	Battery charger low temperature limit	0 °Celsius	Set by hardware
D3	Battery charger high temperature limit	50° Celsius	Set by hardware
D4	Battery charging current	210 mA	Set by hardware
D5	Battery utilization	100%	Battery considered low below 3.1 Volts
D6	Battery Current when FLR is powered by the internal battery	1.4 mA	At Zero 1-Wire activity and with measurement rate at 8 seconds duel to completely re-laxed fuel surface
D7	External 24 Volt power supply current	3 mA	At Zero 1-Wire activity and with measurement rate at 8 seconds due to completely re-laxed fuel surface. Battery charging completed.
D8	External 24 Volt power supply current	6.3 mA	At Zero 1-Wire activity and with measurement rate at 280 msec. (maximum rate) due to fuel sloshing. Battery charging completed.
D9	External 24 Volt power supply current	70 mA	At Zero 1-Wire activity and with measurement rate at 280 msec. (maximum rate) due to fuel sloshing. Battery charging active.
D10	Expected duration of 500 mAh internal bat-tery	10 days	At Zero 1-Wire activity and with measurement rate at 8 seconds duel to completely re-laxed fuel surface.

Parameter	Device Characteristics	Value	Comments
D11	Expected duration of 1000mAh internal battery	20 days	At Zero 1-Wire activity and with measurement rate at 8 seconds duel to completely relaxed fuel surface
D12	Ultrasonic centre frequency	500 KHz	Depending on sensor model
D13	Nominal PZT excitation Voltage	150 Volt	Peak-to-peak value
D14	Analogue Output Range	0→3Volts	0 Volts is 0 mm depth. 3 Volts is 1000 mm depth.
D15	Analogue Output: output resistance	440 Ohms	
D16	Maximum tolerable voltage at pins INST, MODE	3 Volts	
D17	Minimum tolerable voltage at pins INST, MODE	-0.2 Volts	

4.2 Electrical connections

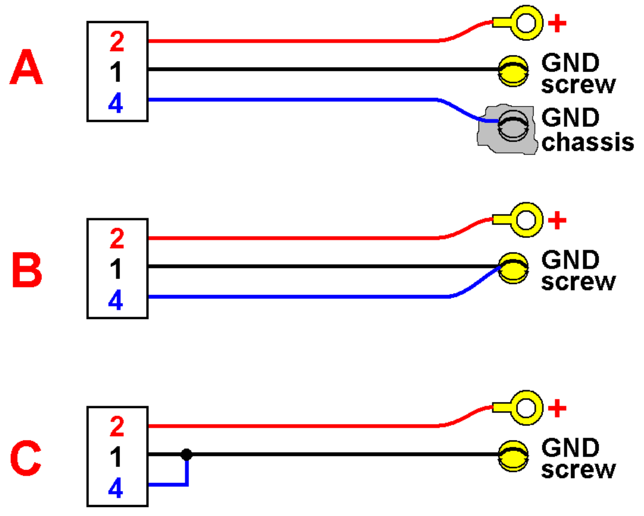


Picture 6: device connections

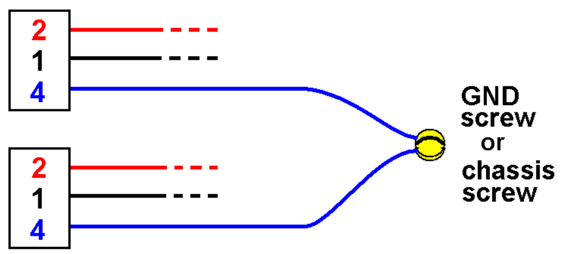
Important:
The vehicle must have Negative Ground meaning that the battery's negative terminal is connected to the vehicle chassis (GND). The device is not suitable for vehicles with a positive Ground.

Important:
If the fuel tank is metal it must be Grounded to the vehicle chassis (It normally is for safety reasons).

Pin	Signal	Type	Description
1	GND for VCC	GND	External power supply negative terminal (Vehicle Ground)
2	VCC	VCC	External power supply positive terminal (+6 to +31Volt)
3	Internally connected to 1		
4	Chassis	GND	Connect as shown in case A or B or C. A is the most pref-erable and C the least. In A pin 4 is connected directly to the same chassis ground with the fuel tank. B is usually easier. At B line 4 connects to line 1 at the GND chassis screw only.

<table>
<tr><th>Pin</th><th>Signal</th><th>Type</th><th>Description</th></tr>
<tr><td></td><td></td><td></td><td>


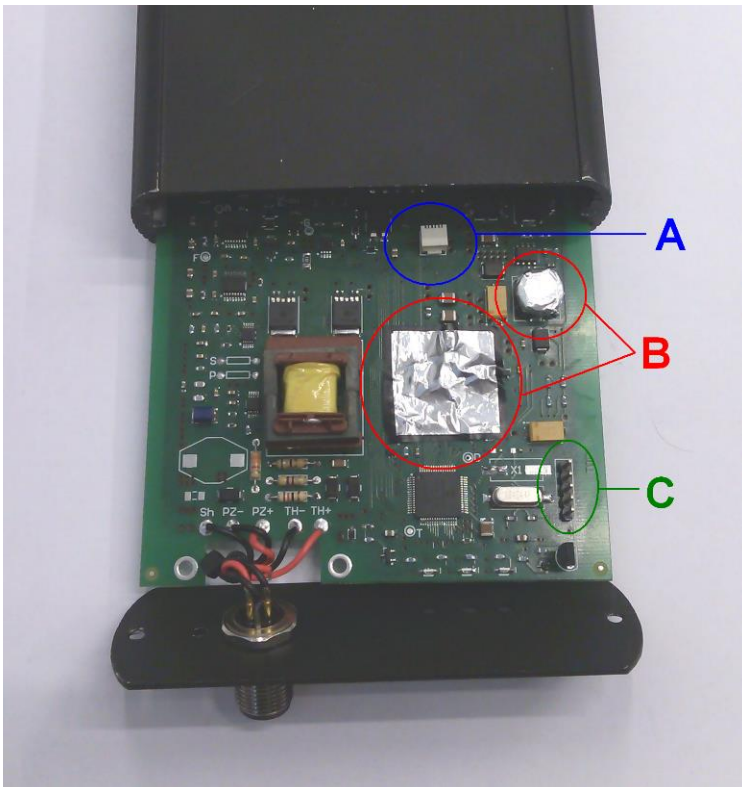
Special case: When the truck has two tanks, two devices must be used. For this case, connection C is not acceptable, only A and B are. If neither A nor B are possible - and only then - leave pin 4 of each device unconnected. Connect pins 4 as shown.



Pins 4 should not be bridged with a short cable but have <u>separate</u> cables at least 30 cm long each to the ground or chassis screw. If this is not possible - and only then - leave pins 4 unconnected.
</td></tr>
<tr><td>5</td><td>INST</td><td>Input</td><td>Connect this pin to 7 or 8 or 9 to enter “Installation mode”</td></tr>
<tr><td>6</td><td>MODE</td><td>Input</td><td>Unused</td></tr>
<tr><td>7</td><td rowspan="3">GND I/O</td><td rowspan="3">GND</td><td rowspan="3">Internally connected. Ground for Inputs 5 and 6, RS232 port and Analogue Output</td></tr>
<tr><td>8</td></tr>
<tr><td>9</td></tr>
</table>

Pin	Signal	Type	Description	
10	ANALOGUE	Output	Fuel level positive Analogue output (0→+3Volt). Ground taken from 7 or 8 or 9. Output impedance is 440 Ohms.	
11	1W_Gnd	GND	1-Wire negative terminal	Pin 11 is dedicated ground for 1-Wire. Pins 11 and 12 are filtered together inside the fuel sensor by a common mode inductor to provide rugged 1-Wire communications. Do not ground other stuff to pin 11 or connect pin 11 to other ground nodes.
12	1W+	I/O	1-Wire communications active data line	
13	RS232 Tx	Output	RS232 communications port	
14	RS232 Rx	Input		

4.3 Electronics Box



Picture 7:

Electronics box.

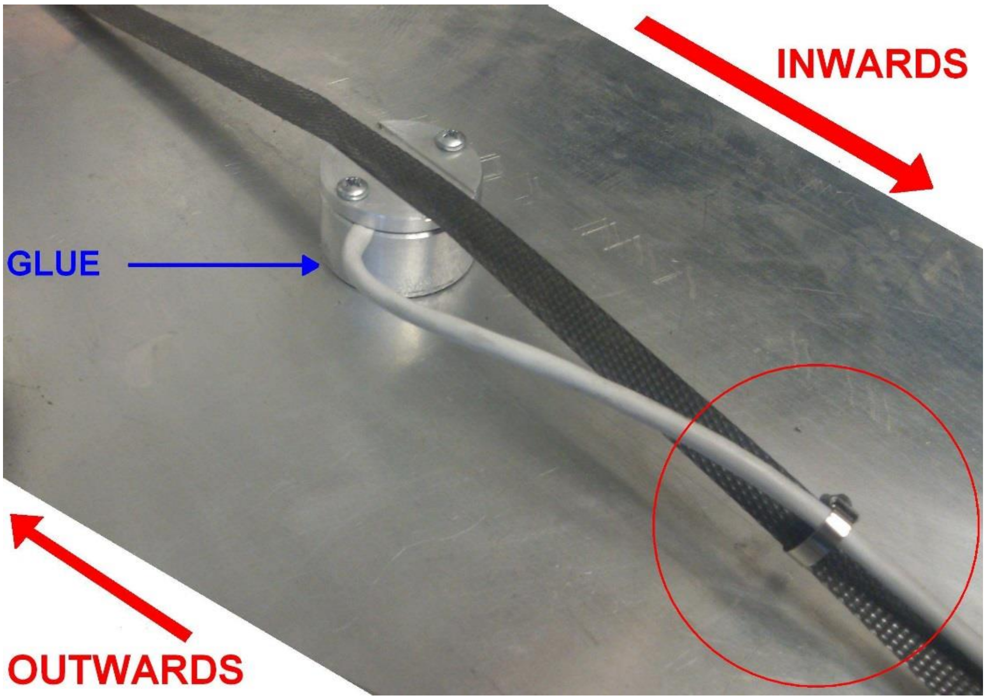
A: Internal battery connector.

B: Inductor EMI shielding - DO NOT REMOVE!

C: In-circuit programming pins.

To open the box unscrew from the side shown here (sensor cable connector side) carefully so as not to damage the cabling of the connector. Push in the multi-pin connectors of the other side, for the circuit board to be pushed out a little. Then, carefully pull out the board holding it from its sides.

4.4 Sensor mounting



Picture 8:
Upside down picture of sensor mounting at the bottom of the tank. The sensor is glued with proper glue at the bottom of the tank and fastened with 16mm steel strapping tape to hold in place. The sensor has a groove for the 16 mm tape. In the picture black plastic tape is used instead for clarity of colours. Use a metal tire-up to secure the cable as shown in the red circle.

- The sensor is glued on the bottom of the tank with proper epoxy glue. The two component DP105 glue by 3M is recommended. It is best to use the recommended glue as other glue may cause very bad acoustic contact.
  The glue is applied so that it covers completely and well all the sensor face surface with effort not to create bubbles.
  The sensor is then pressed with much force to the installation spot to ensure that the glue layer becomes as thin as possible.
  Be careful that the sensor does not slip away while you are pressing. If it does clean the glue from the tank bottom and re-apply the glue on the sensor face. The DP100 Glue has work life around 3 minutes (you can move the sensor around for 3 minutes), handling strength time 20 minutes (The bond is strong to handle after 20 minutes) and full cure time 1-2 days (to reach final state).
  All these are at 23 degrees Celsius. At higher temperatures these times become shorter and at lower temperatures these times become longer. The glue gets so

hard that it is impossible to remove the sensor by hand. To remove the sensor if needed, it must be hit with a hammer sideways so that the glue bond breaks.

- The installation spot should not have any paint and should be a clean and slippery-smooth polished surface for good acoustic contact and strong glue bond. The surfaces to be glued must be cleaned thoroughly for the glue to apply correctly. Use alcohols like ethanol or isopropanol if available. If the installation spot is painted, the paint should be removed so that a clean and smooth metal surface is available. Remove the paint with caution not to damage the surface.
- The cable of the sensor should point inwards to the truck to be easily mounted to the vehicle.
- The sensor has a groove at its back side so that it can be strapped to the tank with 16mm steel strapping tape. This tape surrounds the tank and holds the sensor in place. To apply the tape you must use either one tool (combined tensioner + sealer) or two tools (separate tensioner and sealer). These tools and the tape itself are common materials. Strapping with plastic tape instead of steel is not recommended as the sun causes it to break after a while.
  Do not over-tension the metal strap.
  The main purpose of strapping is to prevent the sensor from breaking off and falling on the road causing a dangerous situation. If strapping is not acceptable or not feasible at the selected installation spot then it is not necessary if there is close a point where the sensor's cable can be secured so that if the sensor breaks off it will hang from its cable not touching the ground. In this case the sensor will still have to be temporarily strapped with plastic tape or other means for 2 days for the glue to harden properly.
- The sensor cable is secured on the strapping tape with metal tire-ups. Again, plastic tire-ups should be avoided because the sun causes them to break after a while.

5 INSTALLATION

1. **Reading.** To proceed with the installation you should first read the following:
   a. Chapter **1** “Introduction and basics”.
   b. Paragraph **2.3** “Device modes and LED signalling”.
   c. Paragraph **3.4** “Electrical connections”.
   d. Paragraph **3.5** “Electronics Box”.
   e. Paragraph **3.6** ”Sensor mounting”.

2. **Determine the tank material** with the help of a magnet. If the magnet sticks it is steel (iron) and hard sensor head H1 or H2 should be used. If not it is Aluminium or plastic and soft sensor head S1 should be preferred. H2 would also do here but would be less tolerant to installation tolerances (not properly prepared tank surface, incorrect glue application, etc.). Most new truck tanks are Aluminium for a lot of reasons.

3. **Verify that the tank is grounded** with the help of a multimeter. Do this by checking the continuity or ohmic resistance between the tank and a ground/chassis screw. You may have to scratch the surfaces to get conductive contact. It is very unlikely that the tank is not grounded in the chassis, but if it is not use a wire to ground it. If still you cannot ground it leave it as it is.

4. **Tank must have enough fuel.** The tank must have at least 15 cm of fuel inside. The more it has the better. If you can arrange for a full tank it is the best.

5. **Place the tank in horizontal ground.** The truck should rest at a ground with as small slope as possible. This applies for both directions front-to-back and left-to-right.

6. **Find tank geometric centre.** The sensor will be placed as close as possible to this spot. The reasons are explained in 1.2.

Picture 9: finding the geometric centre of the tank

7. **Put the internal battery in the electronics box.** As described in paragraph 3.5, unscrew the electronics box from the sensor connector side and remove the lid with caution not to damage the cabling. Connect the internal battery and close the box. The three LEDs will flash simultaneously.

8. **Connect the sensor to the box.** Connect the sensor to the extension cable and the extension cable to the electronics box. Make sure you route the cable from the back of the tank and not the front so that you can later mount it on the vehicle with ease.

9. **Electrically connect box to truck.** Connect the four pin Molex connector to the truck wiring. Do the cable connections before plugging the connector to the fuel sensor device. Connect as shown in paragraph 3.4. For pin 4 avoid connection scheme C if you can. Connection scheme B is easy and works ok. In this connection scheme pin 4 is connected with a wire to a ground screw on the vehicle chassis. The same chassis ground screw can accept the cable that carries negative power (GND) to fuel sensor pin1 and to the ENAiKOON tracking device. So, with scheme B you have three wires running from the fuel sensor + tracking device combination to the truck (Positive power wire and two ground wires). Scheme A is preferred but it might not be easy to implement. After the connections are completed plug the connector to the fuel sensor device. When it receives power from the tuck the LEDs will stop flashing and the device will enter installation mode.

Picture 10: connecting power and ground

10. **Set the device to “Installation mode”.** Connect to the 10 pin Molex connector the cable prepared for sensor installation instead of the cable used to interface to Locate. This cable has a bridge wire from pin 5 to GND I/O that activates “Installation mode” and two wires from pin 10 and GND I/O to connect to a multimeter to read the Analogue fuel depth output. When the cable is plugged the fuel sensor will enter

installation mode. This is signalled by the Green LED (right) being permanently ON.

11. **Find candidate installation spots on the tank bottom.**

The spots must:

a. Be as near to the geometric centre as possible.

b. Not have obstructions over them. You can verify this by examining the top of the tank, by peeking from the fuel opening to see if you can locate compart-ment walls and the float sensor and with the help of the device itself.

c. Be parallel to the horizontal plane. Check this with the help of a spirit level placed directly on the candidate spot. Check doth directions i.e. front-to-back and left-to-right. A maximum error of 2 degrees from the horizontal level should not be exceeded. Instead of putting the spirit level directly on the tank you can put the sensor with the spirit level in the groove at its back.

Picture 11:
Checking both directions (front-to-back and left-to-right) with a levelling spirit to find horizontal candidate installation spots. A maximum error of 2 degrees from the horizontal level should not be exceeded.

12. **Clean the candidate spots** well with an iron kitchen sponge and some cleaning fluid. If the tank has grease or oil stains use for cleaning paint thinner or other similar diluter.

Picture 12:
Clean the bottom of the tank with an iron kitchen sponge and proper liquid cleaner

13. **Check the candidate spots with the device.** Put a good amount of coupling gel on the face of the radiator so that it covers it completely and press it on the selected spot. The Yellow LED (middle) must go permanently ON signalling a good quality signal and a measured depth over 15 cm. If it does not light permanently the spot is not good (e.g. it is under a compartment separator) and a new spot must be checked. If you have the suspicion that you have located a compartment separator you can check by putting the sensor in nearby positions and seeing if the LED goes ON. Do not choose as a final spot one that is closer than 8-10 cm to a compartment separator. Make sure there is always enough gel on the sensor's face. Every time you go to a new spot reapply gel. When a spot approved by the Yellow LED is found note the multimeter reading of the Analogue output. The Analogue output is 0 for 0mm and 3Volts for 1000mm so set the multimeter to the appropriate voltage scale. Then take a multimeter reading from another spot approved by the Yellow LED. If the readings are close (1 cm difference is 30mVolts difference) then both spots have no obstructions. If one reading is noticeably smaller it means that there is an obstruction in the specific spot that causes a false sound reflection (probably the float of the resistive sensor) and so the spot is not good. If the tank is not full enough, you may miss an obstruction that is above the fuel level. In the end of this process you should have found the best spot. Never choose a spot that is not found adequately horizontal with the levelling spirits.

14. **Clean for the glue.** Clean the selected spot well. A cloth wetted with water will remove the water based gel. If you used machine grease instead of the gel you should wet the cloth with a proper diluter. Wipe dry with a dry cloth. Clean the radiator

face in the same way.

15. **Apply the glue** on the radiator face. As described in paragraph 3.6 the DP100 Glue has work life around 3 minutes (you can move the sensor around for 3 minutes) and handling strength time 20 minutes.

Picture 13:

Apply the glue. Apply much glue so that the entire surface is well covered. Make sure there are no gaps and bubbles.

16. **Push the sensor to the selected spot** with care for it not to slip away. Use the spirit level to check if you lost the alignment. Usually you do not have to check both directions. The error will be usually in the left-right direction which is also the direction of the sensor's groove and the strapping tape. Do minor adjustments not exceeding the glue work life and not displacing the sensor much so as to avoid leaving the glue behind and the sensor surface with inadequate amount of glue for good acoustic contact. Press to make the glue layer as thin as possible.
<u>At all times check that the Yellow LED stays ON.</u> While pressing, do a small circular massage-like movement for the glue to take its proper distribution. Sometimes, alt-

hough the sensor is placed at the correct installation spot found with the steps mentioned previously, the Yellow LED will not light. The small circular massage-like movement will distribute the glue properly and the LED will light.

Picture 14:
press the sensor to make the glue layer thin and bring the sensor closer to the tank bottom

17. **Strap it to place before the glue work time expires.** Be careful not to displace it while tensioning the strap tape. It is better if one holds it in place while another tensions the tape. Apply enough tension for a firm hold.

Picture 15:
Strap the sensor before the glue work time expires. Use 16mm steel strapping tape. This picture is taken with plastic tape. You can see the sensor at the bottom of the tank.

18. **Connect the device to Locate.** Unplug the 10pin Molex cable used for installation and plug the cable that connects to Locate. The Yellow LED must flash periodically indicating correct measurements.

6 FUEL SENSOR PROTOCOL SPECIFICATIONS.

6.1 1-Wire protocol standard DS18B20 commands.

The FUEL SENSOR keeps a scratchpad similar to a DS18B20 and accepts the standard commands: SEARCH ROM, SKIP ROM, READ ROM, READ SCRATCHPAD and WRITE SCRATCHPAD

Scratchpad								
Byte	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0-R	FLSB<7:0>							
1-R	FMSB<7:0>							
2-R/W	TH	CL	LP	XG	SD<3:2>		Unused	
3-R/W	SEL<7:6>		Unused					
4-R/W	Unused							
5-R	TBLLSB<7:0>							
6-R	TBLMSB<7:0>							
7-R	DV	INST	FUEL SENSOR		COP	RATE<2:0>		
8-R	CRC							
R=Readable byte W=Writable byte								

TBLLSB<7:0> and TBLMSB<7:0> for SEL<7:6>=0b00								
Byte	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
TBLLSB<7:0>	VBATLSB<7:0>							
TBLMSB<7:0>	IN	0	V5	STAT<4:3>		BM	VBATMSB<1:0>	
TBLLSB<7:0> and TBLMSB<7:0> for SEL<7:6>=0b01								
Byte	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
TBLLSB<7:0>	AP<7:0>							
TBLMSB<7:0>	AS<7:0>							

TBLLSB<7:0> and TBLMSB<7:0> for SEL<7:6>=0b10								
Byte	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
TBLLSB<7:0>	TLSB<7:0>							
TBLMSB<7:0>	TMSB<7:0>							
TBLLSB<7:0> and TBLMSB<7:0> for SEL<7:6>=0b11								
Byte	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
TBLLSB<7:0>	0	0	0	0	0	0	0	0
TBLMSB<7:0>	VE<7:0>							

Byte 0 Data Provided by FUEL SENSOR.
FLSB<7:0>: Least Significant byte of Depth measurement.

Byte 1 Data Provided by FUEL SENSOR.
FMSB<7:0>: Most Significant byte of Depth measurement.

Byte 2 Settings provided to FUEL SENSOR.
TH<7>: Select AGC background noise threshold.

0: High threshold.

1: Low threshold.

CL<6>: Level measurement filter clipping.

0: Clipping disabled.

1: Clipping enabled.

LP<5>: Additional low pass filtering of measurements.

0: Additional filtering disabled.

1: Additional filtering enabled.

XG<4>: Extra gain at TOF amplifier.

0: Extra gain disabled.

1: Extra gain enabled.

SD<3:2>: Low depth enhancement feature.

00: Feature disabled.

01: Small margin.

10: Medium margin.

11: Big margin.

<1:0>: Unused.

Byte 3 Settings provided to FUEL SENSOR.

SEL<7:6>: Selects the table to be displayed in Bytes 5 and 6.

<5:0>: Unused.

Byte 4 Settings provided to FUEL SENSOR.

<7:0>: Unused.

Byte 5 Data Provided by FUEL SENSOR.

TBLLSB<7:0>: Least Significant byte of Selectable Data Table.

Byte 6 Data Provided by FLR.

TBLMSB<7:0>: Most Significant byte of Selectable Data Table.

Byte 7 Data Provided by FUEL SENSOR.

DV<7>: Valid Scratchpad Data.

0 = Data is not valid.

1 = Data is valid.

INST<6>: Device operation mode.

0 = Normal Mode.

1 = Installation Mode.

FUEL SENSOR <5:4>: 0b10 to discriminate that the device is a FUEL SENSOR and not a DS18B20 which reads 0b01.

COP<3>: Echo consistency.

0 = Echoes received ok.

1 = Echoes constantly lost.

RATE<2:0>: Measurement rate.

000: NA.

001: Measurement every 50 msec.

010: Measurement every 280 msec.

011: Measurement every 500 msec.

100: Measurement every 1 sec.

101: Measurement every 4 sec.

110: Measurement every 8 sec.

111: NA.

TBLLSB<7:0> and TBLMSB<7:0> for SEL<7:6>=0b00

TBLLSB Data Provided by FUEL SENSOR.

VBATLSB<7:0>: Least Significant byte of battery voltage measurement.

TBLMSB Data Provided by FUEL SENSOR.

IN<7>: State of auxiliary input.

0: Inactive.

1: Active.

<6>: 0.

V5: Status of external power supply to the FUEL SENSOR.

0 = Power is not OK.

1 = Power is OK.

STAT<4:3>: Battery charger Status.

00 = Test mode.

01 = Charge Complete.

10 = Charge in Progress.

11 = Not active (Standby, temperature fault, etc).

BM: Battery voltage Measurement Mode. It supplements the battery voltage measurement stored in VBATLSB<7:0> and VBATMSB<1:0>. It is used because the FUEL SENSOR cannot read accurately the voltage if it is powered from the internal battery and it is too low.

0 = Invalid battery voltage measurement and battery low.

1 = Valid battery voltage measurement.

VBATMSB<1:0>: Most Significant byte of battery voltage measurement.

TBLLSB<7:0> and TBLMSB<7:0> for SEL<7:6>=0b01

TBLLSB Data Provided by FUEL SENSOR.

AP<7:0>: Address of Expected Firmware Programming Packet.

TBLMSB Data Provided by FUEL SENSOR.

AS <7:0>: Firmware Version of new FUEL SENSOR firmware.

TBLLSB<7:0> and TBLMSB<7:0> for SEL<7:6>=0b10

TBLLSB Data Provided by FUEL SENSOR.

TLSB<7:0>: Low byte of Temperature.

TBLMSB Data Provided by FUEL SENSOR.

TMSB<7:0>: High byte of Temperature.

<u>TBLLSB<7:0> and TBLMSB<7:0> for SEL<7:6>=0b11</u>

TBLLSB Data Provided by FUEL SENSOR. Always reads 0x00. Reserved for future use.

TBLMSB Data Provided by FUEL SENSOR.

VE <7:0>: Firmware Version of FUEL SENSOR.

Converting numerical values	
Measured Depth value at FLSB<7:0> (low Byte) and FMSB<7:0> (high byte)	[Depth in mm] = [value]/4. Example: Value 0x03E8 is in decimal 1000 and means 1000/4=250mm fuel depth.
Temperature value at TLSB<7:0> (low byte) and TMSB<3:0> (high byte).	[Temperature Celsius] = ([value]/4)-20. Example: Value 0x00b4 is in decimal 180 and means (180/4)-20=25 degrees Celsius.
Measured Battery voltage at VBATLSB<7:0> (low byte) and VBATMSB<1:0> (high byte).	[Battery Voltage in Volts] = [value]x6/1024 Example: Value 0x0266 is in decimal 614 and means 614x6/1024=3,598 Volts.

6.2 1-Wire protocol extended commands (1) for FUEL SENSOR firmware upgrade.

The FUEL SENSOR accepts the custom ROM command 0x74 for firmware upgrade. This command is custom for FUEL SENSOR and is not used by any standard 1-Wire device. Its binary code differs at least by two bits by any other standard 1-Wire ROM command so as not to be confused in the case that noise alters the reception of one bit at a slave device.

The 0x74 command is address-less which means that all the FLRs on the bus will accept it. The 0x74 command along with its data bytes are a total of 32 bytes.

This is the length of the 1-Wire data packet transmitted by Locate by a “+CLIONE4” command. This 32 byte sequence that follows the 1-Wire Reset pulse is as follows:

Bytes after the Reset pulse sequence for the 0x74 command. Protocol PR=0x00.							
0	**1**	**2**	**3**	**4**	**5**	**6**	**7**
0x74	0x74	PR	As	Ap	Ax	D0	D1
8	**9**	**10**	**11**	**12**	**13**	**14**	**15**
D2	D3	CRC1	D4	D5	D6	D7	D8
16	**17**	**18**	**19**	**20**	**21**	**22**	**23**
D9	D10	D11	D12	CRC2	D13	D14	D15
24	**25**	**26**	**27**	**28**	**29**	**30**	**31**
D16	D17	D18	D19	D20	D21	CRC3	00

Name	Description	Values	Comments
PR	Protocol of 32 byte packet	0→0xFF	Current value PR=0x00
As	Version of new Firmware	0→0xFF	
Ap	Address of the current Firmware Programming Packet	0→42	For PR=0x00. Each packet is 704 bytes of flash.
Ax	Address inside the Firmware Programming Packet indicated by Ap.	0→31	For PR=0x00. 32 indicates end of new firmware
D0-D21	22 bytes of FUEL SENSOR flash data.	0→0xFF	
CRC1	CRC of bytes 2→9		
CRC2	CRC of bytes 11→19		
CRC3	CRC of bytes 21→29		

Firmware upgrade sequence

1. The master inquires the current Firmware Programming Packet address Ap from all FUEL SENSORs by issuing a READ SCRATCHPAD command.
2. He selects the smaller Ap and issues 32 transmissions with Ax ranging from 0 to 31. The transmissions must be transmitted in increasing Ax order (Ax=0 is first and Ax=31 is last). All FUEL SENSORs present on the bus will accept the new data.
3. The master waits for 90msec at minimum for the Firmware Programming Packet to be written in the flash memory of the FUEL SENSOR. This can be done either by waiting or by issuing three more 32-byte transmissions with all bytes (0→31) set to zero (0x00). The FUEL SENSOR may not give a Presence Pulse to one or both of these packets because while the flash is being written the 1-Wire communications are OFF.
4. The master repeats Step 1 until the end of the new firmware. After each step the FUEL SENSOR increases its Ap. If the master does not get an increased Ap it means that the data was not received correctly.
5. The last Firmware Programming Packet has Ax=32 instead of Ax=31 at its last transmission. The FUEL SENSOR will then update the firmware automatically.

Important details:

1. To reset the programming sequence, or to re-write the latest packets, the master can transmit an Ap smaller then the currently required. For example, if the FUEL SENSOR has successfully received the packet with Ap=30, a transmission with Ap=20 and Ax=0 will reset the current Ap from 30 to 20. Transmission with smaller Ap, as in this case, must always start from the beginning of the packet i.e with Ax=0. If it starts with Ax>0 it will be ignored.
2. Packets with Ap bigger than the currently expected by the FUEL SENSOR or with Ax bigger than the one expected by the FUEL SENSOR are ignored.
3. The programming can be done without inquiring feedback from the FUEL SENSOR. To do this start always from Ap=0, Ax=0. In the case of reception failure the data will have to be retransmitted from the beginning.
4. The reprogramming sequence can be done in parallel to the FUEL SENSOR’s normal operation and may be completed in any timing desired.
5. If the programming sequence fails at a point the master can inquire the current Ap and continue from this point instead of restarting from the start.

6. Packets with As different than expected are rejected. To change As the transmission must start from the beginning Ap=0, Ax=0.
7. Packets with PR different than the PR the currently operating version uses are rejected. The PR feature enables to change the firmware reload protocol in the future without compatibility problems.

6.3 RS232 data output

The device periodically transmits a RS232 packet of 21 bytes with a period of approximately 8 to 10 seconds. The device does not accept RS232 received data. The packet contains the 1-Wire data bytes in RS232 format.

Byte	Data	Description
0**	0xAA	Message Identifier. Always 0xAA.
1	ID7	8 bytes of device's **unique ID** ID7 is the CRC*** of bytes ID0 to ID6
2	ID6	
3	ID5	
4	ID4	
5	ID3	
6	ID2	
7	ID1	
8	ID0	
9	S0	**Scratchpad byte 0** as described in paragraph 6.1
10	S1	**Scratchpad byte 1** as described in paragraph 6.1
11	S2	**Scratchpad byte 2** as described in paragraph 6.1
12	S3	**Scratchpad byte 3** as described in paragraph 6.1
13	S5	**Scratchpad byte 5 for SEL<7:6>=0b00** as described in paragraph 6.1
14	S6	**Scratchpad byte 6 for SEL<7:6>=0b00** as described in paragraph 6.1

Byte	Data	Description
15	S7	**Scratchpad byte 7** as described in paragraph 6.1
16	S11	**Scratchpad byte 5 for SEL<7:6>=0b10** as described in paragraph 6.1
17	S12	**Scratchpad byte 6 for SEL<7:6>=0b10** as described in paragraph 6.1
18	S13	**Scratchpad byte 5 for SEL<7:6>=0b11** as described in paragraph 6.1
19	S14	**Scratchpad byte 6 for SEL<7:6>=0b11** as described in paragraph 6.1
20**	SCRC	**CRC***** of bytes S0 to S14

** Byte 0 is transmitted first and byte 20 last.

*** The equivalent polynomial for CRC is the one used in Dallas (Maxim) DS18B20 1-Wire thermometers and is:
$CRC=X^8+X^5+X^4+1$.

Explanation and algorithm for CRC evaluation can be found in Application Note AN27 of Maxim "Understanding and Using Cyclic Redundancy Checks with Maxim iButton Products.

Baud Rate	**9600 bps**
Configuration	**8-N-1** (8 data bits, No Parity, one Stop bit. The common PC configuration).
Transmission period	**8 to 10 seconds** approximately

6.4 Cable scheme FUEL SENSOR -> RS232