DIGITAL FUEL GAUGE

DFG-2010

SeaBug Electronics

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Using the Digital Fuel Gauge

The Digital Fuel Gauge takes the place of a standard analogue fuel gauge, but offers many more features:

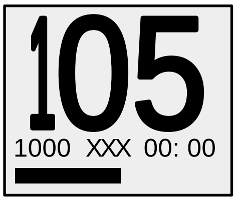
- Large Digital Display of Fuel level in litres (10 second average), plus bar-graph display to mimic analogue gauge
- Display of RPM, Estimated Fuel Consumption, Range at current RPM, Engine Run Time (HH:MM), Engine Last Run Time
- Alarms:
    - Missing Tachometer Pulse / Fan Belt failure [1 sec on / 1 sec off] until ignition turned off
    - Reserve Level reached [5 long beeps = Morse Zero] plus every 10 minutes [1 long beep = Morse “T” - Tank]
- Display of total Engine Run Time since Reserve Level reached
- Default Fuel Calibration closely matches standard gauges
- Accurate User Calibration with selectable steps of 1, 2, 5, 10, 20, 50 or 100 Litres (100 steps maximum)
- RPM / Tachometer Pulse Calibration Function
- All user calibration values and Reserve Timer stored in non-volatile memory (EEPROM)
- Red LED backlight to preserve night-vision, wired to existing instrument light circuit
- Operates using a variety of existing sender units, both low and high resistance at full scale

Power on the fuel gauge. After booting up, and assuming the ignition is off and there is fuel in the tank, the display will appear similar to that on the left. The large numbers show the fuel level in litres. The fuel level is also represented by the bar-graph at the bottom. Here this is about 50% of the display width, so indicates that the tank is 50% full. It can be deduced that the tank in this example holds 210 litres.

The LAST RUN field shows the time (HH:MM) the engine was last run for, at present this is zero.

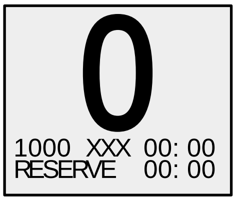
Turn on the ignition, but do not start the engine; the display changes to show that the ignition has been turned on. If left in this state for 30 seconds, the display will flash between WARNING / NO TACH and the alarm will sound in sync with the flashing. The 30 delay only applies when the ignition is first turned on, at any other time a missing tachometer signal (possibly a broken fan belt) will alarm immediately.

The engine run timer will begin to count up from zero in HH:MM whenever the ignition is turned on, and the colon between the digits will alternate between left and right every second.



Turn off the ignition, then turn it on and start the engine; the display changes to show the RPM (1000 in this example).

To the right of the RPM there are two numbers, flashing alternatively (shown XXX here). These show the estimated fuel consumption in litres/hour at the current RPM, and the engine hours possible with the remaining fuel. If it is not obvious which is which, the Litres/hour is showing when the time colon is on the Left, the fuel “Range” is showing when the time colon is on the Right.



If the fuel tank sensor reaches its lower limit, the digital display shows 0. In addition, the alarm will sound 5 long tones (Number Zero in Morse Code) and will repeat a single tone (Morse “T”) every 10 minutes.

The bar-graph will be replaced by the Reserve Timer. The text alternates between RESERVE / HRS USE, and a new timer is displayed under the engine run timer. This timer is cumulative, and maintained if power is removed (unlike the engine run hours). The value is stored to EEPROM every minute, when the * appears to the right of HRS USE. The only way to reset the reserve timer is to add fuel!

Plug Connections (viewed from pins)

1	IGNITION	YE
2	PWR/INS 12v	RD
3	PWR GND	BK
4	ALT TACH	GN
5	SPARE	BN
6	SENSOR GND	BK
7	INS/LIGHTS	OG
8	N/C	----
9	SENSOR +V	BU

Location of Button and DIP Switch

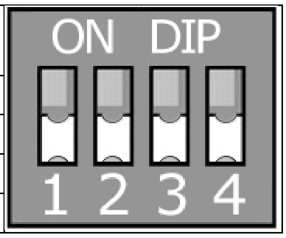
Calibrating the Digital Fuel Gauge

Technical Details

Inside the case is a 4-way DIP switch and a button, both used for setting various modes; the DIP switches are normally left in their OFF positions (as in picture on previous page, and the graphic below). The functions of the switches are shown here. Note that each mode is selected by an ON switch at boot time, but other switches are sometimes used once the mode has been set.

For more details, see the Calibration sections below.

SW	Normal Mode	Tank Calibration Mode	RPM Function Mode	Test Mode	Last Delete Mode	Restore Mode
#1	OFF	**ON**	Select 10^4 digit	OFF	OFF	**ON**
#2	OFF	X10 Multiplier	**ON**	OFF	OFF	**ON**
#3	OFF	X5 Multiplier	Select 10^0 - 10^3 digits, as binary	**ON**	OFF	**ON**
#4	OFF	X2 Multiplier		OFF	**ON**	**ON**



All user settings are stored in a non-volatile memory called EEPROM, it can be considered similar to a USB Flash Drive. The gauge will always warn you before overwriting any settings (`WRITE EEPROM?`) giving you the option to quit by un-powering.

Tank Calibration Mode

The following procedure must be done in calm conditions, with an accurate fuel delivery pump.

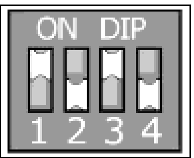
Empty the fuel tank completely using a pump or syphon. Take the opportunity to remove any sludge and debris.

Unscrew the two fuel gauge cover retaining screws, and carefully slide the cover in the direction away from the fascia.

Locate the red DIP switch, with switches 1234 whose ON positions are upwards towards “ON DIP”. SW #1 selects Tank Calibration Mode. SW #2 - #4 control the Calibration Step; this is the volume by which the tank must be filled as each calibration step is stored in the memory.

Locate the raised button (next to the DIP switch at the “1” end) this is referred to as the “KEY”. Pressing this will proceed with each calibration step and store the data in temporary memory. The sounder will beep when the KEY is pressed.

#1 ON	Calibrate Mode ON
#2 OFF	X10 Multiplier OFF
#3 ON	X5 Multiplier ON
#4 OFF	X2 Multiplier OFF



Switch DIP SW #1 to ON (Calibration Mode) and select the Calibration Step on DIP SW #2 - #4 using their multipliers of X10, X5 and X2.

The example shows settings for Calibration Mode with a 5L calibration step.

```
<TANK CAL SET>
REBOOT TO QUIT

CAL STEP:    5L

KEY TO PROCEED
```

Power on the fuel gauge, the display will appear as shown on the left. The message `REBOOT TO QUIT` advises that you can quit the calibration mode by powering off, no settings will be changed.

The Calibration Step can be altered at this time using SW #2 - #4 as above.

To proceed, press the KEY as prompted.

```
<TANK CAL SET>
READING       0
DATA:         7
FUEL:        0L

KEY TO PROCEED
```

The gauge is now waiting for `READING 0`, representing an empty tank, or 0L. The DATA (`7`) corresponds to the resistance of the sender in the tank, and may have a <u>slightly</u> different value.

Now slowly add a measured amount of fuel (preferably from containers) until the data figure <u>just</u> begins to rise. This becomes the “EMPTY” point, and the fuel added represents the “RESERVE”.

When enough fuel has been added to reach this EMPTY point, press the KEY to store the data.

Now begins a normal fuel delivery, but in 5L stages. The counter on the fuel delivery pump must start from 0 Litres to avoid any confusion which will lead to calibration errors.

```
<TANK CAL SET>
READING       1
DATA:         8
FUEL:        5L

KEY TO PROCEED
```

The gauge is now waiting for `READING 1` which represents 5L in this example. The DATA (`8`) again corresponds to the sender resistance. Now slowly add <u>exactly</u> 5L of fuel to the tank.

When the `DATA` reading has stabilised, press the KEY to save the value of the data for 5L. As a backup, make a note of the `DATA` reading if possible.

Continue filling the tank in 5L stages, pressing the KEY after each 5L has been added. Eventually, one of two things will occur: the tank will overflow, or the `DATA` figure will no longer rise as fuel is added. The latter means that the sender in the tank has hit the end-stop. Either way, the calibration is almost complete .

```
<TANK CAL SET>
REBOOT TO QUIT



WRITE EEPROM ?
```

Slide SW #1 to the OFF position (Normal Mode) and press the KEY. The message `COMPLETED!` will appear on the LCD. The gauge is now waiting for confirmation that you wish to write the data to EEPROM (the non-volatile memory), overwriting any previous calibration data. Assuming this is correct, press the KEY again. (If something has gone wrong and you wish to abort and restart, just power off).

```
<TANK CAL SET>
REBOOT TO EXIT
INDEX      127
WRITING      0
READING      0
VERIFIED   128
```

The screen will now change to this display showing the EEPROM update taking place, this takes about 30 seconds. When it has completed message `REBOOT TO EXIT` will appear.

Power off, and return all DIP switches to OFF. Refit the cover (see NOTE below first).

NOTE It is likely that the last reading made by the gauge will not represent a full 5L, as it is impossible to predict when to finish the calibration process until the tank overflows, or the sender hits the end-stop. To allow for this, the gauge has an optional mode to delete the last entry (or more if the process is repeated). For more details, see Last Entry Delete mode below:

RPM Function Mode

The RPM Function correlates the relationship between the tachometer pulse produced by the alternator, and the actual RPM of the engine. The main factors that affect this relationship are: the number of tachometer pulses per revolution of the alternator, and the gearing produced by the crankshaft and alternator pulleys on the alternator belt; this gearing has the effect of multiplying the number of pulses received by the gauge. These factors are related by the formula:

$$Tach\ Frequency\ at\ Gauge = Tach\ Frequency\ at\ Alternator \times \frac{Crankshaft\ Pulley\ Diameter}{Alternator\ Pulley\ Diameter} \quad or \quad F_g = F_a \times \frac{D_c}{D_a}$$

In order to convert F_g to RPM, a function is required which counteracts these factors. As D_c is normally larger than D_a by some margin, and F_a is normally several times the rotation speed of the alternator, these factors both tend to increase F_g. Therefore the required function must reduce F_g to convert it to RPM; in other words it must divide it by some value (N), viz:

$$RPM = \frac{1}{N} \times F_g \quad so \quad RPM = \frac{1}{N} \times \left(F_a \times \frac{D_c}{D_a}\right) \quad or \quad RPM = \frac{F_a}{N} \times \frac{D_c}{D_a}$$

This then is the purpose of the RPM Function Mode in the gauge: to set the value of N such that the RPM is displayed correctly.

```
<RPM FUNC SET>

FUNC: 43210
          ^
TACH:    XXX Hz
RPM      XXX
```

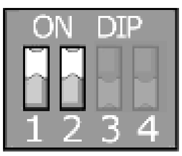
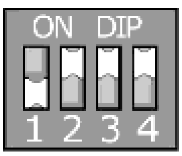
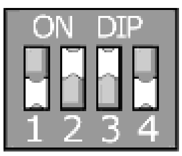
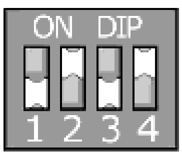
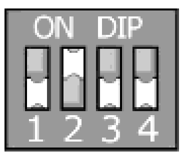
Switch DIP SW #2 to ON (RPM Function Mode) and power on. After loading the EEPROM data, the display will appear as shown on the left. Note the number to the right of FUNC: - this is the divider N as above, but for simplicity it is shown multiplied by 1000, thus eliminating the decimal point. The number shown will be different, the digits 43210 are used here to illustrate the columns.

Note also the pointer cursor `^` under the 0 column, and the digits to the right of `TACH:` and `RPM:` The `TACH` value is shown in Hz (cycles per second) and is for information only.

Those familiar with mathematics will realise that the columns `43210` represent decreasing powers of ten: 10^4 down to 10^0 but even those with "*mathphobia*" should recognise 10^2 (ten squared) as being 100. This notation is just a more flexible way of expressing the "HTU" that children write above the Hundreds, Tens, and Units when learning arithmetic.

What has all this mathematics got to do with a fuel gauge? The problem is that each digit of N is changed by first moving the cursor under each of the five columns, but there are only three switches left to do so. The solution is binary numbers. For those familiar with binary, the columns 3210 are selected by forming their binary code on DIP SW#3 (2^1) and DIP SW#4 (2^0), with column 4 being selected with DIP SW#1, which overrides the other switches.

If the last few paragraphs made little sense, the pictures below show the switch positions needed to select each digit:

FUNC: 43210 (^ under 4)	FUNC: 43210 (^ under 3)	FUNC: 43210 (^ under 2)	FUNC: 43210 (^ under 1)	FUNC: 43210 (^ under 0)
				

Each digit of N is changed by first moving the cursor under each of the five columns, then pressing the KEY to increment the digit. The digits roll around to 0 after 9 is reached, except the digit on the left (4) which has a maximum of 5. In addition, the lowest number that can be set is 1000 (which equates to $N = 1$). Therefore the range of N is 1 to 59.999, which is more than enough.

There are two ways set the RPM Function: direct input of a calculated value, and trial and error; the latter requires an accurate tachometer (or stroboscope) on the crankshaft pulley. To calculate the value, find the frequency multiplier of the alternator from the manufacturer's data (this is normally 6) and calculate the value using the diameters of the pulleys in the formula above.

To set the RPM function by trial and error, first run the engine and allow it to warm up. Measure the RPM of the crankshaft with an accurate tachometer, then work along the columns from left to right. An example may make this clearer; assume an actual Crankshaft RPM reading of 1000 RPM, with FUNC: having an initial value of 10000:

Fuel Gauge	FUNC:	Comments
RPM: 1464	10000	The fuel gauge is reading too high, so N must be increased, change first digit to 2
RPM: 732	20000	Reading now too low, N must be decreased, revert to last "high" value of FUNC then move to next digit
RPM: 1330	11000	Reading still too high, N must be increased …
	. . .	*Intermediate values not shown*
RPM: 1045	14000	Reading still too high, N must be increased
RPM: 976	15000	Reading now too low, N must be decreased, revert to last "high" value of FUNC then move to next digit
RPM: 1038	14100	Reading still too high, N must be increased …
	. . .	*Intermediate values not shown*
RPM: 1002	14600	Reading still too high, N must be increased
RPM: 995	14700	Reading now too low, N must be decreased, revert to last "high" value of FUNC then move to next digit
RPM: 1002	14610	Reading still too high, N must be increased
RPM: 1001	14620	Reading still too high, N must be increased
RPM: 1000	14630	READING CORRECT
RPM: 1000	14640	READING CORRECT
RPM: 999	14650	Reading now too low, N must be decreased, revert to mid or lowest correct reading, and adjust final digit if required

From the table above, it can be seen that the absolute correct value of FUNC lies between 14630 and 14640, but as both of these values gave a correct reading at 1000 RPM further action is not strictly necessary. It is worthwhile checking that the RPM is displayed correctly at the engine speed used for normal cruising, and with a charging load on the alternator.

To store the value of FUNC, slide all switches to the OFF position (Normal Mode) and press the KEY. The message COMPLETED! will appear on the LCD. The gauge is now waiting for confirmation that you wish to write the data to EEPROM. To proceed, press the KEY as prompted.

Note that if a tachometer or stroboscope is not available, a mains powered fluorescent light may be used as a stroboscope at 3000 RPM (50Hz mains) or 3600 RPM (60Hz mains). Alternatively, many digital multimeters have a Frequency function that could be utilised with a suitable sensor; please contact us for further details.

Test Mode

Test Mode is selected by setting DIL SW #3 ON. Unlike other modes, it can be activated or deactivated either before booting, or during normal operation. If activated before booting, it considerably slows the display of the EEPROM load then pauses for 20 seconds afterwards to enable the data to be monitored. It then displays the normal screen, but with the large digits replaced by various diagnostic data, which alternate with their labels and values:

```
FUEL       XXXL
aT8 fR8 fIn [I]
TM0    rpm0
ignSec   resSec
 NORMAL DISPLAY
 NORMAL DISPLAY
```

< Line 0 (top): shows the fuel level in-lieu of the large digits
< Line 1: aT8 raw fuel A/D value, fR8 mean A/D value, fIn index of look-up, [I] its value
< Line 2: TM0 raw tachometer frequency in Hz, rpm0 RPM before rounding to nearest 10
< Line 3: ignSec, resSec actual seconds of engine and reserve timers

Clearly, these data are of little interest to users, but are included here in case activated by mistake.

Last Entry Delete Mode

As noted above, it is likely that the last reading made by the gauge will not represent a full 5L, as it is impossible to predict when to finish the calibration process until the tank overflows, or the sender hits the end-stop. To allow for this, the gauge has a process to delete the last entry (or more if the process is repeated).

Procedure for LAST ENTRY DELETE

- Power off the unit. Set DIL SW #4 ON, all other switches OFF. Power on.
- After loading the EEPROM, the unit asks if you want to delete the last entry. To do so, press the KEY.
- As a safeguard, the unit now prompts you again before writing the new values to EEPROM . To do so, press the KEY.
- The unit now goes through the EEPROM update for about 30 seconds. Power off when completed.
- Return all DIP switches to OFF. Refit the cover.