



SPEEDBOX

Instruction Manual

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Version 1.0



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1. Introduction

The SPEEDBOX is a very high accuracy non-contact speed sensor that has been designed for professional automotive testing, as well as for other industrial and high-end motorsport applications. It outputs a low latency, non-interpolated speed measurement comprised of GPS and inertial data, combined using an adaptive filter for exceptional performance even in non-ideal GPS environments. It offers an extremely reliable design that is based on our years of racing experience. The high accuracy speed measurement is output in a variety of forms that are suitable for integration into most data logging and display systems - CAN, RS232, USB, analogue and a fully configurable digital pulse output are all provided as standard. Analogue and digital inputs are also provided in order to allow the measurements from the SPEEDBOX to be synchronized to external events such as pedal depression or a laser barrier signal.

The SPEEDBOX uses Race Technology's very own high accuracy 20Hz PurePhase GPS solution, in real-time combination with precision 200Hz accelerometer data. It is optimized for speed measurement and outperforms even top of the range 'survey-grade' GPS receivers in this area. This unique hybrid GPS+inertial technology offers lower noise, lower latency and superior bandwidth to "GPS-only sensors". It is also far more resistant to drop outs. This means that it offers an ideal replacement/upgrade for "fifth wheel", optical and GPS-only sensors in a wide variety of automotive testing applications. These applications include brake testing, chassis dynamics, accident reconstruction, tyre testing and stability management testing, to name but a few. The SPEEDBOX is also supplied with Race Technology's new Performance Monitor software, which allows in-car testing and analysis of test results in conjunction with a laptop PC.

The SPEEDBOX avoids the inaccuracies, wear and calibration requirements of devices such as wheel speed sensors, requiring only a good view of the sky to give a speed output that is far more accurate than a calibrated wheel speed sensor.

IMPORTANT: The SPEEDBOX is only intended for testing off the highway and in a controlled environment. Every precaution should be taken to ensure that all equipment is properly secured in the vehicle before proceeding with any test work. Test work must only be carried out after taking due consideration for safety.

2. What's in the Box?

The complete SPEEDBOX system consists of the following:

- SPEEDBOX unit
- Standard magnetic mounting GPS antenna
- Power cable
- USB cable
- Transit case (with foam interior)
- Software CD
- SPEEDBOX reference manual
- SPEEDBOX instruction manual

If you have purchased a SPEEDBOX-RTK the RTK antenna strip will be provided in place of the standard antenna.

If anything is missing please contact Race Technology.

3. Introduction to the SPEEDBOX

3.1. What the SPEEDBOX Can Do

Key features of the SPEEDBOX include:

- **High accuracy 200Hz speed output.** Inside the SPEEDBOX is a high precision tri-axis silicon accelerometer. Readings from this unit are combined with the GPS speed output to give a 200Hz combined speed output that has both high accuracy and fast dynamic response with no interpolation.
- **20Hz GPS speed and position output.** The raw GPS speed and position information is calculated and output at 20Hz.
- **3 Axis acceleration measurements.** Raw longitudinal, lateral and vertical acceleration data is output at 200Hz. A 2g accelerometer is fitted as standard, a 6g option is also available.
- **Wide range of output formats.** Available output formats are CAN, RS232, USB, analogue voltages and digital pulse.
- **Analogue and digital inputs.** Analogue voltages and external triggers can be input to the SPEEDBOX, allowing external events to be precisely aligned with SPEEDBOX data.
- **Configurable.** The SPEEDBOX is supplied with a PC-based configuration utility that allows details of the outputs to be configured.
- **Upgradeable firmware.** The firmware of the SPEEDBOX is flash upgradeable through the USB or serial port of a PC.
- **Software and documentation.** The SPEEDBOX is supplied with a comprehensive software and documentation CD.

3.2. What is the RTK option?

The SPEEDBOX-RTK is a factory-fit option that is available as an upgrade to the standard SPEEDBOX. It combines all of the features of the standard SPEEDBOX, with the following added extras:

- **Yaw** – this is defined as the rotation orientation of the vehicle about its vertical axis
- **Pitch** – this is defined as the vehicle's attitude being nose up or down
- **Body slip angle** – this is defined as the difference between the yaw and the heading

All of these RTK measurements are output at 20Hz.

Note: Whilst heading and gradient are output from the standard SPEEDBOX, they are only available when the vehicle is moving. All of the core functions of the standard SPEEDBOX (including speed, acceleration, position and distance) are output with the same level of accuracy by the SPEEDBOX-RTK.

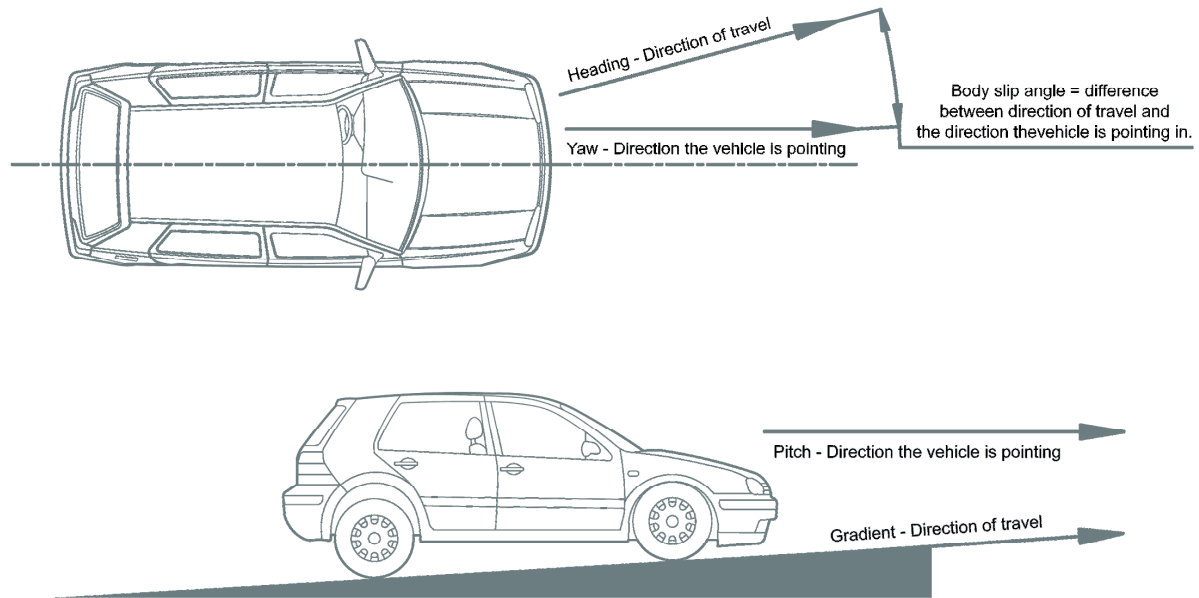


Figure 1: Difference between yaw and heading, pitch and gradient

For the angular yaw and pitch measurements, a second GPS receiver and antenna is used. A differential solution between the two GPS antennas is obtained. This allows the position of the two antennas, relative to each other, to be determined extremely accurately (to within millimetres). This enables yaw and pitch to be accurately calculated to within tenths of a degree. As yaw and pitch are “direct” measurements, they do not require the vehicle to be moving. The slip angle is calculated from the yaw and heading measurements once the vehicle starts to move.

The SPEEDBOX-RTK is a specialist measuring instrument. As such, there are a number of points that must be considered when using it:

- The processing techniques used require both antennas to obtain a full “carrier” GPS lock from a set of satellites common to both.
- A standard GPS solution requires four satellites. An RTK solution, however, requires a minimum of five satellites.
- As good GPS reception is so crucial in this application, the GPS antenna mounting instructions should be read and followed with special care by RTK users.

The limitations of the system must also be understood:

- A full carrier lock can often be lost during standard highway driving, especially in the presence of tall adjacent buildings, trees in leaf, bridges and other obstacles. Whereas the speed output is relatively robust to sub-optimal GPS reception, an RTK solution is not.
- A good clear view of the sky is recommended when yaw and pitch data from the RTK option is required. It is best suited to test and race tracks - where a clear view of the sky is largely guaranteed. Whilst the RTK is less suited for road testing or use in a built up, urban area, results may sometimes be obtained under these conditions, depending on the GPS reception available.

- RTK works in a different way to a normal GPS fix. A normal GPS lock will tend to “degrade” from good to poor, before losing a lock completely. An RTK solution either has a very high accuracy lock, or no lock at all.

All of the subsequent instructions for installing and operating the standard SPEEDBOX should be followed for the SPEEDBOX-RTK. Additional, RTK specific, notes are provided where required.

4. Installing the SPEEDBOX

4.1. Installation Checklist

The following checklist is designed to be a quick reference for connecting the system in day-to-day usage. It is recommended that the more detailed explanations of each step are read in their entirety before initially installing the unit.

- Ensure the power is disconnected.
- Connect the supplied antenna to “RF 1” on the unit. For the RTK option, connect the rear antenna to “RF 1” and the front antenna to “RF 2”.
- Mount the antenna(s) on the vehicle roof – do not crush the cable in the doors or windows.
- Secure the unit safely in the vehicle, taking careful note of the mounting orientation.
- Connect the power to a 9 – 36V DC supply, e.g. a “cigarette-lighter” type plug, or other fused power supply.

4.2. Mounting the SPEEDBOX unit

In order to give accurate acceleration readings, the SPEEDBOX should be mounted so that it is flat, level, and can't move. The orientation of the unit is important. The unit must be mounted with the direction of travel as shown on the top of the unit. When mounted correctly the accelerometers will read as follows:

Longitudinal: positive for acceleration

Lateral: positive for turning right

Vertical: positive when the unit is upright

The speed calculation is robust to a mounting angle of up to 20° from level, for best accuracy mount as level as possible. Speed accuracy readings taken whilst travelling over bumps are particularly prone to errors caused by an incorrect mounting angle. Neither the raw 20Hz GPS position and speed outputs nor the angular measurements from the RTK option are sensitive to the mounting orientation.

Note: Theoretically, the SPEEDBOX should be mounted vertically below the GPS antenna (Antenna 1 on an RTK system) to ensure that the accelerometers and the GPS antenna “see” the same velocity. In practice this is a small effect that can generally be ignored.

The unit can be securely restrained in the required position, either by bolting it in place through the four 4mm diameter holes that are pre-drilled in the unit, or by using a secure locking tape such as “Scotch-Lock”.

4.3. Mounting and connecting the GPS antenna

The correct mounting of the GPS antenna is of utmost importance in ensuring that the highest accuracy is achieved.

The GPS unit requires a 3.3V active antenna (supplied) to be fitted to the “RF1” connection on the SPEEDBOX. This must be mounted in a position that gives a good view of the sky with it's base pointing downwards. It is **STRONGLY** recommend that you mount it on the

roof of the vehicle. Mounting the antenna on the bonnet or the boot of the vehicle may give substandard results due to the reduced number of satellites in view. This is particularly important due to the fact that any alteration in vehicle course will change the satellite constellation used.

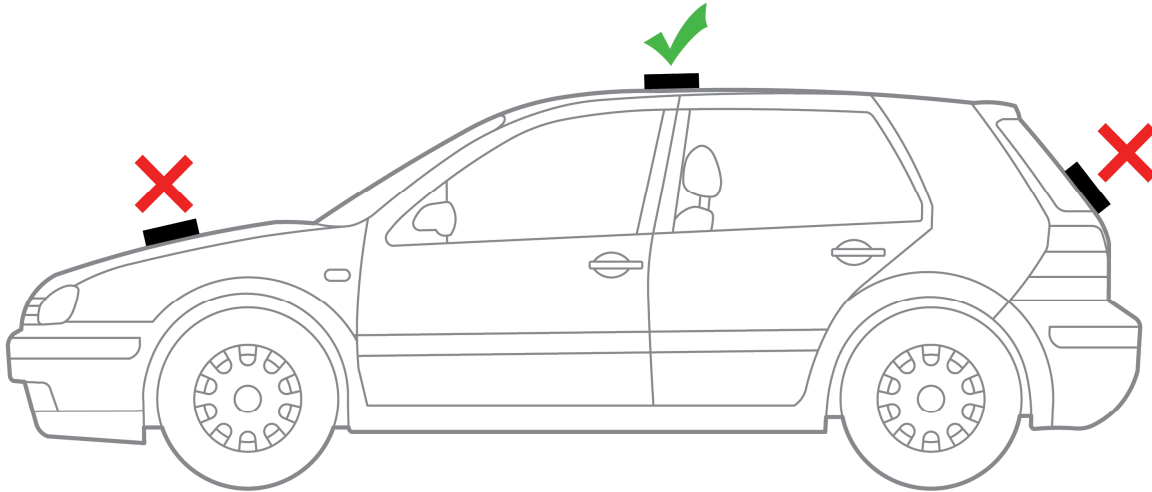


Figure 2: Correct GPS antenna mounting position on the roof of the vehicle

In view of the importance of the antenna mounting position, a the following additional guidelines are set out below:

- The antenna must not be covered with tape
- The antenna must not be subjected to high levels of vibration. To prevent this, isolate the antenna from vibration as much as possible.
- The antenna must be physically remote from sources of electrical noise. By far the biggest source of radio interference is a gasoline engine's ignition system, so keep the antenna away from all aspects of it. Avoid include the engine management system, coils, high tension leads and ignition control modules.
- Avoid trapping, pinching or kinking the antenna cable. The lead from the GPS antenna to the receiver is a special cable and it is not normally practical to repair it. If you do trap, pinch or cut it, then the antenna will have to be replaced. Do not attempt to fit the antenna cable into a shut gap, or compress it with a door or window seal.
- If at all possible, mount the antenna on a metal substrate (mounting on the roof of the car is ideal). The GPS radio signal is amplified if the antenna is mounted on a metal plate, and the bigger this is, the better.

Note: the “RF2” connection is not connected on the standard SPEEDBOX.

Race Technology currently supplies three different types of antenna:

- Standard (as supplied)
- High sensitivity
- Interference rejecting.

The standard antenna works well in almost all cases. The high sensitivity antenna can improve signal reception under some circumstances. The interference rejecting antenna should be used where there is a known RF interference problem - they give excellent interference rejection, but provide a slightly “noisier” GPS signal.

4.4. Mounting and connecting the GPS antennas – RTK option

The magnetic mounting antenna strip is a flexible magnetic strip. It contains two antennas that are mounted in the correct orientation and at a known distance from each other.

- The baseline of the antenna strip is 80cm, so the SPEEDBOX-RTK must be configured to use this baseline using the configuration software supplied. If the unit is not configured to this baseline, it will be unable to obtain a lock. (This configuration is the default setting for new units when they are supplied with the antenna strip).
- The antenna strip must be mounted in the correct orientation, as shown on the strip. The wires from the two antennas are labelled “RF 1” and “RF 2”, and should be attached to the corresponding connections on the SPEEDBOX.
- Treat the cables with care. If they are damaged, then it is likely that the whole assembly will have to be replaced.

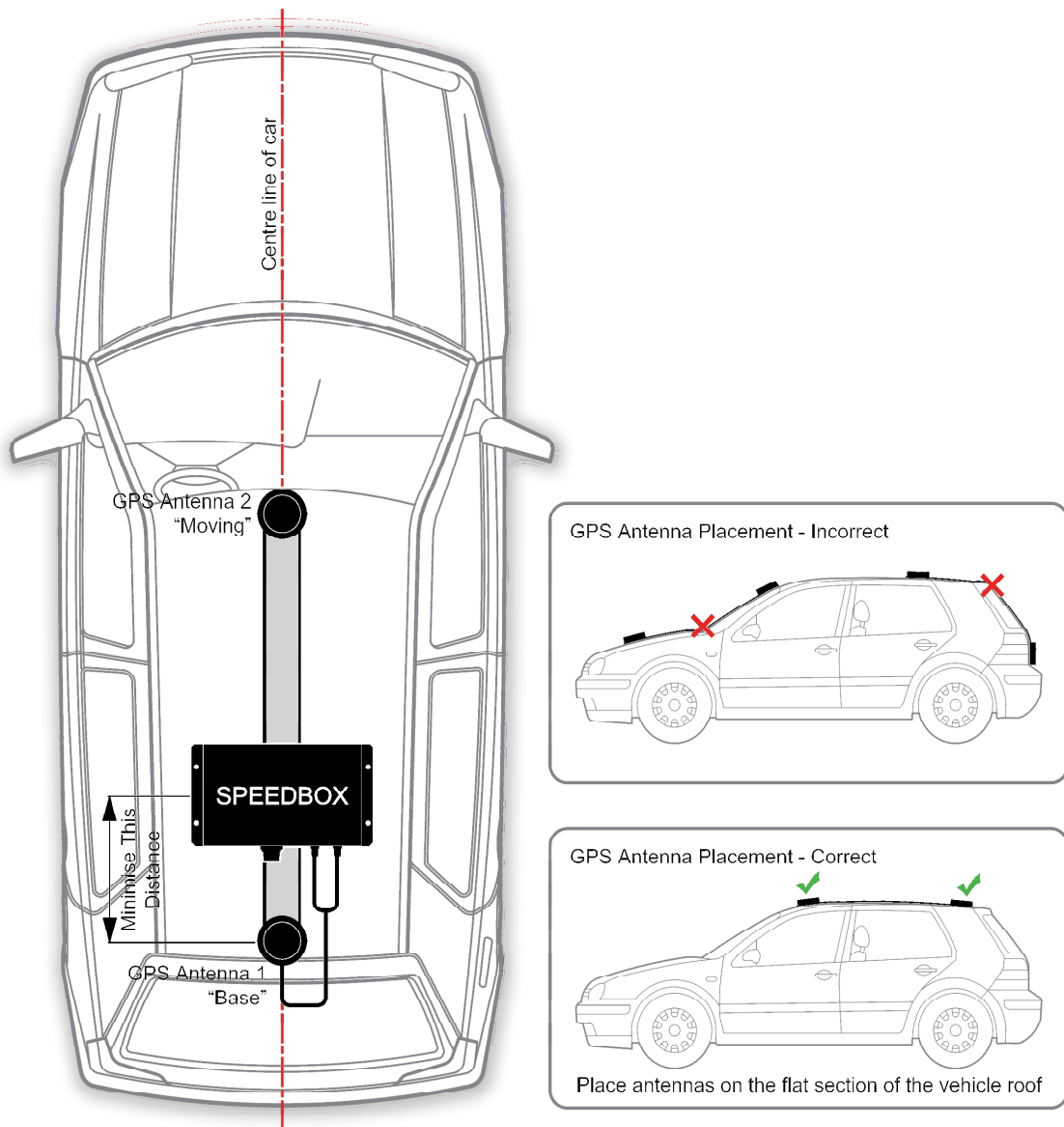


Figure 3: Mounting arrangement for the magnetic antenna strip (RTK option only)

4.4.1. Using two separate GPS antennas for RTK measurements

In some circumstances it may be impossible to use the magnetic strip - if for an example an obstruction exists between the front and rear antenna locations; if the available baseline is too short; if a longer baseline than 80cm is required; or if the use of antennas that are different to those on the strip is desired. In these circumstances, two separate antennas are used to provide the GPS signal to the RTK unit. As long as they are set up correctly, the results will be just as good as when using the magnetic strip. If, however, they are set up incorrectly, then the RTK solution will fail.

It is vitally important that both of the antennas used are of the same type. Using two different types of antenna may cause the RTK solution to fail.

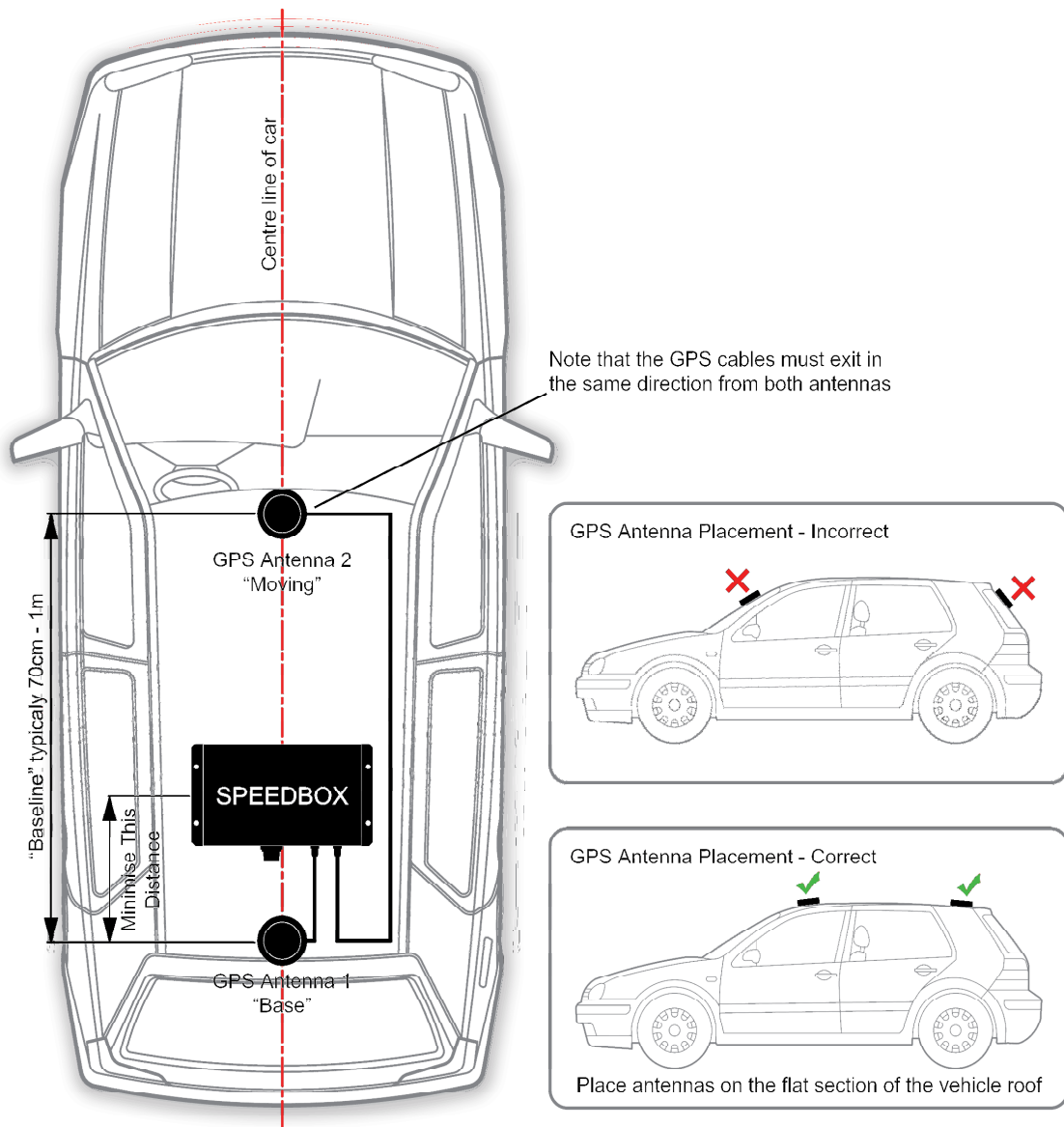


Figure 4: Mounting arrangement for two separate antennas (RTK option only)

The general arrangement for mounting two antennas for the RTK unit is shown in Figure 5 above. Both antennas should be mounted on the roof of the vehicle, on the vehicle centreline. The rear antenna is the “base” antenna, and must be connected to “RF 1” on the unit. The forward antenna is the “moving” antenna, and must be connected to “RF 2” on the unit. If the antennas are connected the wrong way around, the unit will not reliably obtain an RTK solution when the vehicle is moving. Both antennas should be mounted in the same orientation; i.e. the cable should emerge from the same side of both antennas to minimise the effect of antenna “phase centre”. It is also absolutely essential that the antennas are of the same type, model and manufacturer.

4.5. Power

The SPEEDBOX requires a stable DC power supply, which must be in the range 9 – 36V. This should be connected to the cable loom assembly that is supplied with the SPEEDBOX

via a fused connection to the vehicle. A 500mA fast blow type fuse is recommended. Once connected to the power supply, the SPEEDBOX will automatically power up and commence its initialisation routine. The current consumption of the SPEEDBOX is approximately 200mA @ 12V.

Unreliable power supplies are a common source of problems. In the event of any problems, please check the reliability of the power source or try an alternative supply in the first instance. The SPEEDBOX may also be powered from an external battery pack. If you require a battery pack, Race Technology keeps a wide selection in stock - please contact us with your requirements. Because of the current supply requirements, only rechargeable batteries should be used. Disposable cells are not suitable.

4.6. Connections - General

The power and GPS connectors are on the rear of the unit, with all other input / output connectors mounted on the front. Full information on signal levels and pinouts for these connectors can be found in the SPEEDBOX reference manual.

A 3.3V active GPS antenna must be connected to "RF1". RF2 is only used with the RTK option.

4.7. Connecting the SPEEDBOX to a Race Technology data logger or display

The SPEEDBOX serial output is 100% compatible with all other Race Technology products. This means that when correctly configured and connected directly to one of our data loggers or display units, the results will appear “seamlessly” in either our data analysis software or on the display. Further details on connecting the SPEEDBOX to some of our common products are given below:

4.7.1. Connecting the SPEEDBOX to the DL1 or DL2

The SPEEDBOX uses Race Technology’s PurePhase GPS engine. This is optimised specifically for automotive applications and produces more accurate and more rapidly updated speed measurements than can be achieved by the commercial GPS receiver that is used in the DL1 or the 5Hz DL2. As such, the SPEEDBOX can usefully be connected to the DL1 or DL2 to provide an upgrade to the quality and rate of the GPS data that they sample.

In order to connect the SPEEDBOX to the DL1 or DL2 you need to do the following:

- Configure the DL1 or DL2 to accept RT format serial data over its serial port.
- Disable the DL1 or DL2’s own internal channels for all GPS data, and accelerometer data. If you have two sources of the same data, then you will get unpredictable results.
- Connect the SPEEDBOX to the logger using a null modem cable that is connected between the DL1/DL2 and an RS232 output on the SPEEDBOX. It is also necessary to connect a GPS antenna to the DL1/DL2 (not shown) since the DL1 can not read the date and time over RS232. The DL1/DL2 must therefore get this from the GPS signal.

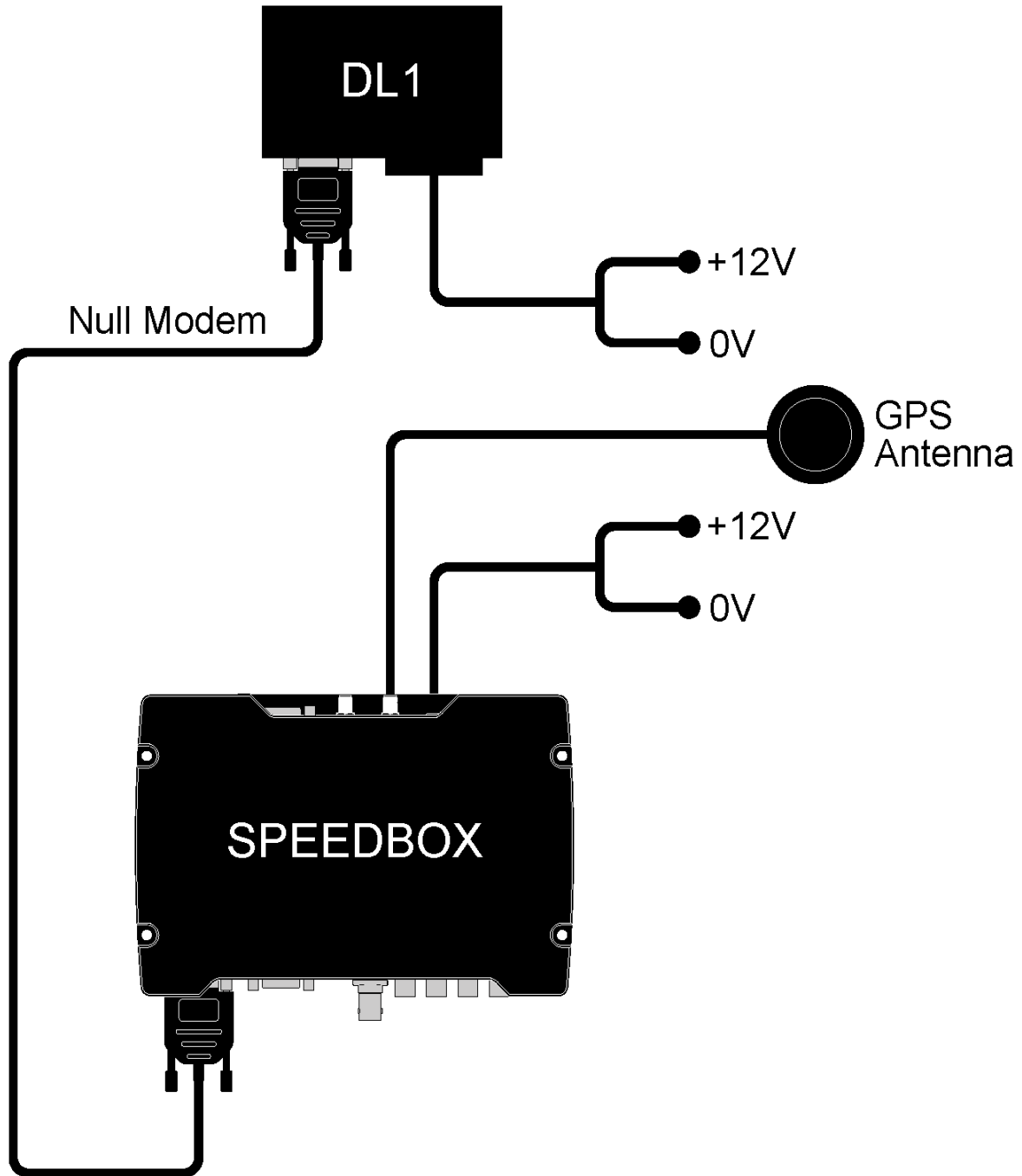


Figure 5: Arrangement for connecting a SPEEDBOX to a DL1 datalogger

4.7.2. Connecting the SPEEDBOX to the DASH1

The DASH1 can be connected directly to the RS232 output on the SPEEDBOX wiring loom, and will receive its power through this connection. Once the DASH1 has been correctly configured, it will immediately decode and display any messages output by the SPEEDBOX. The DASH1 can be configured either directly from the PC or using a DL1/DL2. If you are configuring from a PC, a special serial cable is required. This will supply power from the PC to the DASH1. This cable can be purchased from Race Technology if required.

4.8. Connecting the SPEEDBOX to other data logger types

The SPEEDBOX is fitted with a range of available output options. This allows it to be connected to as wide a range of data acquisition systems as possible. The options available are: CAN, digital pulse, analogue, USB and serial (RS232).

The choice of which output to use may depend on several factors. CAN, USB and serial are the first choice for high accuracy readings, since these outputs are not generally subject to any type of noise or interference issues. However, there is a small latency between the measurement being taken and the CAN or serial messages that are decoded by the receiver. The digital pulse and analogue outputs are both ultra-low latency outputs, but the digital pulse output is only suited to speed or distance measurement and the analogue outputs may need to be calibrated to the user's logger. They may also be subject to signal noise. Further notes on each of the output types are given below:

4.8.1. CAN

The SPEEDBOX can output a variety of CAN messages, using Race Technology's CAN data message format. The rate at which each message is output is configurable, at up to 200Hz for inertial-based messages, such as accelerations and combined speed, and at up to 20Hz for GPS-based messages. Additionally, there is a trigger timestamp message, which is output in response to detected trigger events, and can be either enabled or disabled. Until GPS lock is achieved, all GPS-based messages are output at only 1Hz, and are output at the full configured rates once GPS lock has been obtained, and thereafter even if GPS lock is lost.

A detailed description of the Race Technology CAN data format, including the message contents and the default addressing scheme, is contained in the SPEEDBOX reference manual, and in the knowledge base on the Race Technology web site. A CANdb (.dbc) file is available to aid message decoding. If the CAN addresses are changed from the default settings, the supplied CANdb file will no longer decode the messages. The SPEEDBOX supports both 11 and 29bit addressing, Bitrates are configurable to 125kbps, 250kbps, 500kbps or 1mbps.

In the case of the CAN output, the latency depends on both the presence of other traffic on the CAN network, the bit rate that has been selected, and how many CAN messages have been configured for output, and at what rate. This means that it cannot be considered deterministic. The SPEEDBOX will output queued inertial messages before queued GPS messages, in order to minimise the latency of the inertial messages. The remaining CAN messages, outputting the GPS data, typically have a latency of between 50 to 100ms after the point to which the data refers. The messages may be aligned with the GPS time to which they pertain with reference to the GPS time field in CAN message RT_GPS_Time, if that message has been configured for output.

4.8.2. Pulse

The digital pulse output has the advantage of having the lowest latency - typically this is below 2ms - but it is only useful for measuring speed (frequency) and distance (pulse count). The pulse output can be used to replace other common speed sensors, for example fifth wheel, optical speed sensors and GPS-only sensors. In order to allow it to replace as many existing sensors as possible, with minimal change to the data acquisition system, the pulse output has been made extremely configurable, as described below.

There are two modes of pulse output: 1) fixed pulse width, or 2) 50% duty cycle. In both cases, the pulse frequency is proportional to speed and the pulse count to distance. The number of pulses per meter may be set using the configuration software. In the fixed width mode, the high time of the pulse is always constant, and may be varied from 10 to 1000 μ s using the configuration software. In the 50% duty cycle mode, the pulse high and low times are equal at any given speed, and the minimum allowable high or low time is 25 μ s.

For both modes, the number of pulses per meter output may be configured using the configuration software to between 1 and 400. A higher value of pulses per meter will give greater resolution, but will saturate at a lower speed. A lower value of pulses per meter will give lower resolution, but will allow a higher speed to be reached before saturation occurs. The configuration software shows the maximum speed that can be represented before saturation for any entered value of pulse configuration.

For both pulse modes, the low and high pulse levels are 0 and 5V respectively. The output impedance is 50 Ω

4.8.3. Analogue

There are 4 analogue channels on the SPEEDBOX, each of which may be configured either as an output or as an input, labelled “ADC/DAC 1” to “ADC/DAC 4”. By default, all 4 channels are configured as outputs upon leaving the factory.

The analogue outputs have a low latency, typically below 2ms. Each output channel can be configured to output any one of the allowable parameters, using the configuration software. In addition, the gain and offset of the channel voltage in relation to the output parameter can be configured. Full details on how to do this are in the configuration software section. The analogue channels can output a range of -5 to 5V when connected to 50 Ω impedance, and can output a range of -10 to 10V when connected to infinite impedance.

The vast majority of the noise on the analogue outputs lies within 1mV of the mean DC output, when sampled at rates between 1 and 100kHz. There may also be noise spikes of extremely short duration on the analogue output caused by cross talk from the pulse output. These are not normally detected by the sampling system due to their short period, but if the analogue outputs are being sampled and the pulse output is not required, it may be desirable to disable the pulse output using the configuration software.

When an analogue channel is configured as an input, the measurable input range is from 0 to 16V. If a channel is configured as an input and the corresponding Race Technology serial message is enabled, then the measured voltage on the channel will be output over the serial channel.

4.8.4. Serial and USB

The SPEEDBOX has 2 serial outputs, labelled RS232 1 and RS232 2 on the unit. There is also a USB connector; plugging a cable into the USB connector will switch the RS232 2 output to USB, automatically disabling RS232 2 and enabling USB output.

Both RS232 channels can be used to output data in any of the available formats, which are Race Technology format, NMEA format, and uBlox binary format. The messages that are transmitted can be set using the configuration software; each message can be enabled or disabled, and the rate at which the message is output can also be set. Both RS232 channels

can also be used to configure the unit, but only RS232 2 can be used to reflash the firmware of the unit. A brief explanation of the 3 available data formats is given below. Full descriptions of all messages available from the SPEEDBOX are given in the SPEEDBOX reference manual.

Race Technology data format is a binary data format. Source code in VB6 and ANSI C is available for converting the serial data into physical values if required. The Race Technology format data can be natively used by the Race Technology Monitor and Analysis software. This is the most efficient format in terms of data / byte.

NMEA is a widely used and recognised format in the GPS field, outputting ASCII (human readable) data. The SPEEDBOX follows the NMEA 2.3 standard. Details of the NMEA messages available from the SPEEDBOX are given in the SPEEDBOX reference manual, and details of the NMEA standard are widely available on the internet. The advantages of using the NMEA format include the fact that it is widely recognised by other equipment, and is human readable. It is not as efficient as a binary protocol.

The uBlox data format is a binary format. A full description of the format is available on the Internet at www.u-blox.com. The uBlox uCenter software can also be downloaded from the website to view the data. The unit will also accept configuration messages that turn messages on or off, and the signal to save the message configuration.

The baud rate at which the serial messages transmit is also configurable independently for each channel. The default rate is 115200 baud, which is the highest rate that most PC serial ports support, and available rates range from 4800 baud to 921600 baud. We recommend that the baud rate for each channel is left at the default of 115200 baud unless there are good reasons to change it, since this is the default connection rate of the configuration software, and will thus minimise the possibility of forgetting that the baud rate has been changed, and then wondering why the configuration software does not connect (you can change the baud rate of the configuration software, but you have to remember to do it!). Possible reasons to change the speed include interfacing with legacy equipment that expects NMEA data at a fixed lower baud rate, and increasing the maximum data throughput when high speed serial data acquisition is available by increasing the baud rate.

4.9. Connector Details

Full details of all the connector pinouts and signal levels are given in the SPEEDBOX Reference Manual.

5. Operating the SPEEDBOX

5.1. Powering up and Initialising the SPEEDBOX

Once the SPEEDBOX has been installed and connected, as described in the installation instructions, it can be powered up. When it is powered, the SPEEDBOX will automatically commence its initialisation routine. Within a few seconds the unit will begin to produce output data from the accelerometer. Meanwhile, the SPEEDBOX will search for a satellite lock. This may take up to a few minutes, depending on conditions. It is therefore recommended that the SPEEDBOX is powered up at least ten minutes before use, to ensure that the initialisation process is completed before any testing commences. This also ensures that the analogue outputs and the accelerometers will be closer to full operating temperature before testing commences; the largest temperature related variations in output occur in the first 5 – 10 minutes or so following a cold start.

There are a number of LEDs on the SPEEDBOX in order to provide a visual indication of the status of the unit. Additionally, the SPEEDBOX continuously provides GPS status messages over the CAN output as described in the output format section. The meaning of the status LEDs is described in the next section.

5.2. SPEEDBOX status indicators

The SPEEDBOX has eight LED indicators, labelled “Power”, “Status”, “GPS Status 1”, “GPS Status 2”, “Timepulse”, “Trigger Active”, “SBAS” and “Error”. The information provided by these LEDs is described below.

Power

The power LED (red) lights once the unit has booted and is running correctly. Whilst the firmware continues to run it blinks off very briefly once per second.

If the power LED fails to illuminate and blink when power is applied, the most likely cause is that no power, or insufficient power, has been applied to the unit. Please check that there is a supply of at least 9V (and less than 36V!), and that the supply is capable of a power output of at least 4W.

Status

The status LED (green) will either be off, flashing or continuously on. This will indicate the status of the GPS lock obtained by the unit. The meaning of the output is:

- Continuously off: No GPS lock.
- Short flashes at 1Hz: GPS lock, without carrier (either speed is from Doppler, or position only is available).
- Long flashes at 1Hz: GPS lock with carrier speed.
- Continuously on (RTK only): RTK solution obtained.

GPS Status 1

This LED (green) will be continuously on when GPS receiver 1 has any kind of lock (even position only), and off otherwise.

GPS Status 2

This LED (green) is identical to the GPS Status 1 indicator, except that it indicates whether GPS receiver 2 has a lock, and is only used on the RTK unit.

Timepulse

This LED (yellow) flashes at 1Hz 50% duty cycle when the GPS receiver has a lock. The falling edge of the output is precisely synchronised with the second boundaries of GPS time. I.E. the LED is lit for the second half of each second.

Trigger Active

This LED (blue) is lit continuously whilst the trigger is active.

SBAS

This LED (yellow) will be lit when satellite based augmentation systems (such as WAAS and EGNOS) are used to improve the GPS solution. This is not currently implemented.

Error

The LED (red) flashes a number of times to indicate various possible error states. When the LED is off, there are no errors indicated. When the error LED flashes, the error states are as indicated below.

- 1 flash: GPS module 1 failure
- 2 flashes: GPS module 2 failure
- 3 flashes: GPS antenna 1 short circuit
- 4 flashes: GPS antenna 2 short circuit

5.3. Taking measurements with the SPEEDBOX

When normal operation is established, the SPEEDBOX will by default provide continuous data over all of the output channels (some outputs can be configured to only start outputting in response to an external trigger, as described in the next section). It is ready to commence testing. The outputs from the SPEEDBOX are designed to be logged by a PC or data logger. They can also be connected to a Race Technology dashboard, if a real time in-vehicle display is required. Alternatively, the Race Technology monitor software can be used to view the output data in real time, via a serial connection to a laptop or PC.

5.4. Synchronising external events with SPEEDBOX measurements

One common requirement during testing is for events external to the SPEEDBOX, such as pressing a pedal, or passing a certain point, to be accurately synchronised with the measurements made by the SPEEDBOX. In order to do this, it is possible to connect external triggers to the SPEEDBOX, that can be used to switch the low latency outputs of the

SPEEDBOX, and/or timestamp the events relative to GPS time so that the events can be later reconciled to the SPEEDBOX measurements.

There are two trigger inputs on the SPEEDBOX. Trigger 1 is on a BNC connector. Trigger 2 is on pin 9 on the expansion port. Both triggers can be configured independently.

Each trigger can be configured to generate CAN and/or RS232 timestamps. These timestamp messages contain the ID of the originating trigger, the type of trigger (rising or falling edge), and the GPS time of week of the trigger, to a resolution of microseconds. GPS time of week is the number of seconds that have passed since midnight GMT on Saturday night.

Either or both of the triggers can be configured to activate either or both of the low-latency outputs (pulse and/or analogue). The outputs can be configured to be output either based on the trigger level (high or low), or toggled on a trigger transition (rising or falling edge). If the outputs are to be toggled by the trigger, the initial state (on or off) can be set. Both triggers can be configured to toggle a given output. If both triggers are configured to output based on level, then the most recent trigger to change level will set the output.

An example is given below:

Example : The user is performing a brake test, and only wants analogue and pulse output to start from the moment that the pedal is pressed, until the vehicle reaches a halt. It is also required to record this distance over CAN. The pedal sensor outputs zero volts until the pedal is pressed, and then outputs 5V whilst the pedal is depressed.

With the pedal sensor attached to the BNC input, the output needs to be configured to activate on a high level, so that when the pedal is pressed and the 5v is present, the output is activated. It is important during the test that the brake pedal remains pressed for the duration of the test. If the pedal is released during the test the output will be disabled.

In order for the test distance to be recorded over the CAN bus, it would be necessary to enable the RT_SB_Cumulative_Distance_2 message using the configuration software. This distance value output by this message would be reset to zero when the pedal press started the active test, and would be held at the final distance when the pedal release (level triggered case) or second pedal press (edge triggered case) ended the active test.

6. Using the supplied software with the SPEEDBOX

6.1. Installing the Supplied Software

The software CD that is supplied with the SPEEDBOX contains the latest build of Race Technology's software suite. This contains powerful tools that can be used to view and analyse the data from the SPEEDBOX, and a utility that can be used to reflash the SPEEDBOX with the latest firmware. To install the software, please ensure that any earlier versions of the Race Technology software are uninstalled. Use the Race Technology uninstaller rather than the Windows uninstaller in order to ensure that the software is properly removed ("*Start->Programs->Race Technology v7->Other->Uninstall*"). Insert the Race Technology CD and run the installer program. Now, verify that the software is installed. It should be under "*Start->Programs->Race Technology v7*".

Full instructions for downloading data to the analysis software and reflashing the SPEEDBOX are given later in this manual. Instructions for using the analysis software itself are outside of the scope of this manual. A full and comprehensive help file is installed with the software. You can find this under "*Start->Programs->Race Technology v7->Documentation*". In addition, all of the help documentation is available in the Knowledge Base section of the Race Technology website.

6.2. Installing the USB port drivers

It is entirely possible that the required drivers for the USB serial converter are already present on the PC. Connect the SPEEDBOX to the PC using the provided USB A-B cable. If the drivers are required the PC will prompt for them to be installed. Follow the onscreen instructions and load the drivers from the Race Technology CD provided.

6.3. Viewing the output of the SPEEDBOX with the "Lite Monitor" software

The monitor software allows the output from the SPEEDBOX to be viewed in real time on a PC. It also allows it to be streamed to disk for loading into the analysis software. Before using the monitor software, the SPEEDBOX must be connected to the PC using a null modem type serial cable connected between an RS232 output on the SPEEDBOX and a serial port on the PC, or using a USB type A to type B cable to connect the USB port of the SPEEDBOX to a USB port on the PC.

Start the Lite Monitor software. This will typically be found in "*Start->Programs->Race Technology V7->Lite Monitor*". Use the box in the top left of the window to select the correct serial port. Always ensure that the baud rate is set at 115200, since this is the baud rate used by the SPEEDBOX. Press the button labelled "*Connect*" to display the serial data output by the SPEEDBOX on the monitor.

In order to record the data being displayed, press the button labelled "*Stream to disk*" and enter a file name when prompted. Stop recording by pressing "*Stop streaming*". The .run file saved can be opened in the analysis software by double clicking on it.

In addition to the Lite Monitor, there is also a more powerful, fully configurable monitor program included in the software suite. Use of the full monitor program is outside the scope

of this manual, but - as with the analysis software - full instructions can be found either in the help software installed from the Race Technology CD or on the Race Technology website.

6.4. Configuring the SPEEDBOX from the PC

In order to configure the SPEEDBOX, first ensure that an RS232 output is connected to a serial port on the PC using a null modem cable. It can also be configured via USB connection. Start the configuration software, which will be found under “*Start->Programs->Race Technology v7->Configuration->Speedbox 20Hz*”. Before connecting to the SPEEDBOX, ensure that the correct serial port has been selected in the box in the top left corner of the configuration window. Now press the “*connect*” button. The software will read the details of the logger and its current configuration settings, as shown in Figure 11 below.

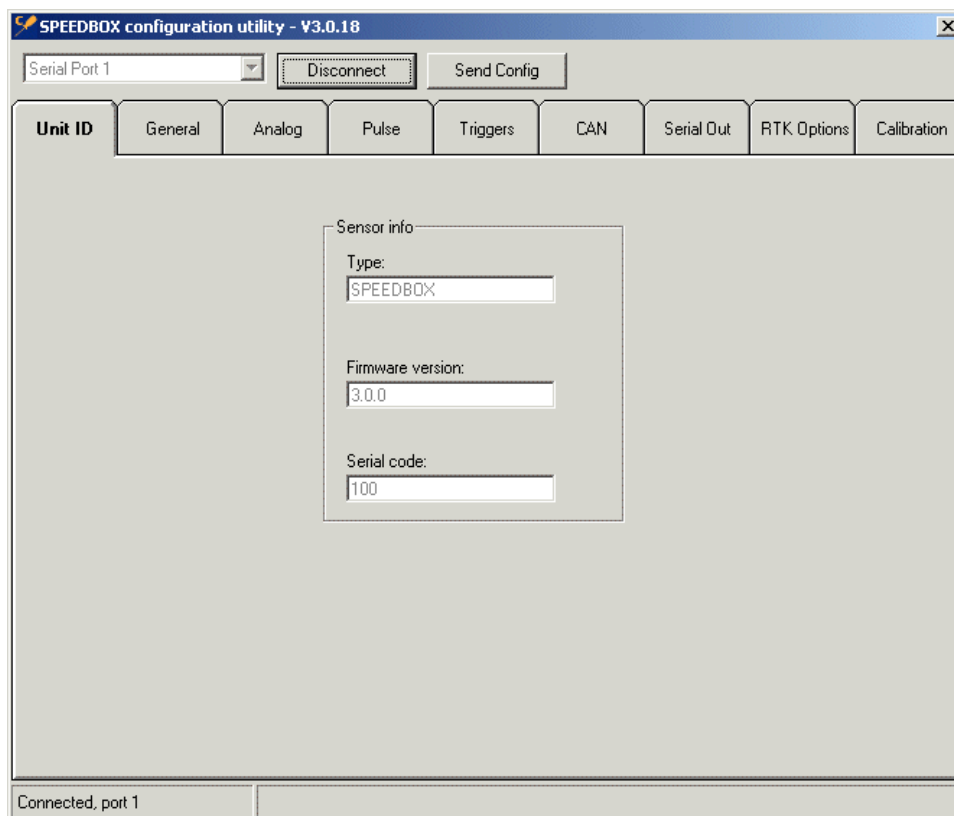


Figure 6: The SPEEDBOX configuration utility

The fields that can be modified are in black, whereas fields that are read only are greyed out. Modify any parameters that you wish to change, then press the “*Send Config*” button. This will send the new configuration to the SPEEDBOX. The program will indicate success by displaying a dialogue box, in which case the new configuration will have been written into the non-volatile memory of the SPEEDBOX, and will be remembered even if the power is disconnected. This can be verified by restarting the configuration software and reading the configuration again. The user configurable parameters that can be changed with the SPEEDBOX configuration software are described in the following sections.

6.4.1. Analog/Digital Options Tab

This tab allows the analogue and pulse outputs to be configured, as shown in Figure 12. A detailed description of the various parameters is given below:

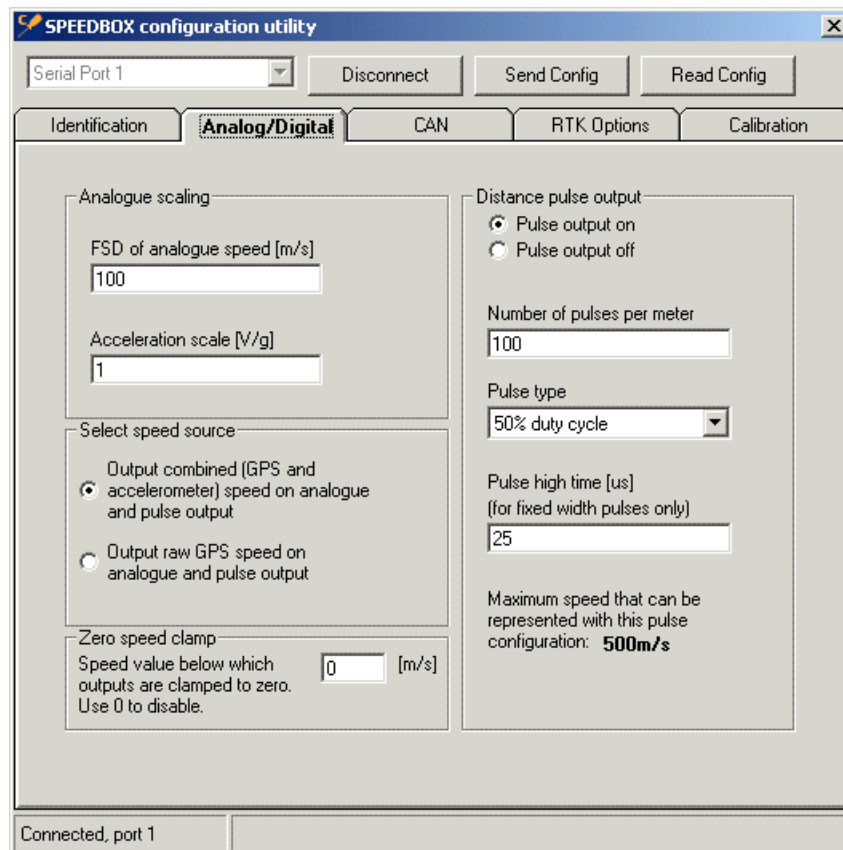


Figure 7: The Analogue/Digital configuration tab

6.4.1.1. Analogue Scaling

The “Analogue scaling” field allows you to alter both the FSD (Full Scale Deflection) of analogue speed and the acceleration scale. The FSD may be set between 10 and 500m/s. The acceleration scale may be set between 0.1 and 10V per g of acceleration. 2.5v is always equal to 0g.

6.4.1.2. Select Speed Source

The “Select speed source” field allows you to select whether the combined speed is output using either data from the GPS receiver or combined GPS and accelerometer data. For most applications, it is recommended that you use the combined data. In some circumstances, - such as on a boat in rough seas - confounding pitch motion may be present. In this case, it may be preferable to turn off the data from the accelerometers.

6.4.1.3. Distance Pulse Output

The pulse output may be turned off if it is not required. This will eliminate any crosstalk between the pulse and the analogue outputs. This may be desirable if the analogue outputs are being recorded, but pulse output is not required.

The number of pulses per meter should be set according to the required application. A higher number of pulses will provide better resolution at low speeds. In order to reach higher speeds however, a lower number of pulses should be set. The default setting for this feature is 100 pulses per meter.

The pulse type may be set to either fixed width or 50% duty cycle. In both cases, speed is proportional to the period of the pulse.

For the fixed width case, the pulse high time may be set between 10 and 1,000µs.

At the bottom of the field, there is an indication of the speed at which the readings will clamp at the chosen pulse configuration. This figure will instantly update as you alter the settings to the distance pulse output.

6.4.1.4. Zero speed clamp

There is also the option to add in a zero speed clamp value. This is the measured speed value below which the vehicle is assumed to be stationary, and all the outputs (including pulse, analogue, serial and CAN) are output as zero. Setting the zero speed clamp to zero (the default) will turn it off.

6.4.2. CAN Options Tab

The CAN configuration tab, shown in Figure 13, displays the CAN address and configuration information for your unit. Nine addresses will be displayed for a standard SPEEDBOX, and twelve for a SPEEDBOX-RTK. These may be changed, but the admissibility of addresses depends upon the type of addressing mode that has been selected.

The addressing mode can be set to either 11 bit or 29 bit addressing, using the address type box at the bottom of the tab. Next to this is the CAN baud rate box. 500 kbit is set as the default.

Note: The SPEEDBOX must be power cycled before changes to the CAN baud rate will take effect.

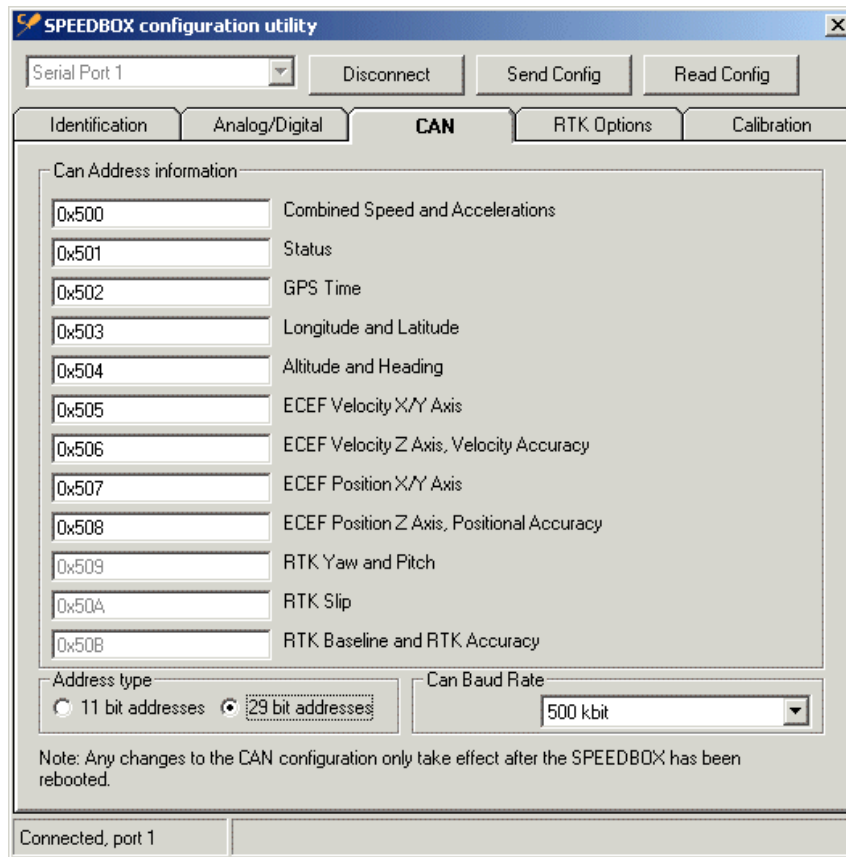


Figure 8: The CAN configuration tab

6.4.3. RTK Options Tab

The RTK options configuration tab is shown in Figure 14. In this example, the unit was a standard SPEEDBOX, so the fields are greyed out and not editable. Conversely, all of these fields would have been editable if a SPEEDBOX-RTK had been used.

Apart from the baseline, which must be set equal to the distance between the two antennas, all of the other fields represent an engineering compromise between differing goals - such as the speed to achieve lock and the likelihood of false lock. As such, there are no “correct” values for these entries. The default values have been found to give a good compromise during extensive testing; any change to the values should be undertaken with care, and with careful monitoring as to whether the results benefit the user or not.

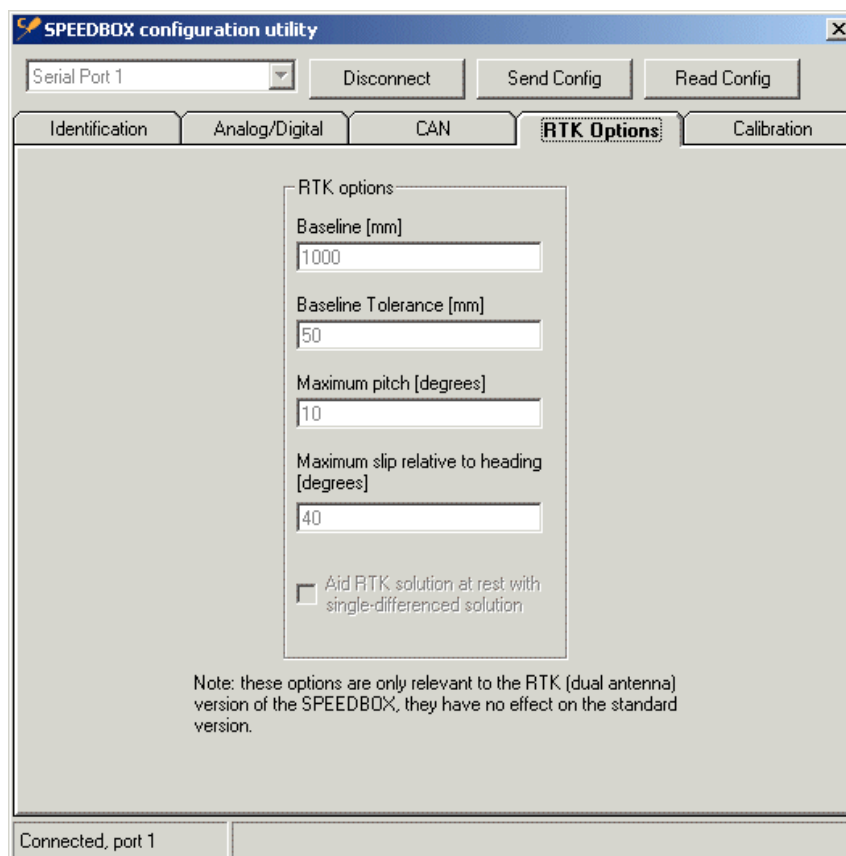


Figure 9: The RTK configuration tab

The baseline (the distance between the antennas) is set at a default of 800mm. This is the distance between the antenna centres on the optional magnetic strip mount. If the optional magnetic strip mount is not used, this distance **must be the same** as the distance between the two antennas. Failure to set this correctly will prevent an RTK lock from being achieved.

The base line tolerance is the maximum margin of error that is allowed in the positioning of the antennas and in the obtained solution. An excessively wide tolerance is more likely to allow an incorrect RTK solution. A narrow tolerance decreases the likelihood of getting a correct RTK solution. This is particularly true if the antennas are not perfectly positioned. We recommend using the default baseline tolerance setting of 50mm. Any reduction below 40mm should be carefully investigated before use in important testing.

The Maximum Pitch should be set to the maximum level of pitch that the vehicle is expected to undergo. The smaller this level is, the quicker it will be to find an RTK lock. However, if the selected level is then exceeded, an RTK lock is likely to be either unobtainable or incorrect.

The maximum slip relative to heading indicates the maximum allowable disparity between the direction in which the vehicle (the unit) is pointing and the direction that it is heading. Again, a larger maximum slip angle will mean that it will take longer for the unit to get a lock. However, if this angle is exceeded, it is likely that no proper lock will be obtained.

Note: This is the maximum body slip that is assumed only when getting an initial lock. Once an RTK lock has been established, there is no limit on the level of body slip that will be tracked.

The final option allows the initial acquisition of an RTK lock at rest to be aided by the difference between the standard GPS solutions of the two antennas. Under some conditions, this option might help to get an RTK lock when the unit is stationary. However, due to the limitations and inaccuracies of a standard GPS solution this option is normally only helpful for long baselines (2m+).

6.5. Trouble-shooting connection problems

6.5.1. USB connection

If the USB serial port does not show up on the configuration software, ensure that the correct drivers are installed for the drivers. If there are any problems the drivers can be re-installed from the software CD.

6.5.2. Serial Connection

Check that a working null modem cable is being used to connect the PC to the SPEEDBOX. Verify this by using the cable in a known working serial link.

Note: Many modern PCs do not properly implement the full RS232 specification in order to cut costs. In the event that all of the above issues have been checked and problems persist, try using either an alternative PC, or an alternative serial port.

6.6. Re-flashing the SPEEDBOX

The SPEEDBOX firmware can be re-flashed to take advantage of any software changes or new features that are introduced. Race Technology actively implements a programme of continuous product improvement. Therefore, new firmware upgrades may be introduced from time to time, either to fix bugs or to introduce new features. These will be available for download and installation from the Race Technology website. Re-flashing is done through a serial or USB connection to a PC. Full details of how to perform the re-flashing process are provided in the Race Technology online help system.

7. Technical Specification

GPS	20Hz, no interpolation. Tracking loops optimised for applications up to 4g. Tracks all satellites in view.
GPS Antenna	Magnetic base, 3.3v active antenna with SMA connector.
Power Supply Requirements	DC, 9 to 36V. Current consumption approximately 200mA @ 12V.
Case Construction	Anodised aluminium.
Connector Type	SMA female bulkhead connector for GPS antenna 9 way d-type male connectors for RS232 9 way d-type male connector for CAN 9 way d-type male connector for expansion port LEMO 0B four pin socket for Analogue channels BNC socket for trigger input BNC socket for pulse output
Serial Output	Race Technology, UBLOX, and NMEA messages. Individually configurable for each port at speeds of up to 115.2kbaud.
CAN Output	Combined speed Longitudinal acceleration Lateral acceleration Vertical acceleration SPEEDBOX status GPS position (lat/long/altitude and ECEF X/Y/Z formats), GPS position accuracy, GPS velocity GPS velocity accuracy GPS time GPS heading and number of satellites used in GPS solution output at 20Hz. With RTK option yaw, pitch slip estimated baseline and estimated accuracy

	<p>With IMU option Yaw rate Pitch rate Roll rate</p> <p>Output at 3.3V level, 11 or 29-bit addressing, user configurable addressing and baud rate (125/250/500kbps/1Mbps).</p>
Analogue Output	<p>Combined speed Longitudinal acceleration Lateral acceleration Vertical acceleration GPS heading GPS gradient GPS speed GPS speed accuracy GPS number of satellites in solution GPS derived lateral acceleration GPS derived motorcycle lean angle</p> <p>With RTK option: RTK yaw RTK pitch RTK slip RTK baseline RTK accuracy</p> <p>With IMU option: Yaw rate Pitch rate Roll rate</p>
Pulse Output	<p>User configurable pulse rate: 1-400 pulses per metre pulse at 5V, high period user configurable from 10 to 1000µs, or 50% duty cycle. . Output impedance 50Ω, minimum recommended termination impedance 1kΩ.</p>
Accelerometers	<p>3-axis, precision digital output. 2g minimum full scale on both axes, 6g option available. Resolution of 0.001g.</p>
Vibration	<p>Factory tested at 25g, 50Hz sinusoid for 5 minutes</p>
Temperature	<p>Factory tested from -20°C to +70°C</p>