SPEEDBOX
Instruction Manual

Version 1.0

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-GPS ideal environments. Packaged in a high quality machined aluminium enclosure which is sealed to IP65, 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, analogue and a fully configurable digital pulse output are all provided as standard.

The SPEEDBOX uses Race Technology's very own high accuracy 20Hz ***Pure*****Phase** GPS solution. It is optimized for speed measurement and outperforms even top of the range 'survey-grade' GPS receivers in this area. This unique GPS 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 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 car before proceeding with any test work. Test work must only be carried out after taking due consideration for safety.

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2. Contents

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4. What's in the Box?

Please take a few moments to ensure that you have received the following items with your purchase:

- SPEEDBOX unit
- Standard magnetic mounting GPS antenna
- Wiring harness
- Null modem type serial cable
- Transit case (with foam interior)
- Software CD
- This instruction manual

If you have purchased a SPEEDBOX-RTK a second standard GPS antenna will also be supplied.

Note: The RTK antenna strip described in this manual is an additional cost option – it is not supplied as standard with the SPEEDBOX-RTK.

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5. Introduction to the SPEEDBOX

5.1. What the SPEEDBOX Can Do

Key features of the SPEEDBOX include:

- **High accuracy 200Hz speed output.** This is the headline output of the unit. Inside the SPEEDBOX is a high precision dual 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.
- **2 Axis acceleration measurements**. Raw longitudinal and lateral acceleration data is output at 200Hz. A 2g accelerometer is fitted as standard, which is suitable for most OEM testing and motorsport applications; a 6g option is also available.
- **Wide range of output formats.** Available output formats include CAN, RS232, analogue voltages and digital pulse. Custom output messages, such as NMEA over RS232, can be added on request.
- **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 serial port of a PC.
- **Water resistant.** The SPEEDBOX is housed within a machined aluminium billet casing that is water resistant to IP65 standard.
- **Software and documentation.** The SPEEDBOX is supplied with a comprehensive software and documentation CD.

5.2. 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 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 and have no meaning when it is stationary. 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.

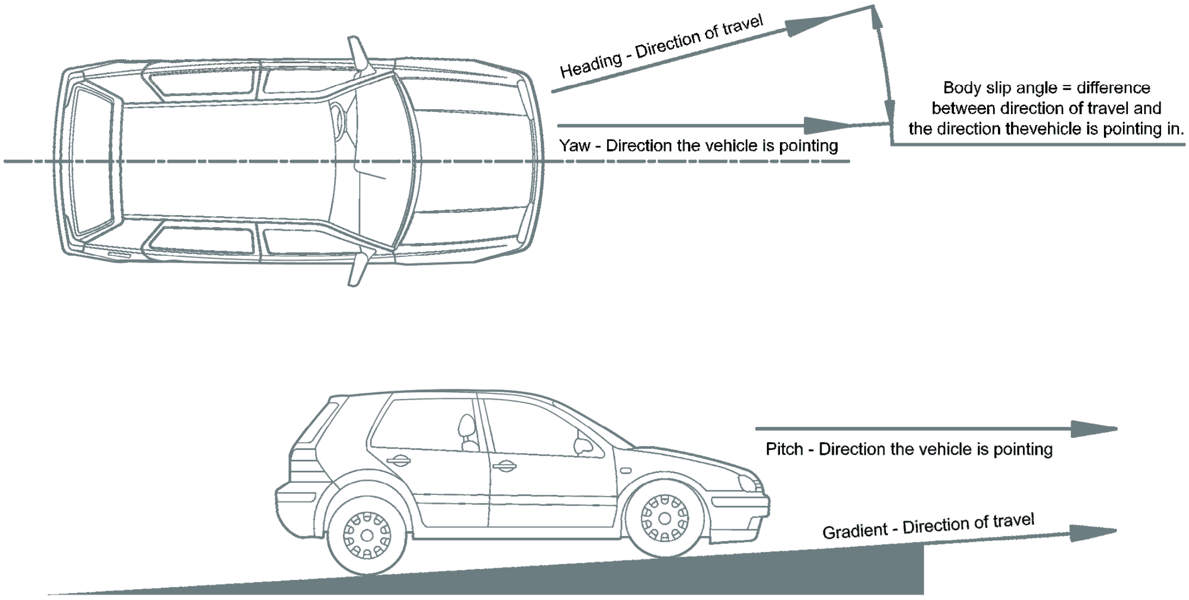

Figure 1: Difference between yaw and heading, pitch and gradient

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 using a technique called "Moving-base real time kinematic (MB-RTK) differencing". This is an advanced processing technique that is fundamentally different from a normal GPS fix. It allows the position of the two antennas, relative to each other, to be determined extremely accurately (to within millimetres). Knowing the relative position of the second antenna to the first with such high precision allows 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

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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.

- When using the RTK option, it is possible to obtain an incorrect result under certain “unusual” conditions. Whilst this phenomenon is far more likely to happen when the vehicle is stationary and will only last for a short period of time, it must be borne in mind when interpreting the results.
- RTK works in a different way to a normal GPS fix, and its properties are somewhat different. A normal GPS lock will tend to “degrade” from good to poor, before losing a lock completely. An RTK solution behaves differently - it either has a very high accuracy lock, or no lock at all – there is very little in between.

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.

6. Installing the SPEEDBOX

6.1. 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 OFF.
- Connect the supplied antenna to “GPS 1” on the unit. For the RTK option, connect the “base” antenna (which is nearer to the rear of the vehicle) to “GPS 1” on the unit and the “moving” antenna (nearer the front of the vehicle) to “GPS 2”.
- Connect the 12-way Binder connector on the loom to “CONN 1” on the unit.
- 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 12V DC supply, e.g. a “cigarette-lighter” type plug, or other fused power supply.

6.2. Mounting the SPEEDBOX unit

In order to give accurate acceleration readings, the SPEEDBOX should be mounted so that it is flat and level. It should also be securely restrained so that it cannot move in relation to the vehicle. The orientation of the unit is, of course, important. When mounting the unit, please ensure that it is oriented in the following manner:

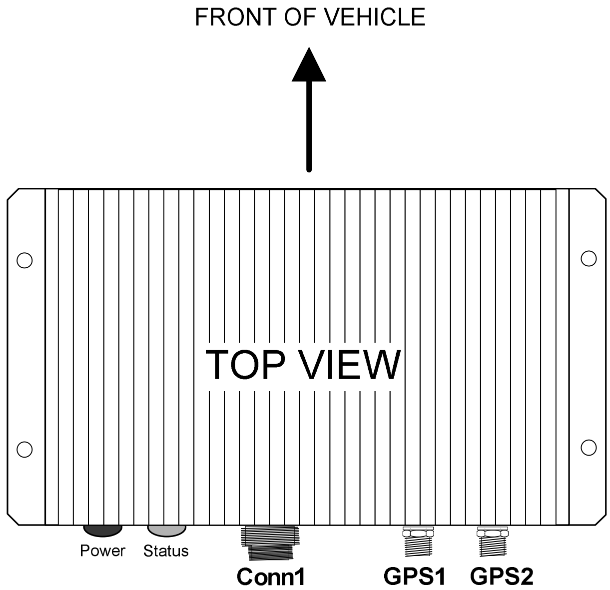

Figure 2: SPEEDBOX mounting orientation and connectors

In the longitudinal direction, this will give positive readings for acceleration and negative readings for deceleration and braking. Lateral acceleration will give positive readings for cornering around a right hand bend and negative for cornering round a left hand bend. The high accuracy speed output from the combined accelerometer and GPS data is robust to a

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mounting angle of approximately 20° from level, but it is advisable to obtain a mounting position as close to flat and level as possible to guarantee best accuracy. 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: Ideally, the SPEEDBOX should be vertically below the GPS antenna to ensure that both the accelerometers and the GPS antenna "see" the same velocity. In practice this is a small effect that, for most tests, can 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. "Scotch-Lock" or other similar products would be suitable for this application.

6.3. 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 "GPS1 Antenna" connection on the SPEEDBOX. This must be mounted in a position that gives a good view of the sky. 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.

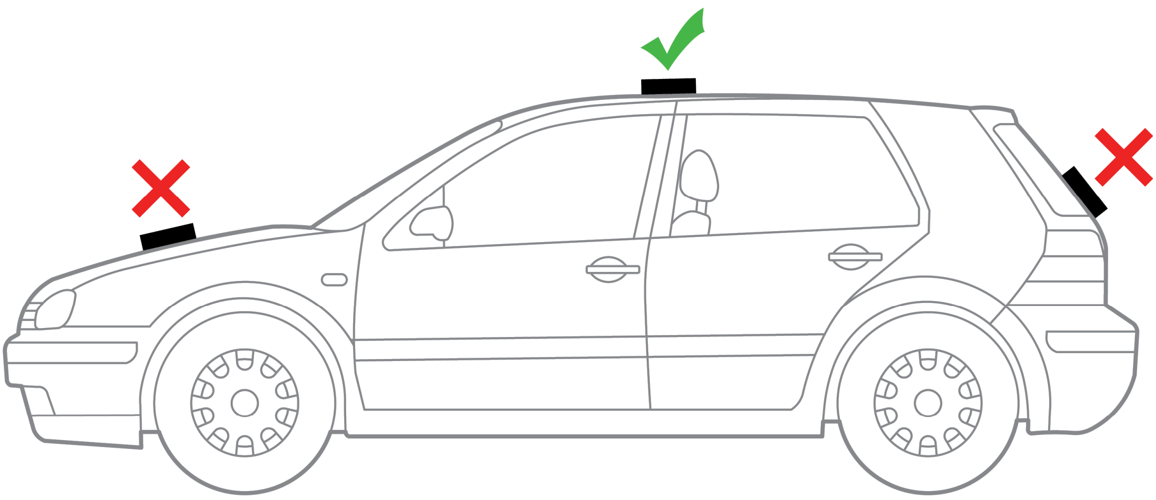

Figure 3: Correct GPS antenna mounting position on the roof of the car giving full horizon to horizon visibility

In view of the importance of the antenna mounting position, a full set of guidelines is set out below:

- The antenna must have a clear view of the sky in all directions. **Note**: It is NOT enough that the antenna can see vertically upwards - it must also be able to see the entire horizon as well. The GPS system actually gets very little positional or speed information from the satellites directly above - far more information is received from satellites that are on, or near, the horizon. If for example, the antenna was mounted in the bottom of a "bucket" (so that it could see upwards but could not see the horizon) then the GPS system would lock and provide positional information - but the accuracy would be very poor. In practice, this means that the antenna must be mounted on the highest point of the vehicle.

- The antenna must be mounted on a horizontal surface. It must also be mounted in a horizontal orientation facing directly upwards, as the underside of the antenna cannot receive GPS information. Similarly, do not mount the antenna on a vertical surface.
- The antenna must not be covered in tape. In particular, dark coloured tapes should not be used. Many tapes absorb the weak GPS radio signal. In general black tapes are the worst in this respect as they contain high amounts of carbon. To be on the safe side, avoid using any tapes whatsoever.
- The antenna must not be subjected to high levels of vibration. Although the antenna is physically robust, vibration can and does affect GPS reception. To prevent this, isolate the antenna from vibration as much as possible.
- The antenna must be physically remote from sources of electrical noise, as the GPS radio signal is very weak and can easily be blocked by radio interference. To obtain a good signal, the antenna must be as far away from any source of radio interference as possible. 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. Things to 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, very high frequency 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. **This is not covered under warranty.** To avoid cable damage, do not attempt to fit the antenna cable into a shut gap that is too small, 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 (termed a ground plane), and the bigger this is, the better. It is not essential for correct operation, but it is highly desirable.
- Care must be taken not to crush the antenna lead with the vehicle window or door closure. If it is accidentally crushed, then the cable may be permanently damaged – this may be the case even if no physical marks are visible. Replacements are available from Race Technology at a relatively low cost should they be required.

Note: the “GPS2 Antenna” connection is unused on the standard SPEEDBOX, and does not need to be connected.

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

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should be used where there is a known RF interference problem - they give excellent interference rejection, but provide a slightly “noisier” GPS signal.

6.4. Mounting and connecting the GPS antennas – RTK option

There are two options for the RTK antenna. You can either use two separate GPS antennas, or the RTK antenna strip. For test work, the RTK antenna strip is typically the most convenient solution. It allows the antennas to be quickly placed at a known fixed baseline, with minimal risk of any installation errors. For permanent applications, it may be desirable to use two separate GPS antennas. This allows for maximum flexibility. **Note**: when fitting two standard antennas, it is particularly important to check that the installation guidelines have been followed – incorrect installation of the antennas will result in either no RTK lock at all, or intermittent and possibly incorrect RTK lock.

All of the points already listed regarding mounting the GPS antenna for the standard SPEEDBOX should be followed when mounting the antennas for the RTK unit. In addition, please bear in mind the following:

- It is doubly important for the RTK option, that the antennas must be mounted on the flattest part of the roof of the vehicle. Both antennas must see the same set of satellites for the RTK solution to work correctly.
- The rear antenna is used as the base antenna, and is connected to “GPS 1”. This is the antenna that is also used for the speed and positional calculations. The SPEEDBOX will not get a lock unless this antenna is connected.
- The front antenna is called the “moving” antenna, and is connected to “GPS 2”. If this antenna is not connected, the SPEEDBOX-RTK will continue to function as a standard SPEEDBOX as long as the base antenna is connected. It will not obtain an RTK lock without the moving antenna being connected.
- The antennas must both be mounted on the centreline of the vehicle for the yaw and slip measurements to be valid.
- All of our GPS antenna products are magnetic mounting – if the surface of the vehicle roof is not magnetic then alternative fixing arrangements will have to be made. Lock tape works well.

6.4.1. RTK antenna strip

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

- The baseline of the antenna strip is a fixed 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. There is a large arrow printed on it which must face towards the front of the vehicle. The wires from the two antennas are labelled “GPS 1” and “GPS 2”, and should be attached to the corresponding connections on the SPEEDBOX.
- Please treat the cables with care. If they are damaged, then it is likely that the whole assembly will have to be replaced.

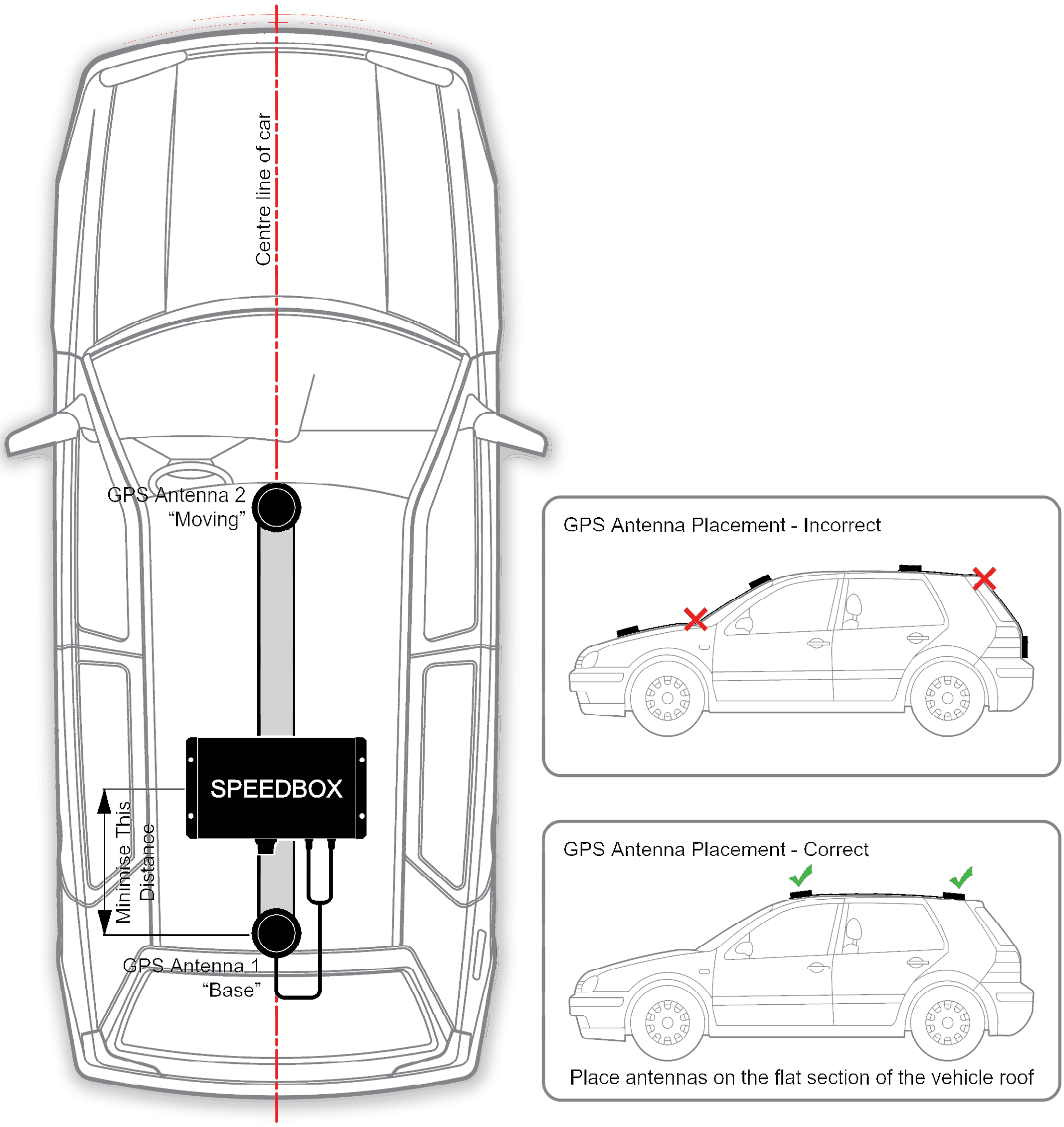

Figure 4: Mounting arrangement for the magnetic antenna strip (RTK option only)

6.4.2. 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.

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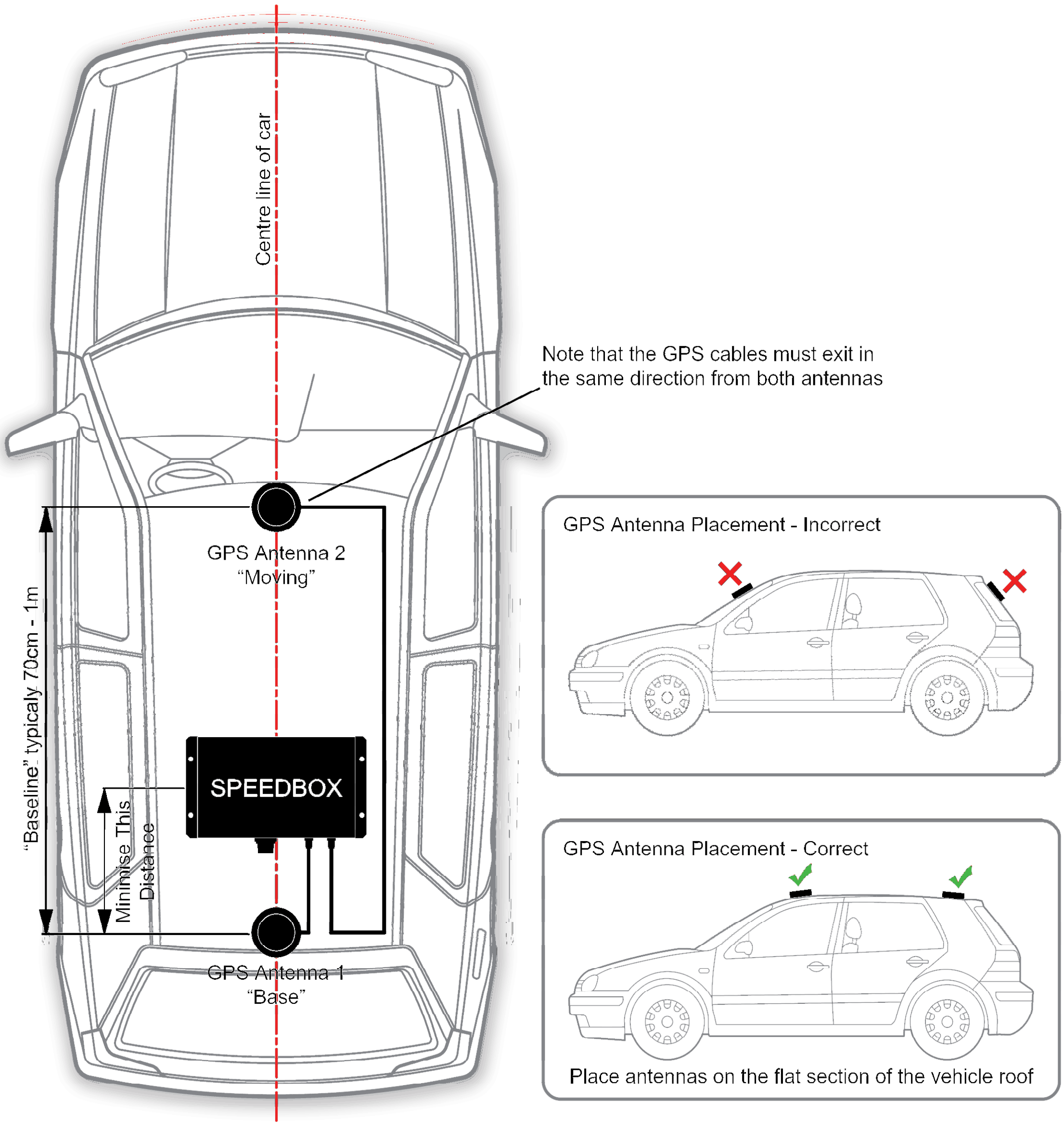

Figure 5: Mounting arrangement for two separate antennas (RTK option only)

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 "GPS 1" on the unit. The forward antenna is the "moving" antenna, and must be connected to "GPS 2" on the unit. If the antennas are connected the wrong way around, the unit will not 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.

6.5. Power

The SPEEDBOX requires a stable 12V DC power supply. 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. It should be noted that the SPEEDBOX remains active whenever it is connected to a 12V supply. This means that it must be disconnected when not in use, otherwise it will drain the vehicle battery.

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.

6.6. Connections - General

There are three connections on the unit - one main connector block, labelled "Conn1", and two GPS antenna connections. These are labelled "GPS1 Antenna" and "GPS2 Antenna" respectively. The main connector block (Conn1) should be connected to the large connector on the supplied cable loom. The other connectors on the loom are all individually labelled. The positive wire on the power lead has a grey or white stripe.

A 3.3V active GPS antenna must be connected to "GPS1 Antenna". GPS2 is only used with the RTK option.

6.7. 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 if it is 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:

6.7.1. Connecting the SPEEDBOX to the DL1 or DL2

The SPEEDBOX uses Race Technology's ***Pure*Phase** 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 GPS position, acceleration, GPS speed etc. 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 the RS232 output on the SPEEDBOX wiring loom. It is also necessary to connect a GPS antenna to the DL1/DL2 (not shown) since the

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SPEEDBOX does not currently supply the date and time over RS232. The DL1/DL2 must therefore get this from the GPS signal.

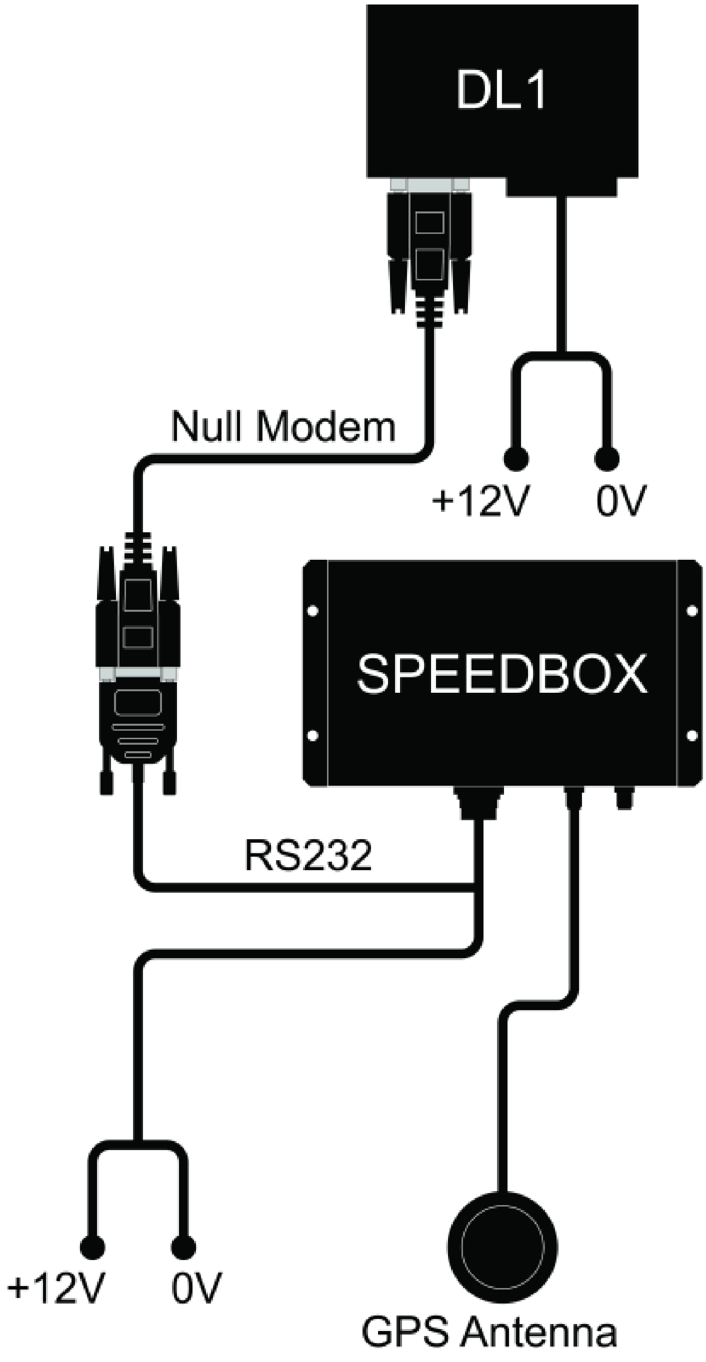

Figure 6: Arrangement for connecting a SPEEDBOX to a DL1 datalogger

6.7.2. 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 that the SPEEDBOX outputs. The DASH1's default configuration, however, is set to display many channels that the SPEEDBOX does not output, in particular all of the analogue channels, and so most screens will display "NO DATA" when connected to the SPEEDBOX. In order to allow the

DASH1 to display more relevant data for the SPEEDBOX, it is necessary to reconfigure the DASH1, either directly from the PC or using a DL1/DL2. If you are doing it 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.

6.8. 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 and serial (RS232).

The choice of which output to use may depend on several factors. CAN and serial are the first choice for high accuracy readings, since these outputs are not 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:

6.8.1. CAN

The SPEEDBOX outputs nine CAN messages using addresses 500h to 508h. In addition to this, the RTK option provides a further 3 messages, on addresses 509h to 50Bh. Message 500h contains the longitudinal and lateral acceleration values, as well as the combined speed output. It is output continuously at 200Hz. Message 501h is the status message containing, amongst other information, the GPS status and the number of satellites locked. It is output at 1Hz until a GPS solution is obtained and at 20Hz thereafter. The remaining CAN messages are only output once a GPS solution has been obtained. They are then output at 20Hz. A detailed description of the content of each message is given in Section 10 of this manual and is also available from the Race Technology online help system or the Race Technology website Knowledge Base. A CANdb file is also available if required.

In the case of the CAN output, the latency depends on both the presence of other traffic on the CAN network and on the bit rate that has been selected. This means that it cannot be considered deterministic. CAN message 500h - containing the accelerations and the combined speed - has the lowest latency. 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 502h.

The CAN addressing mode may be set to either 11 or 29bit and the SPEEDBOX can output CAN bitrates of 125kbps, 250kbps, 500kbps and 1mbps, set using the configuration software.

6.8.2. 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 (counting pulses). The other advantage of the pulse output is that it 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

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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. The two pulse modes are shown in the figures below. The fixed width and 50% duty cycle modes are shown in figures 7 and 8 respectively, at the same two faster and slower speeds. In the fixed width mode, the high time of the pulse is always constant, and may be varied from 10 to 1000μs 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 25μs.

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. 50Ω of output impedance is provided by the SPEEDBOX in order to eliminate "ringing".

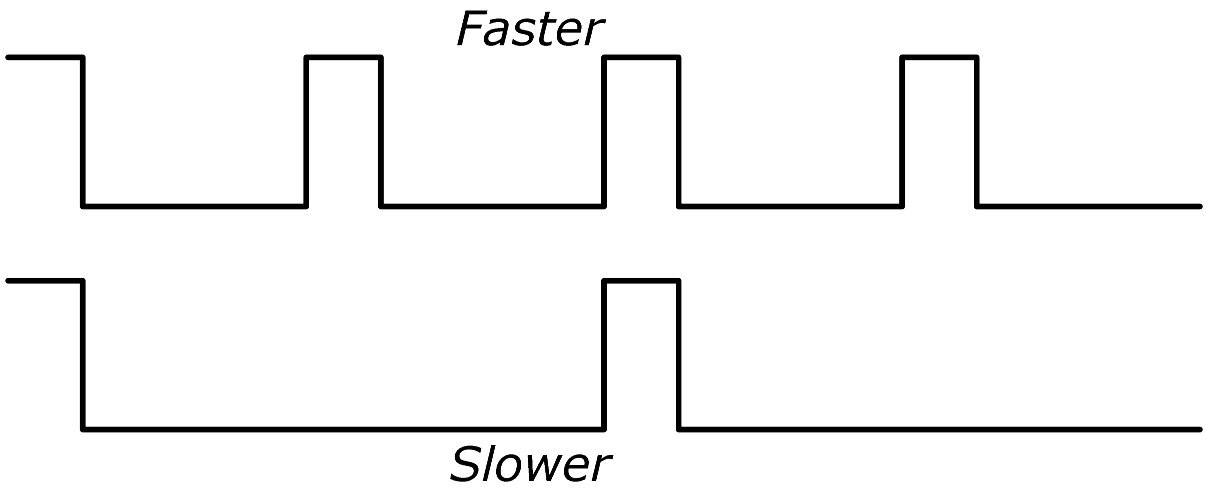

Figure 7: Pulse output at two speeds for the fixed width pulse

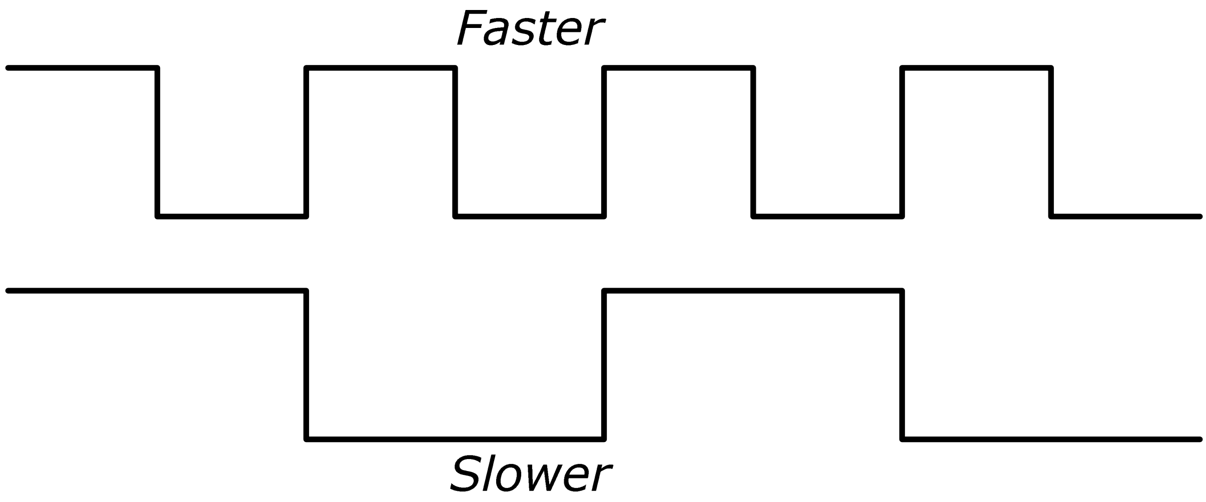

Figure 8: Pulse output at two speeds for the 50% duty cycle pulse

6.8.3. Analogue

The analogue outputs also have a low latency. Typically, this is below 2ms. There are 3 analogue outputs, labelled “DAC A”, “DAC B” and “DAC C”. On the standard SPEEDBOX, longitudinal acceleration is output on A, lateral acceleration on B, and combined speed on C. With the RTK option, yaw is output on A, pitch on B, and combined speed on C.

The analogue outputs nominally output between 0 and 5V but on the SPEEDBOX, all output values are clamped between 0.5 and 4.5V. On DACs A and B, zero acceleration, yaw or pitch are output at 2.5V. The deflection is governed by the scale set in the configuration software, by default 1g/V for acceleration, and 100°/V for yaw and pitch (yaw and pitch are clamped between -180° and 180°).

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.

6.8.4. Serial

The SPEEDBOX outputs serial data in Race Technology format. This is, essentially, a simple wrapper comprising a channel number and a checksum, around raw hex (big-endian) integer data values. A detailed description of the serial data format is given in Section 10 of this manual and is also available from the Race Technology online help system. The serial data format is also fully documented in the knowledge base on our website (under *Software->Main Analysis Software->Technical->Serial Data Format*). Source code in VB6 and ANSI C is also available for converting the serial data into physical values.

The acceleration and combined speed message is output at 200Hz, and the GPS data is output at 20Hz. The acceleration and combined speed message is 11bytes long. This takes approximately 1ms to transmit at 115200kbps. There is a maximum latency between the acceleration reading and the start of transmission within the SPEEDBOX of 0.1ms This means that the combined speed and acceleration serial output should attain a latency of less

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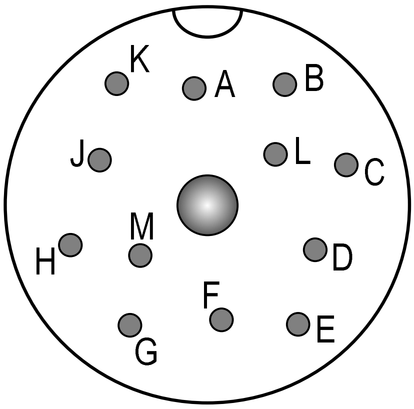
than 2ms. The serial messages outputting the GPS data will have a latency of 50 – 100ms from the point to which the data refers. One of the messages, however, contains the GPS time, which can be used to refer the data from each burst of 20Hz messages to a given point in time. The serial messages can be viewed and logged on the PC, using the monitor program provided with the Race Technology software suite (see the section of this manual referring to the PC software).

6.9. Connector and Wiring Loom Details

6.9.1. Connector Pinout

The SPEEDBOX unit has three connectors: CONN1, GPS1 and GPS2. GPS1 and GPS2 are female SMA connectors, and a 3.3V active GPS antenna is required. CONN1 is a 12 pin male Binder 723-series connector.



A	GND
B	RS232 Tx
C	No connect
D	Pulse
E	CAN H
F	CAN L
G	DAC B
H	DAC A
J	+12V
K	RS232 Rx
L	Analogue GND
M	DAC C

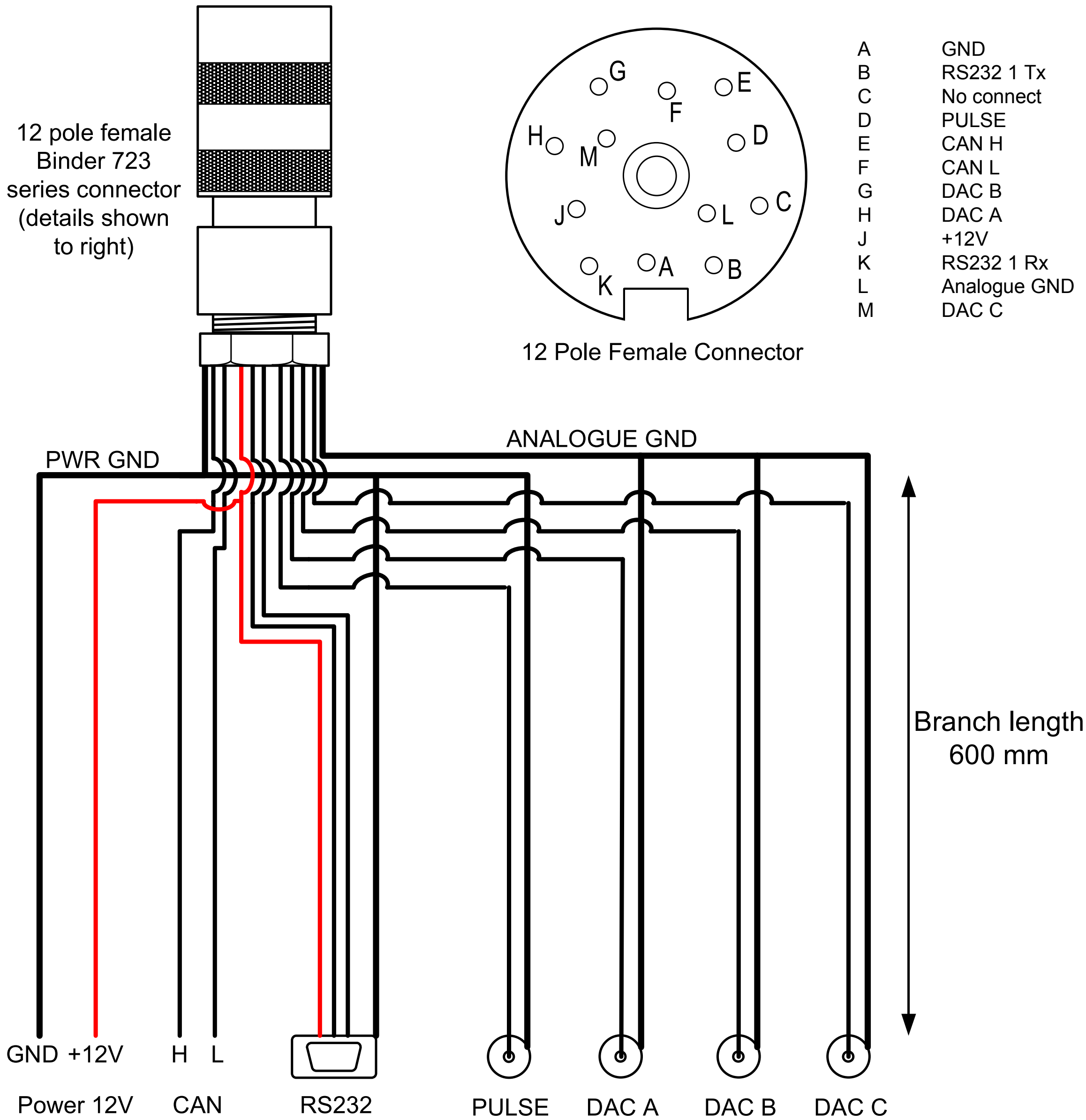
Figure 9: CONN1 (12 pole male Binder 723-series) pinout

6.9.2. Wiring Loom Pinout

The wiring loom supplied with the SPEEDBOX contains the following:

- A 12 pole female connector to connect to CONN1
- Female BNC connectors for the three analogue outputs and the pulse output
- A 9-pin male D-sub connector for RS232
- Tinned wire to connect to CAN
- Tinned wire for connecting to +12V DC supply.

The full pinout of the wiring loom is shown below.



RS232 PINOUT
2: Rx
3: Tx
5: GND
7: +12V

Connector Details

Label	Connector Type
Power 12V	Tinned cable (2 wires)
CAN	Tinned cable (2 wires)
RS232	9 pin D-sub (male)
DAC A	BNC (female)
DAC B	BNC (female)
DAC C	BNC (female)
PULSE	BNC (female)

Cable Colours

Power +12V	Black with white stripe
Power GND	Black
CAN H	White
CAN L	Black

Figure 10: SPEEDBOX wiring loom and pinout

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7. Operating the SPEEDBOX

7.1. 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 anything from a few seconds 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. The SPEEDBOX continuously provides GPS status messages over the CAN output in the following format:

SPEEDBOX Status		
Default address	Data bytes 1-4	Data bytes 5-8
0x501	Byte 1: SPEEDBOX status: 0x00: Power on, no GPS signal. 0x01: Not enough satellites locked for solution. 0x02: At least 4 satellites locked, but unable to reach solution. 0x03: Correct operation. 0x06: GPS signal detected, no satellites found. Byte 2: Version number (major) Byte 3: Version number (intermediate) Byte 4: Version number (minor)	Byte 5: Number of satellites used in GPS solution

7.2. Taking measurements with the SPEEDBOX

When normal operation is established, the SPEEDBOX will provide continuous data over all of the output channels. 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.

7.3. Lights on the unit

The SPEEDBOX has two LED indicators. These are labelled “Power” and “Status”.

The power (red) LED is continuously on when power is applied to the unit. If it fails to illuminate when power is applied please check the power supply.

The status (green) LED 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 (speed is from Doppler).
- Long flashes at 1Hz: GPS lock with carrier.
- Continuously on (RTK only): RTK solution obtained.

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8. Using the supplied software with the SPEEDBOX

8.1. Installing the Supplied Software

The software CD that is supplied with the SPEEDBOX contains the latest build of Race Technology's software suite. This, in turn, 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 ("*Start->Settings->Control Panel->Add or Remove Programs*") to use the Windows uninstaller, or better to use the Race Technology uninstaller found at *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*".

8.2. 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. This should be connected between the RS232 output on the SPEEDBOX wiring loom and a serial port on the PC (or USB to serial adapter if the PC does not have a serial port).

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.

8.3. Configuring the SPEEDBOX from the PC

In order to configure the SPEEDBOX, first ensure that the RS232 output on the wiring loom is connected to a serial port on the PC using a null modem cable. 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.

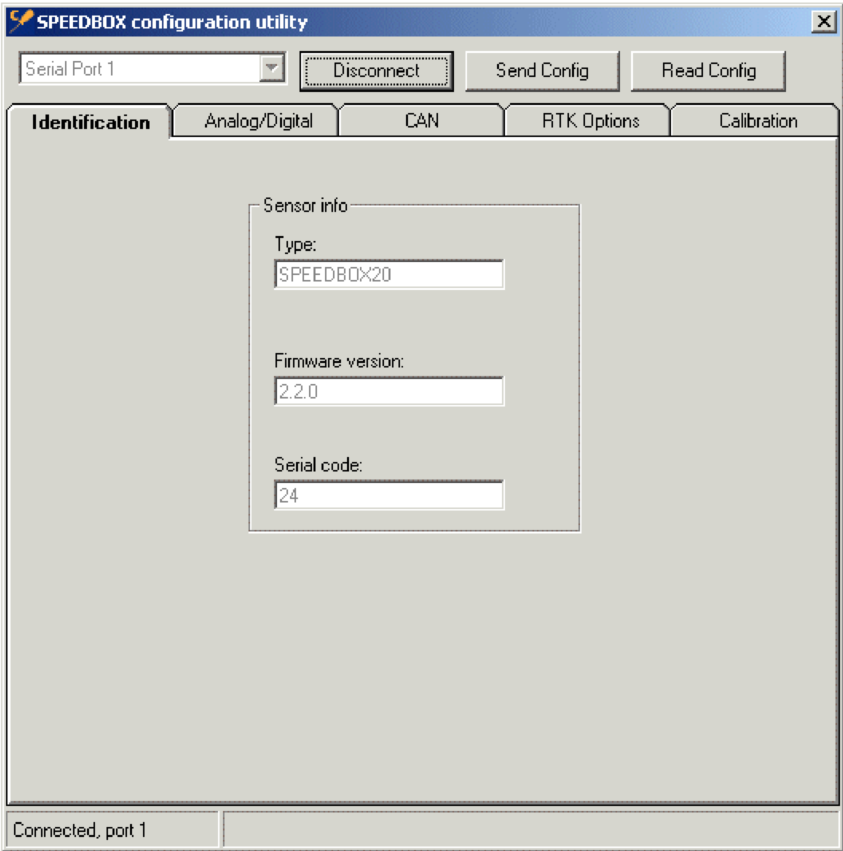

Figure 11: The SPEEDBOX configuration utility

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.

8.3.1. 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:

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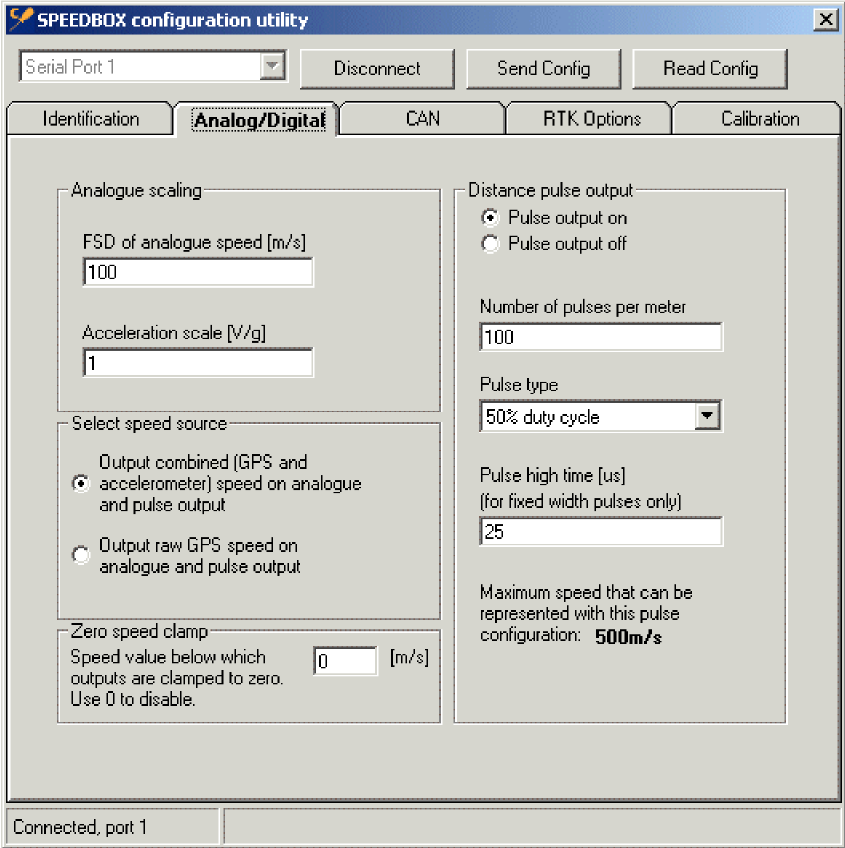

Figure 12: The Analog/Digital configuration tab

8.3.1.1. 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.

8.3.1.2. 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.

8.3.1.3. 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.

8.3.1.4. 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.

8.3.2. 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 any alterations made to the CAN configuration take effect.

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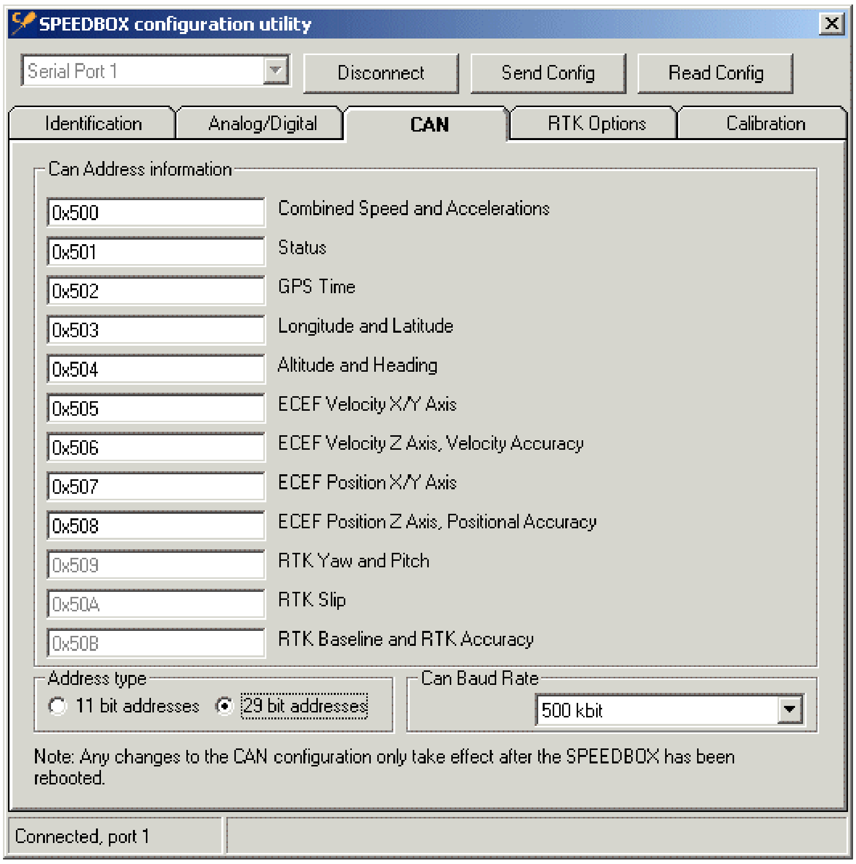

Figure 13: The CAN configuration tab

8.3.3. 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.

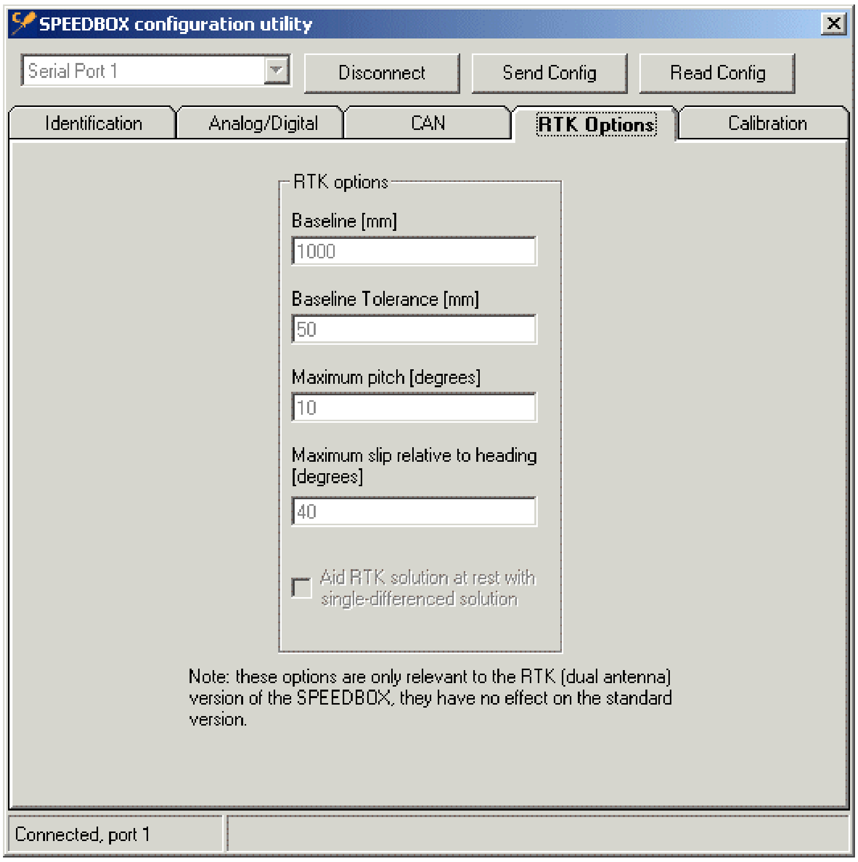

Figure 14: The RTK configuration tab

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.

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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+).

8.4. Trouble-shooting connection problems

8.4.1. SPEEDBOX

Check that the SPEEDBOX is switched on and working, and that the red power LED has lit.

8.4.2. 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. USB to RS232 adaptors have often been found to give a more reliable link, and are available direct from Race Technology if required.

8.5. 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 connection to a PC. Full details of how to perform the re-flashing process are provided in the Race Technology online help system.

9. Technical Specification

GPS	Outputs position, speed, position accuracy, speed accuracy and heading every 50ms with no interpolation. GPS tracking loops optimised for applications up to approximately 4g. Tracks all satellites in view.
GPS Antenna	Magnetic base, 3.3v active antenna with SMA connector.
Power Supply Requirements	12v nominal input, minimum of 10v, maximum of 15v. Current consumption approximately 200mA @ 12V.
Case Construction	CNC machined billet aluminium, anodised black, sealed to IP65 standard
Connector Type	SMA female bulkhead connector for GPS antenna, Binder 723 series 12-way male bulkhead connector to supplied wiring harness for all other connections. Sealing better than IP65.
Main Processor	High performance 200MHz TI DSP
Serial Output	2-Axis acceleration and combined speed output at 200Hz. GPS position, GPS speed, GPS heading, GPS altitude and GPS time output at 20Hz. RS232 voltage levels using standard Race Technology format. 115.2 kbaud
CAN Output	2-Axis acceleration and combined speed output at 200Hz. 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. RTK option also outputs yaw, pitch, slip, estimated baseline and estimated accuracy at 20Hz. Output at 3.3V level, 11 or 29-bit addressing, user configurable addressing and baud rate (125/250/500kbps/1Mbps).
Analogue Output	Longitudinal acceleration, lateral acceleration, combined speed (RTK option outputs yaw, pitch and combined speed), 0-5V output level. User configurable scaling of combined speed output from 10m/s to 500m/s FSD.

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Pulse Output	Frequency proportional to combined speed, pulse at 5V, high period user configurable from 10 to 1000µs, or 50% duty cycle. User configurable pulse rate: 1-400 pulses per metre. Output impedence 50Ω, minimum recommended termination impedance 1kΩ.
Accelerometers	2-axis, precision digital output. Guaranteed 2g minimum full scale on both axes, 6g option available. Resolution of 0.001g.
Vibration	Factory tested at 25g, 50Hz sinusoid for 5 minutes
Temperature	Factory tested from -20°C to +70°C

10. Output Specifications

10.1. CAN Output Specification

Combined Speed, Longitudinal and Lateral Acceleration

Default address	*Data bytes 1 – 4*	*Data bytes 5 – 8*
0x500	Combined accelerometer and GPS speed. Format: Signed, 32bit, little-endian integer. Units: cm/s. Scaling: None.	Bytes 5 - 6: Longitudinal Acceleration Bytes 7 - 8: Lateral Acceleration Format: Both are signed, 16bit, little-endian integers. Units: g Scaling*: Output = g × 1000

*Note: This scaling applies to firmware v2.2.1 onwards. Units with firmware v2.1.0 to 2.2.0 (inclusive) output $m/s^2 * 256$

SPEEDBOX Status

Default address	*Data bytes 1 – 4*	*Data bytes 5 – 8*
0x501	Byte 1: SPEEDBOX status: 0x00: Power on, no output from GPS module. 0x01: Not enough satellites locked for solution. 0x02: At least 4 satellites locked, but unable to reach solution. 0x03: Good GPS lock achieved. 0x06: GPS module active, no lock. Byte 2: Version number (major) Byte 3: Version number (intermediate) Byte 4: Version number (minor)	Byte 5: Number of GPS satellites used in solution. Byte 6: GPS speed source: 0x00: No GPS speed. 0x01: Doppler speed. 0x02: Carrier speed.

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GPS Time

Default address	*Data bytes 1 – 4*	*Data bytes 5 – 8*
0x502	GPS millisecond time of week. The number of milliseconds elapsed since midnight on Saturday night. Format: Unsigned, 32bit, little-endian integer. Units: ms. Scaling: None.	These bytes are reserved to output an estimate of time accuracy in the future. Currently no meaningful estimate of time accuracy is derived from the solution, so these bytes are output as zero.

GPS Position (Longitude and latitude)

Default address	*Data bytes 1 – 4*	*Data bytes 5 – 8*
0x503	GPS longitude. Format: Signed, 32bit, little-endian integer. Units: Degrees. Scaling: Output = degrees × 1e7.	GPS latitude. Format: Signed, 32bit, little-endian integer. Units: Degrees. Scaling: Output = degrees × 1e7.

GPS Altitude and Heading

Default address	*Data bytes 1 – 4*	*Data bytes 5 – 8*
0x504	GPS altitude. Format: Signed, 32bit, little-endian integer. Units: mm. Scaling: None.	GPS heading. Format: Signed, 32bit, little-endian integer. Units: degrees. Scaling: Output = degrees × 1000

GPS Velocity (ECEF X and Y velocity)

Default address	*Data bytes 1 – 4*	*Data bytes 5 – 8*
0x505	GPS ECEF (Earth-centred) X velocity. Format: Signed, 32bit, little-endian integer. Units: cm/s. Scaling: None.	GPS ECEF Y velocity. Format: Signed, 32bit, little-endian integer. Units: cm/s. Scaling: None.

GPS Velocity (ECEF Z velocity and velocity accuracy estimate)

Default address	*Data bytes 1 – 4*	*Data bytes 5 – 8*
0x506	GPS ECEF Z velocity. Format: Signed, 32bit, little-endian integer. Units: cm/s. Scaling: None.	GPS velocity accuracy estimate. Format: Unsigned, 32bit, little-endian integer. Units: cm/s. Scaling: None.

GPS Position (ECEF X and Y position)

Default address	*Data bytes 1 – 4*	*Data bytes 5 – 8*
0x507	GPS ECEF X position. Format: Signed, 32bit, little-endian integer. Units: cm. Scaling: None.	GPS ECEF Y position. Format: Signed, 32bit, little-endian integer. Units: cm. Scaling: None.

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GPS Position (ECEF Z position and positional accuracy estimate)		
Default address	*Data bytes 1 – 4*	*Data bytes 5 – 8*
0x508	GPS ECEF Z position. Format: Signed, 32bit, little-endian integer. Units: cm. Scaling: None.	GPS Positional accuracy estimate. Format: Unsigned, 32bit, little-endian integer. Units: mm. Scaling: None.

GPS MB-RTK Yaw and Pitch [SPEEDBOX-RTK only]		
Default address	*Data bytes 1 – 4*	*Data bytes 5 – 8*
0x509	MB-RTK Yaw between antennas. Format: Signed, 32bit, little-endian integer. Units: degrees. Scaling: Output = degrees × 1e3. Range: -180° to +180°.	MB-RTK Pitch between antennas. Format: Signed, 32bit, little-endian integer. Units: degrees. Scaling: Output = degrees × 1e3. Range: -180° to +180°.

GPS MB-RTK Slip [SPEEDBOX-RTK only]

Default address	*Data bytes 1 – 4*	*Data bytes 5 – 8*
0x50A	Calculated slip angle (MB-RTK yaw – GPS heading). Format: Signed, 32bit, little-endian integer. Units: degrees. Scaling: Output = degrees × 1e3. Range: -180° to +180°.	Reserved for future use.

GPS MB-RTK Estimated Baseline and Relative Positional Accuracy [SPEEDBOX-RTK only]

Default address	*Data bytes 1 – 4*	*Data bytes 5 – 8*
0x50B	MB-RTK Estimated baseline. Format: Unsigned, 32bit, little-endian integer. Units: mm. Scaling: None.	MB-RTK Estimated relative positional accuracy. Format: Unsigned, 32bit, little-endian integer. Units: mm. Scaling: Output = mm × 1e2.

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10.2. Serial Output Specification

Acceleration

Output rate	200Hz
Channel number	8 (0x08)
Data bytes	4
Data bytes 1 and 2	**Lateral Acceleration** Format: Big endian integer (raw hex). 15 data bits, 1 sign bit. Signing: Sign-and-magnitude. First bit (msb) is sign (0 => -ve). Units: g Scaling: Output = g × 256 Eg. Acc(g) = (byte 1 & 0x7F) + (byte 2 / 256) If (byte 1 & 0x80) = 0, acc = -acc.
Data bytes 3 and 4	**Longitudinal Acceleration** Format: All format the same as lateral acceleration above.

Combined Speed

Output rate	200Hz
Channel number	64 (0x40)
Data bytes	3
Data bytes 1 to 3	**Combined Accelerometer and GPS Speed** Format: Big endian (raw hex). 24 data bits, unsigned. Units: kph Scaling: Output = kph × 725.1315278 Eg. Speed(kph) = (byte1 × 0x10000 + byte2 × 0x100 + byte3) × 0.001379060159

GPS Position	
Output rate	20Hz
Channel number	10 (0x0A)
Data bytes	12
Data bytes 1 to 4	**Longitude** Format: Big endian (raw hex). 32 data bits. Signing: Two's complement Units: Degrees Scaling: Output = degrees × 1e7 Eg. Long(deg) = [(byte1 & 0x7F) × 2^{24} + byte2 × 2^{16} + byte3 × 2^{8} + byte4] × 0.0000001 If (byte1 & 0x80) = 1, long = long - 2^{31}.
Data bytes 5 to 8	**Latitude** Format: All format the same as longitude above.
Data bytes 9 to 12	**Positional Accuracy Estimate** Format: Big endian (raw hex). 32 data bits, unsigned. Units: cm Scaling: None

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GPS Speed

Output rate	20Hz
Channel number	11 (0x0B)
Data bytes	8
Data bytes 1 to 4	**GPS Speed** Format: Big endian (raw hex). 32 data bits, unsigned. Units: cm/s Scaling: None
Data bytes 5 to 8	**GPS Speed Accuracy Estimate** Format: Big endian (raw hex). 32 data bits, unsigned. Units: cm/s Scaling: None

GPS Heading

Output rate	20Hz
Channel number	56 (0x38)
Data bytes	8
Data bytes 1 to 4	**GPS Heading** Format: Big endian (raw hex). 32 data bits. Signing: Two's complement Units: Degrees Scaling: Output = degrees × 1e5

GPS Altitude	
Output rate	20Hz
Channel number	57 (0x39)
Data bytes	8
Data bytes 1 to 4	**GPS Altitude** Format: Big endian (raw hex). 32 data bits. Signing: Two's complement Units: mm Scaling: None
Data bytes 5 to 8	**GPS Altitude Accuracy Estimate** Format: Big endian (raw hex). 32 data bits, unsigned. Units: mm Scaling: None

GPS Time	
Output rate	20Hz
Channel number	7 (0x07)
Data bytes	4
Data bytes 1 to 4	**GPS Millisecond Time of Week** Format: Big endian (raw hex). 32 data bits, unsigned Units: ms since midnight on Saturday. Scaling: None

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GPS MB-RTK Yaw Angle [SPEEDBOX-RTK only]

Output rate	20Hz
Channel number	80 (0x50)
Data bytes	2
Data bytes 1 to 2	**GPS MB-RTK Yaw** Format: Big endian (raw hex). 16 data bits. Signing: Two's complement Units: degrees Scaling: Output = degrees × 100

GPS MB-RTK Pitch Angle [SPEEDBOX-RTK only]

Output rate	20Hz
Channel number	82 (0x52)
Data bytes	3
Data bytes 1 to 2	**GPS MB-RTK Yaw** Format: Big endian (raw hex). 16 data bits. Signing: Two's complement Units: degrees Scaling: Output = degrees × 100
Data byte 3	**Reserved for future use.**

GPS MB-RTK Estimated Baseline [SPEEDBOX-RTK only]

Output rate	20Hz
Channel number	90 (0x5A)
Data bytes	4
Data bytes 1 to 2	**GPS MB-RTK Estimated Baseline** Format: Big endian (raw hex). 16 data bits, unsigned. Units: mm Scaling: None
Data bytes 3 to 4	**GPS MB-RTK Accuracy Estimate** Format: Big endian (raw hex). 16 data bits, unsigned. Units: mm Scaling: Output = mm × 10

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