

UWTSD

WISA



Performance Analysis

Motorcycle Dynamics ACHA5004

Reuben Pearson-Warder

2304115

29/03/2026

Contents

1	Introduction.....	1
1.1	Justification.....	1
1.2	Aims	1
1.3	Objectives.....	1
2	Yamaha YCM Data.....	2
2.1	Analysis Overview	2
2.2	Lap Analysis	2
2.2.1	Redgate to Hollywood.....	3
2.2.2	Hollywood to McLeans	4
2.2.3	Coppice to the Esses	6
2.2.4	Melbourne Loop to Start/Finish	7
2.3	Analysis Feedback.....	7
3	Data System Design	9
3.1	Design Overview	9
3.2	Sensor list	9
3.3	Sensor Justification	9
3.4	Bracket Design	10
3.5	Sampling Rates	11
3.6	Wiring Diagram.....	11
4	Calibration, Setup and Testing	13
4.1	Calibration and Setup Overview	13
4.2	Setup.....	13
5	Analysis of Aprilia Data	14
5.1	Data Overview	14
5.2	Analysis	14
6	References.....	15

Figure 2-1- Key for what colour each line is on the telemetry.	2
Figure 2-2 - Redgate to Hollywood telemetry.	3
Figure 2-3- Hollywood to McLeans telemetry.	4
Figure 2-4 - Hopkins Chatter.	4
Figure 2-5- Front Fork velocities.	5
Figure 2-6 - Hopkins Chatter.	5
Figure 2-7- McCoy's mistake into McClean's.	6
Figure 2-8 - Coppice to the Esses telemetry.	6
Figure 2-9 - Hopkins rear wheel skipping into the esses.	7
Figure 2-10 - End of the lap telemetry.	7
Figure 3-1- Front Suspension top bracket.	10
Figure 3-2- Front Suspension bottom bracket.	10
Figure 3-3- Rear suspension potentiometer bracket.	10
Figure 3-4 - Wiring Diagram with all the sensors required.	11
Figure 3-5- Diagram of where each sensor will be placed.	11
Figure 5-1- A lap of the Aprilia RS660 around Pembrey.	14
 Table 1 - List of sensors for the Kawasaki ZXR750	 9

1 Introduction

1.1 Justification

In this report, many different aspects of data analysis and data logging systems will be analysed. This will be from analysing three different riders' behaviour using data from the Yamaha WCM 500 Grand Prix team using 2D, designing a data logging system for the UWTSD Kawasaki ZXR750 as well as calibrating and testing a system to use on the UWTSD Aprilia RS660.

1.2 Aims

In terms of data analysis, the aims are to evaluate each rider's behaviours throughout a lap of Donington Park, for example seeing how aggressive they apply the throttle and how aggressively they are braking, to then suggesting rider improvements and potential set up changes. For the data logging system, the aims are to successfully fit a data logging system, which will include suspension potentiometers to wheel speed sensors. In terms of the Aprilia, the aim is to calibrate each of the sensors correctly to produce accurate data traces.

1.3 Objectives

For the data analysis for the Yamaha YCM, the objectives are to suggest what improvements can be made to both rider and machine to help gain lap time. For the Kawasaki, the objective is to be able to produce a wiring diagram and successful mounts for the bike to show where and how the sensors fit. For the Aprilia, the objective is to successfully analyse the data from the system and check that all the sensors are outputting correctly.

2 Yamaha YCM Data

2.1 Analysis Overview

In this section of the report, a lap of three riders will be analysed around Donington Park GP circuit. These riders are Gary McCoy, Simon Crafar and John Hopkins, all riding the Yamaha YZR500. Firstly, each rider will be analysed corner by corner to see how their actual riding styles are affecting their lap time, for example where they brake and what pressure they are hitting, as well as how aggressively they apply the throttle. This will then be analysed to see what changes the riders can make to their riding to improve their lap time. Alongside this, each rider's suspension trace as well as the calculated suspension velocity will be analysed. By doing this, it will point out any issues the rider may be having with the motorcycle that is causing them to lose lap time and what changes to the suspension can be made to remove the issues.

2.2 Lap Analysis

For this section, the riding inputs of Gary McCoy, Simon Crafar and John Hopkins will be analysed around a qualifying lap of Donington Park. For reference the riders achieved the following lap times:

Gary McCoy: 1.32.787

John Hopkins: 1.31.960

Simon Crafar: 1.32.147



RPM	(min)
V_rear	(m/s)
Throttle	(%)
F_Susp	(mm)
R_Susp	(mm)
F_Brake	(bar)
Gear_Pos	(M)

Figure 2-1- Key for what colour each line is on the telemetry.

As seen in figure 2-1, each parameter in the telemetry has a different colour so it can be differentiated from the other traces. From here, key sections of the lap were looked at to see what each rider was doing.

2.2.1 Redgate to Hollywood

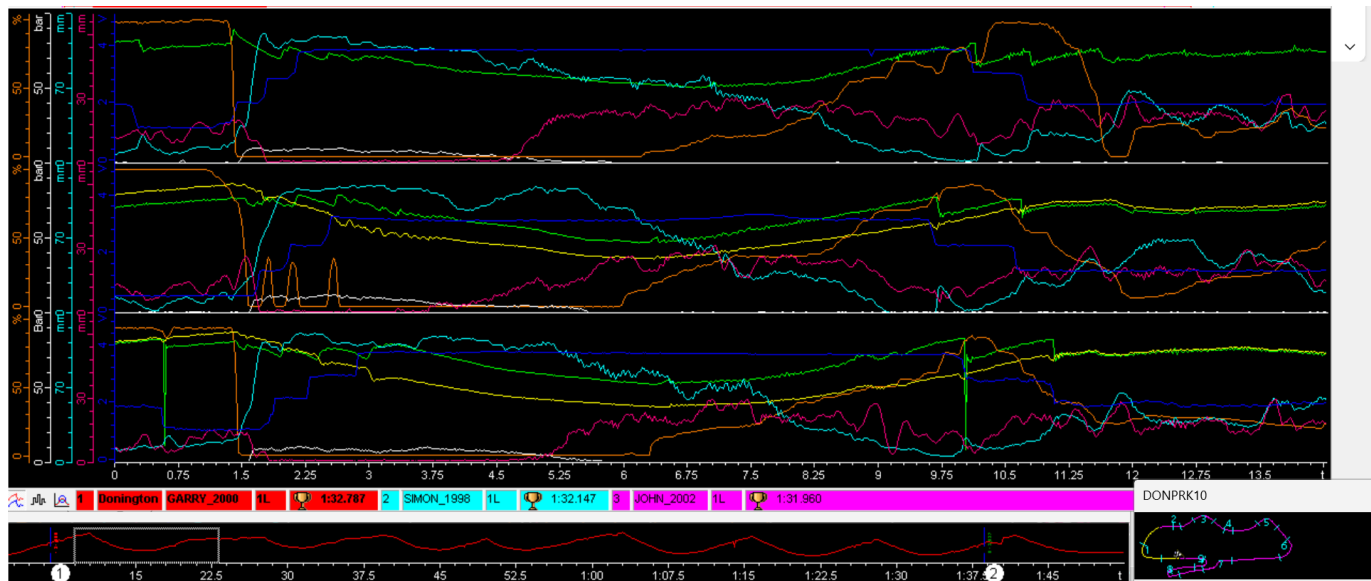


Figure 2-2 - Redgate to Hollywood telemetry.

For each of the data traces, McCoy is on top, Crafar is on the middle and Hopkins is on the bottom. As you can see in figure 2-2, the first notable thing going into the braking zone is how quickly they roll off the throttle. Hopkins and McCoy roll off at nearly the same rate, however Crafar takes a bit longer to roll off and he does it earlier. This could suggest he is lacking confidence heading into the braking zone. Also, Crafar has to blip the throttle whereas the other two do not, meaning he is probably not running an auto-blipper. In terms of brake pressure, Hopkins and McCoy hit peaks of around 10.5 bar and Crafar hits around 11.5 bar. This means Crafar is able to brake harder and later than the other two and carry more corner speed, countering the fact he wasn't feeling confident in the braking zone. As well as this, Crafar's front suspension is a lot more stable throughout the corner whilst the other two's spike at points and chatter, suggesting Crafar's bike is more planted.

On corner exit, the throttle traces for each rider are fairly different. On the initial opening of the throttle, McCoy is the smoothest, Crafar then opens the throttle slightly quicker but needs to roll as the shock compresses and the wheel spins and Hopkins is able to apply the throttle at quite a linear rate and carry the most exit speed where he gains time over the other two. A smoother throttle trace allows more controlled power delivery, reducing rear wheel slip and improving drive out of the corner.

2.2.2 Hollywood to McLeans

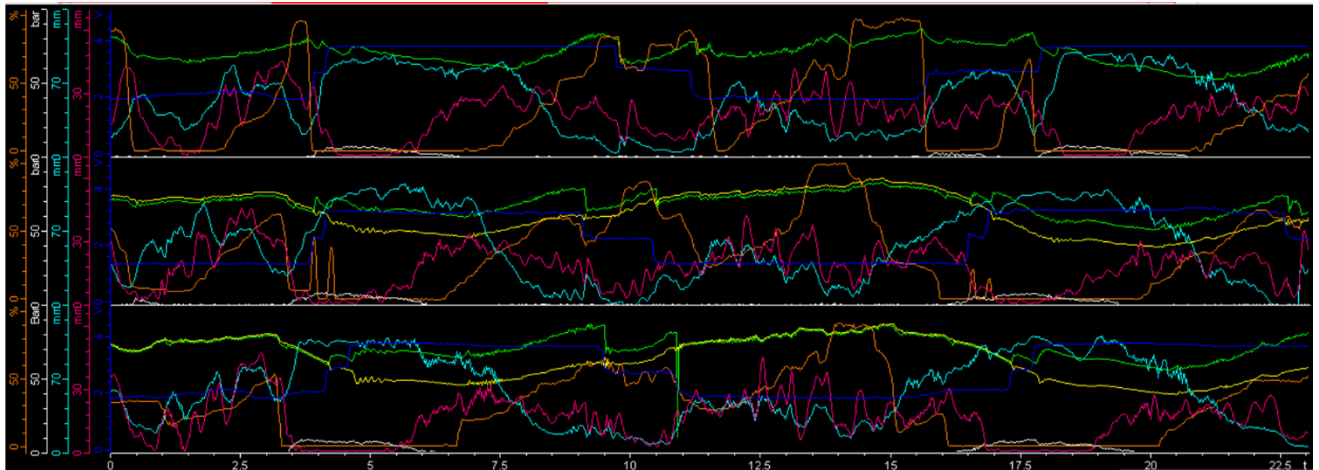


Figure 2-3- Hollywood to McLeans telemetry.

As the riders exit Hollywood, McCoy is the only one able to apply the throttle smoothly, whereas the other two struggle and face a lot of pumping at the rear. One fix for this could be slowing the compression and rebound down on the shock so the bike squats better.

On the approach to the Old Hairpin, looking at the front suspension trace, McCoy's and Crafar's suspension look fairly settled, whereas Hopkins seems to face a bit of chatter on the exit of Old Hairpin. This is odd as he is not as deep in the stroke as Crafar but the bike is unsettled.

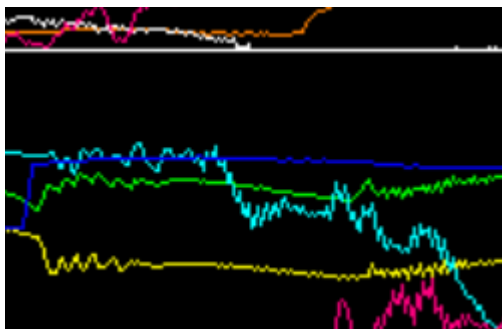


Figure 2-4 - Hopkins Chatter.

However, once the velocities of the forks were calculated, the picture became clearer.

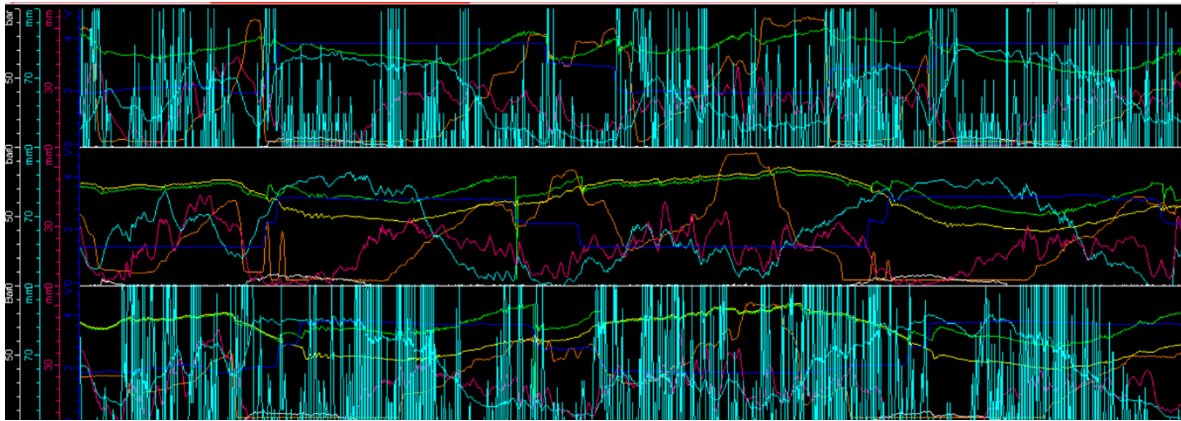


Figure 2-5- Front Fork velocities.

As seen in figure 2-5, Hopkins forks are oscillating a lot more than McCoys. The oscillations in the front suspension suggest the rebound damping is too fast, meaning the forks are not settling quickly enough and causing instability on the exit of the corner. A fix for this should be slowing down the rebound so the front end isn't hopping around, meaning Hopkins can turn the bike better for Starkey's.

There are couple things to note on the way into McClean's. Firstly, Hopkins front end seems to face a bit of chatter on the way in, suggesting again the damping is incorrect or the bike may not be running at the correct ride frequency. The other thing to note is that McCoy has to release the brake and reapply the throttle, potentially meaning he has run wide or not carried enough speed in on entry. This also affects his corner exit as it takes him longer to get back on the throttle than the other two costing him a few tenths.

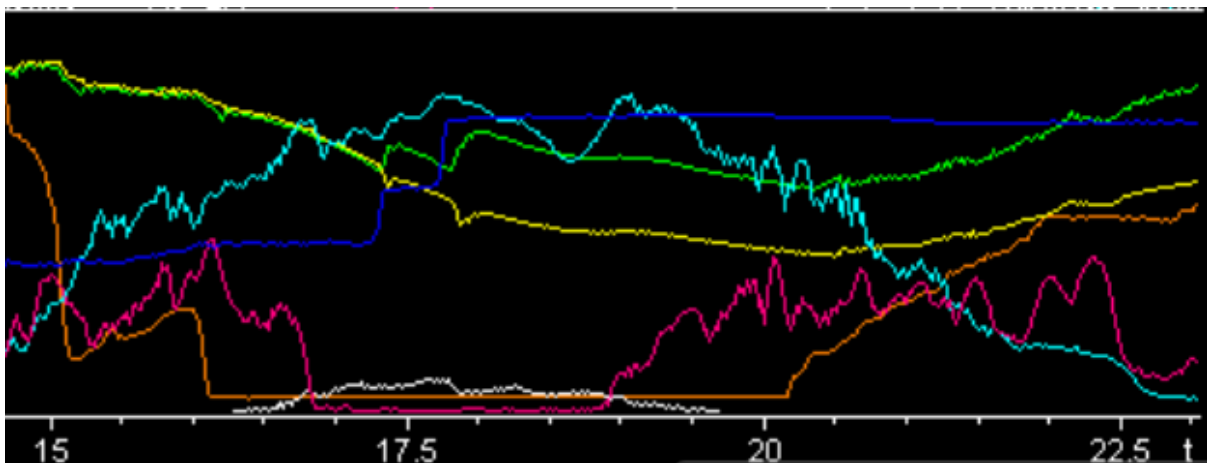


Figure 2-6 - Hopkins Chatter.

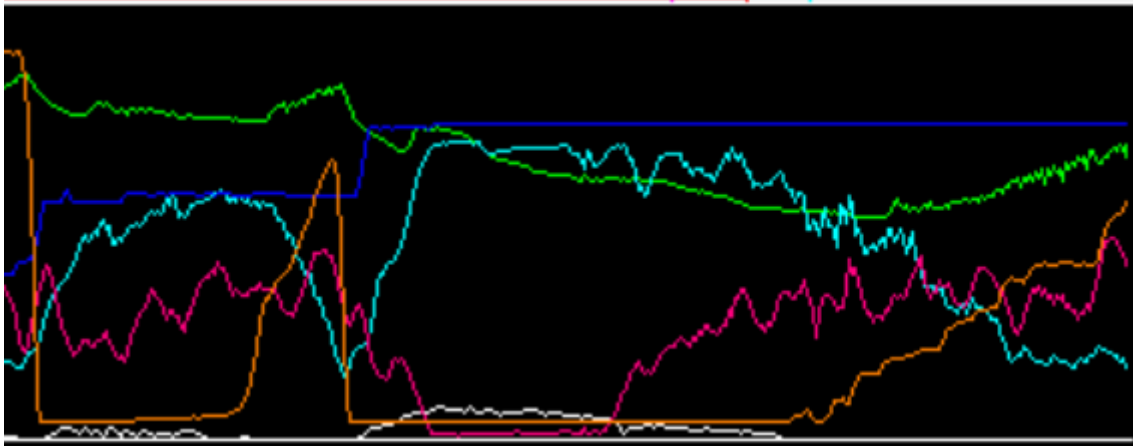


Figure 2-7- McCoy's mistake into McClean's.

2.2.3 Coppice to the Esses

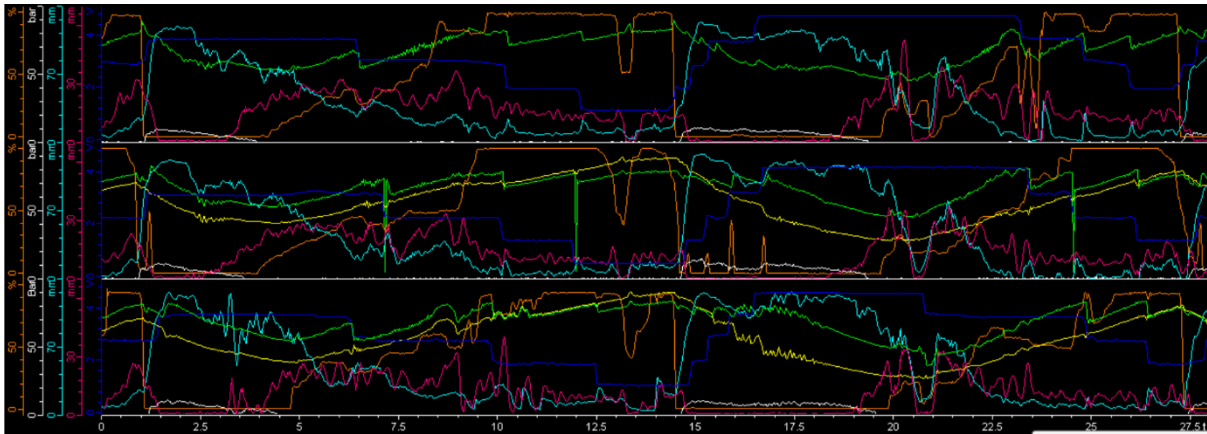


Figure 2-8 - Coppice to the Esses telemetry.

As seen on the way into Coppice at the start of the trace, McCoy's and Crafar's front suspension are settled, but there is a big spike on Hopkins. This again highlights that the damping or spring stiffness is not optimal in Hopkins forks which if solved would further improve his lap time. As they exit Coppice, all three bikes respond similarly, except Hopkins which faces a bit of pumping. On the way into the esses, all the bikes react the same on the front, however Hopkins rear begins to skip on approach. This once again shows Hopkins front is softer than the other two as he gets around 5mm further in the stroke despite applying similar brake pressure. While peak brake pressures are similar, the way each rider applies them is different, with a faster initial load transfer improving corner entry but increasing the chance of instability if not controlled.

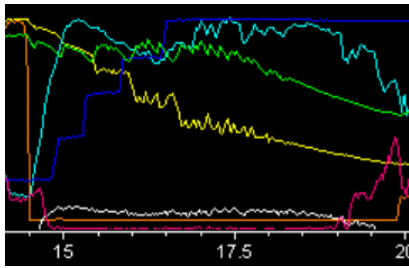


Figure 2-9 - Hopkins rear wheel skipping into the esses.

On the exit of the esses, only Crafar can apply the power effectively, as both Hopkins and McCoy have a couple of stabs at it before the rear end settles, giving Crafar more drive on the way to Melbourne loop and gain in lap time.

2.2.4 Melbourne Loop to Start/Finish

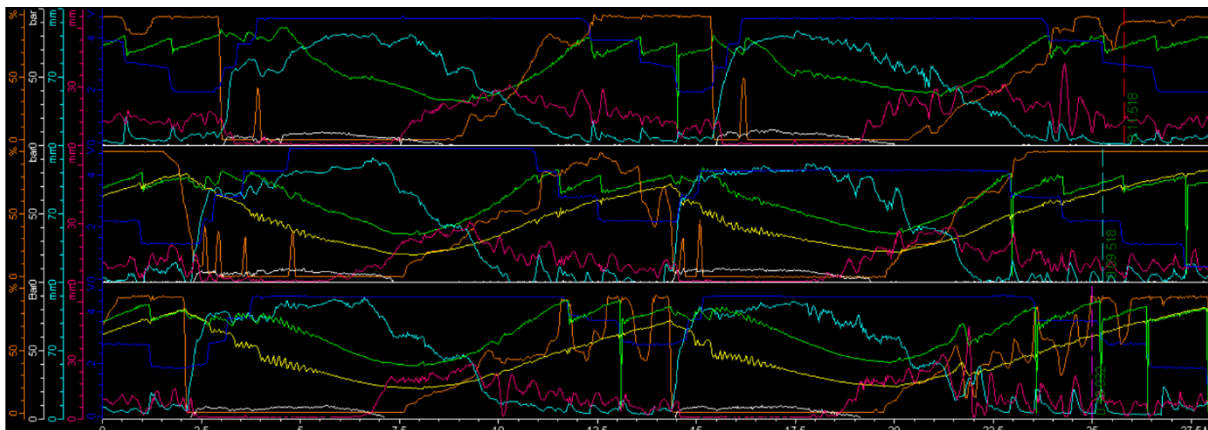


Figure 2-10 - End of the lap telemetry.

As all three enter the final section of the lap, the bikes all seem to behave very similarly. However, it is clear McCoy is not on the limit compared to the other two. Looking at the RPM and rear wheel speed trace, Hopkins and Crafar are pushing harder as the rear wheel skips into both Melbourne Loop and Goddards shown by the spikes on both traces, whereas on McCoy's trace the RPM is very smooth showing he could push harder in this section. The only part where Crafar has an advantage over Hopkins is where he gets on the power. Crafar can get to full throttle out of Goddards quickly without having to roll, whereas Hopkins has to roll around six times to prevent the bike wheeling and sliding. This could also be due to the damping in Hopkins shock being too quick.

2.3 Analysis Feedback

After reviewing the lap, there are a few key takeaways. Firstly, Hopkins' aggressive riding style definitely helped him overcome the issues he was facing to help him set the better lap time. If the team can change the damping settings he should gain even more. For example, if they could get similar setting to what was in Crafar's bike, Hopkins should be able to brake and turn the bike better

as well as get on the power smoother. For McCoy, the bike seems fairly set and he just needs to be a bit more aggressive like Hopkins and try not to make as many mistakes to gain some lap time.

3 Data System Design

3.1 Design Overview

For this Data system, a 2D ECU and data logger would be used. With this system, it gave us enough inputs needed to give us accurate data of the bike whilst it was on track. These inputs were split into three different sections: CAN, analogue and digital. With this system, there could be up to 4 CAN inputs, 4 digital inputs and 12 analogue inputs. After this, it was decided what sensors were needed for data collection.

3.2 Sensor list

Table 1 - List of sensors for the Kawasaki ZXR750

CAN	Digital	Analogue
Gyro	Front Wheel Speed	Airbox Pressure
GPS	Rear Wheel Speed	Front Suspension
	RPM	Rear Suspension
		Front Brake Pressure
		Rear Brake Pressure
		Throttle Position Sensor
		Coolant Temperature
		O2 Sensor
		Lambda
		Tyre Pressure

The sensors were selected to capture accurate data of the bike's performance, including rider input, load transfer and tyre behaviour.

3.3 Sensor Justification

CAN sensors were used for GPS and IMU due to their resistance to electrical noise and ability to transmit accurate data over longer distances. Analogue sensors were used where high resolution and fast response are required, such as suspension movement and pressure measurements. Digital inputs were used for wheel speed as they provide precise pulse signals, allowing accurate calculation of rotational speed.

3.4 Bracket Design

For some of the sensors, brackets needed to be designed so that the sensor can fit onto the bike. These include the front and rear suspension potentiometers. For these brackets, measurements were taken of the forks and the top of the shock and taken into SolidWorks for prototypes to be made.

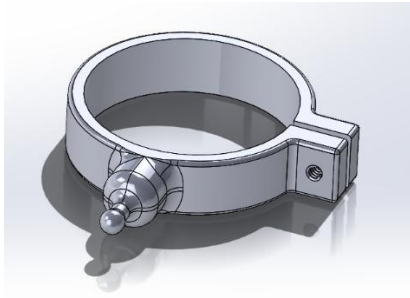


Figure 3-1- Front Suspension top bracket.

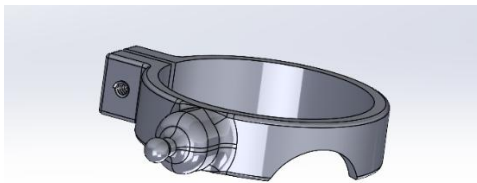


Figure 3-2- Front Suspension bottom bracket.

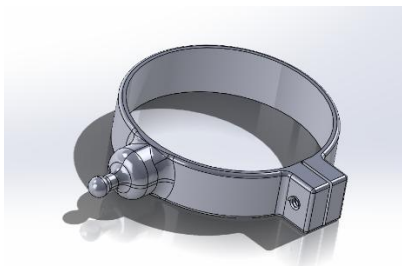


Figure 3-3- Rear suspension potentiometer bracket.

As seen in the figures above, the brackets have been designed with the correct diameter to fit the forks and shock. As well as this, the ball diameter is correct to fit 2D suspension potentiometer mounts (*2D Front Suspension Sensor 150 Mm | 7470HP001A00*, n.d.). For a lot of the other sensors, such as GPS and Gyro, Velcro and cable ties would be used. As well as this, there were a few other 2D mounts that could be used that were in the UWTSD workshop. From this point, a wiring diagram for the bike was created.

3.5 Sampling Rates

The base rate for a 2D data logger is around 800 Hz. For the logger system installed on the bike, the two CAN inputs and all the Analogue inputs run on the base rate of 800 Hz. For the digital inputs, these run at half of the base rate at 400 Hz (Allocation of the Sampling Rates for 2D Logging and Memory Modules, n.d.).

3.6 Wiring Diagram

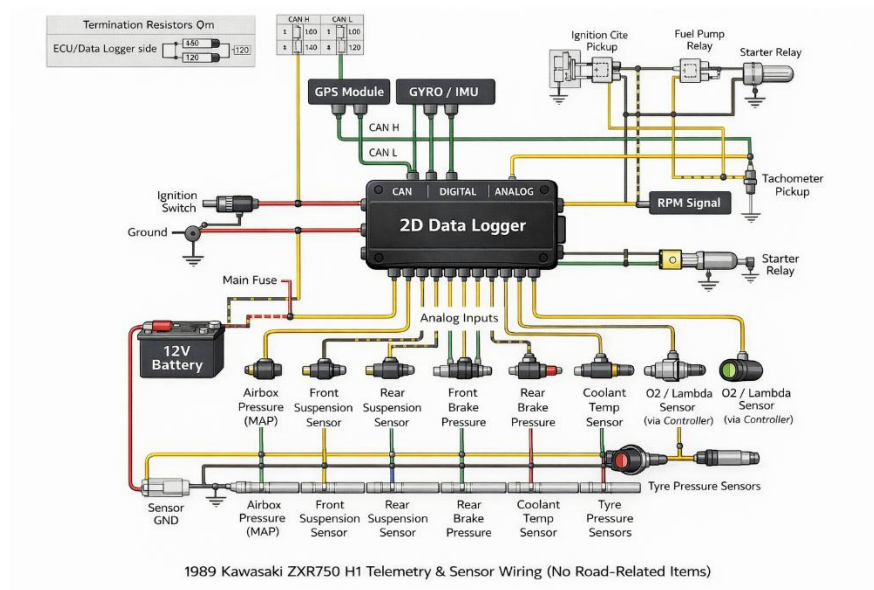


Figure 3-4 - Wiring Diagram with all the sensors required.

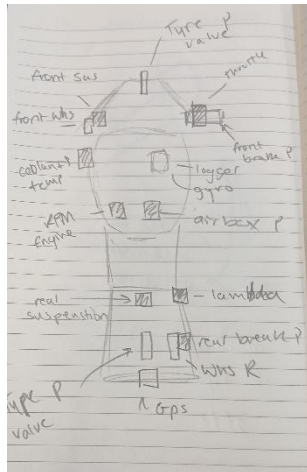


Figure 3-5- Diagram of where each sensor will be placed.

As seen in figure 3-5, this shows where the sensors will be placed. The logger will be situated underneath the tank on the front of the frame, directly connecting to the front suspension potentiometer, throttle position sensor and front wheel speed and front brake pressure. There will

be an extension module that feeds to the rear of the bike. This will connect the rear suspension potentiometer, rear wheel speed and rear brake pressure. GPS will be connected via a CAN line.

4 Calibration, Setup and Testing

4.1 Calibration and Setup Overview

For calibrating a data system, the UWTSD Aprilia RS660 would be used. The Aprilia has many similar sensors as the ZXR750 such as suspension potentiometers and wheel speed sensors. These sensors all needed to be correctly setup before heading out on track so that when the data is analysed it is readable and gives correct readings. Accurate calibration is essential, as incorrect scaling would result in unreliable data.

4.2 Setup

There are different ways to calibrate different sensors, but they all require correct mapping. For the suspension potentiometers which is an analogue sensor, within the calibration menu it will read the travel in volts. For example, 0mm of travel would be 0.9V whereas 100mm would be 4.5V. This was done for both the front and rear suspension on the Aprilia. To zero each of the sensors once they were fitted onto the bike, the Aprilia was placed on the front stand and peg stands. To zero the front, someone would stand on the front wheel so that the forks were fully extended and then in the calibration menu someone would hit the zero button, and the front end would be calibrated. The same process applies at the rear, where someone stands on the rear wheel to fully extend the shock and someone presses the zero button (*Kawasaki ZX-10R Datalogging – Datron Technology, n.d.*). Zeroing sensors incorrectly can introduce errors, particularly with suspension measurements

For a digital sensor, like a wheel speed sensor, the process is slightly different. For a wheel speed sensor to work correctly, it needs to be placed around 5mm away from a speed disc attached to the wheel. Speed sensors do not directly measure speed, they create an impulse when they are triggered. To calibrate this for the Aprilia, the amount of trigger points were counted and put into the calibration menu for each wheel. This is so that the logger knows how many trigger points there are in one rotation of each wheel. (*Moto2 Kit System Page 2 / 84 Content, n.d.*)

Once all the sensors had been calibrated, it was time to test the system on track. On-track testing is important as it highlights issues such as noise or signal instability that are not visible during static setup.

5 Analysis of Aprilia Data

5.1 Data Overview

For this section, the analysis will be of the Aprilia RS660 around a lap of the Pembrey circuit to check whether the system installed on it was calibrated correctly. This will include checking signal quality, making sure the traces read accurately and the overall reliability of it.

5.2 Analysis

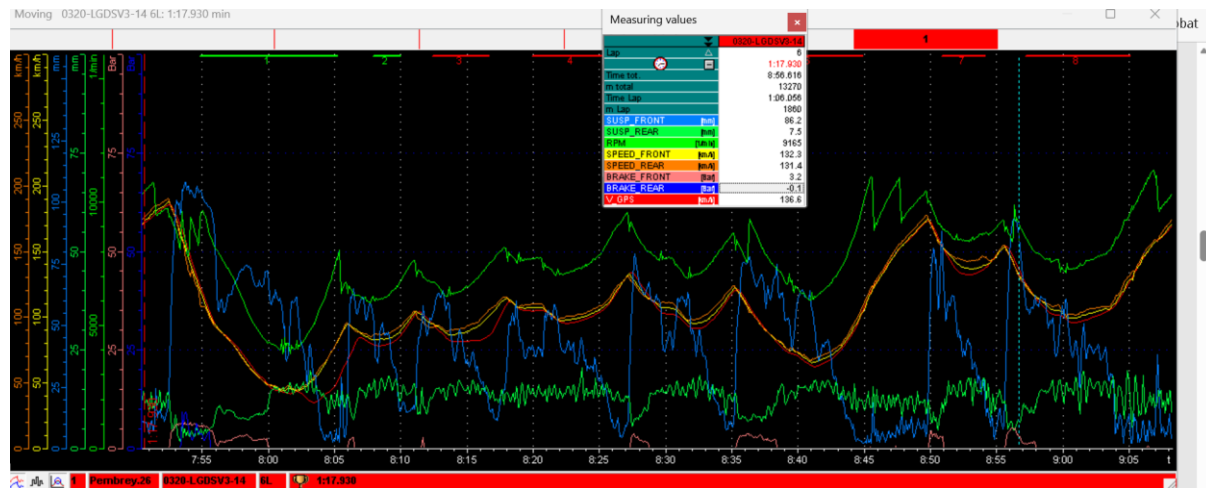


Figure 5-1- A lap of the Aprilia RS660 around Pembrey.

As seen in figure 5-1, this is the telemetry acquired from the Aprilia. The traces of most the sensors can be seen to read clearly, especially when zoomed in. This shows they have been calibrated correctly. However, one sensor that doesn't read as accurately as it should is the rear suspension potentiometer. As seen in the figure, there are many spikes within the trace even when the bike is travelling in a straight line. The noise in the rear suspension trace indicates an issue with calibration, mounting or signal quality. To fix this, the rear suspension potentiometer would need to be recalibrated in accordance with the 2D guide for the suspension travel in volts. Overall, the system performs well, but further improvements in calibration and signal quality would increase reliability.

6 References

2D front suspension sensor 150 mm | 7470HP001A00. (n.d.). Retrieved March 25, 2026, from <https://www.alpharacing.com/en/2d-front-suspension-sensor-150-mm/7470hp001a00>

Allocation of the Sampling rates for 2D logging and memory modules. (n.d.). Retrieved March 26, 2026, from <http://www.2D-datarecording.com>

Kawasaki ZX-10R Datalogging – Datron Technology. (n.d.). Retrieved March 26, 2026, from <https://datrontechnology.co.uk/case-study-category/kawasaki-zx-10r-datalogging/>

Moto2 Kit System page 2 / 84 Content. (n.d.).