



# PRECIOUS GAINS AT THE RAINBOW'S END

From rainbow maps and histograms, to XY charts and maths channels, Graham Templeman explores what we can do with data logger software

EVERY data logger comes with its own software package and, luckily for us, the manufacturers keep an eye on what their competitors are up to. This means that when one company comes up with an innovation, the rest soon follow. So the range of facilities is pretty standard and it all becomes fairly intuitive with a bit of practice.

which shows that for about 75% of the time the driver was able to keep the revs in the 5,000 to 6,500 range which means that it stays pretty well in the best part of a Sports 2000's engine power curve.

The speed chart is on the right hand side and shows the range of speeds for which we have to provide gear ratios.

## HISTOGRAMS

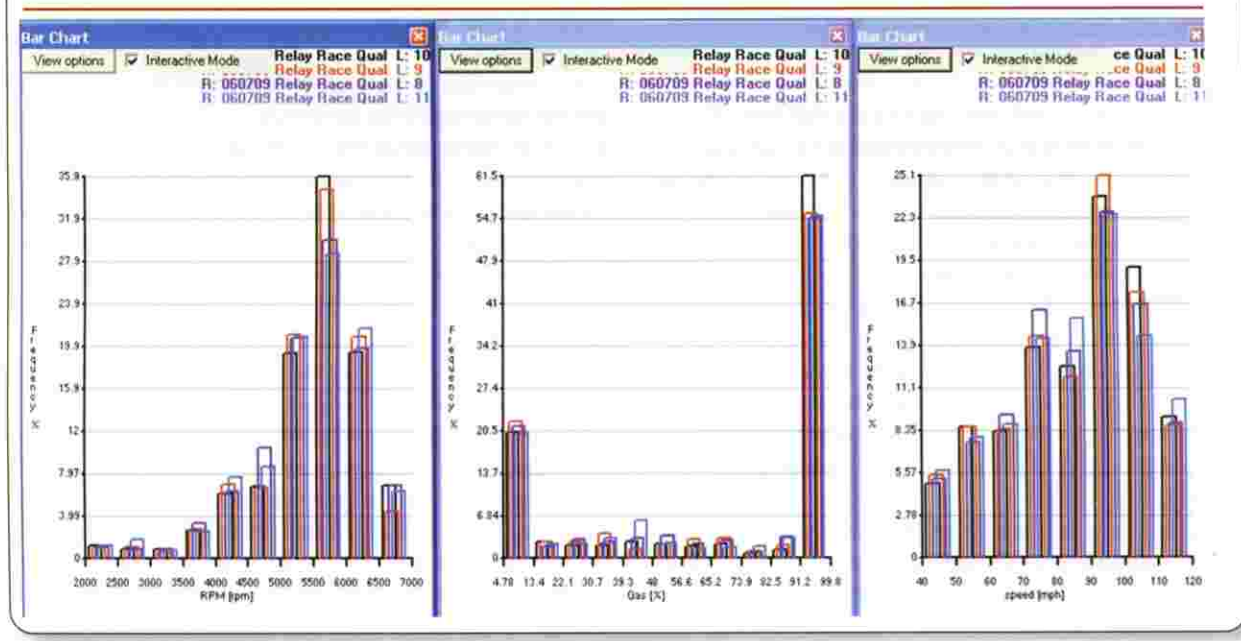
All the packages will provide the facility to produce histograms showing the extent to which a particular variable was present. They are a useful starting point to review the broad general behaviour of the car. The usual set includes engine revs, wheel speed and throttle position. Damper histograms are also useful as a car sorting aid and will be dealt with in a future issue.

An example, taken from the Race Technology DL1, is shown as Figure 1. The three charts show data from the fastest four laps. The left-hand chart is the RPM channel

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On this day, the range was between 40 and 120 so that gives us a starting point for first and top gears. There is a plateau in the 45 to 70 range, indicating some time spent

FIGURE 1 HISTOGRAMS: A USEFUL STARTING POINT



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FIGURE 2 BRAKE TEMPERATURE RAINBOW MAP

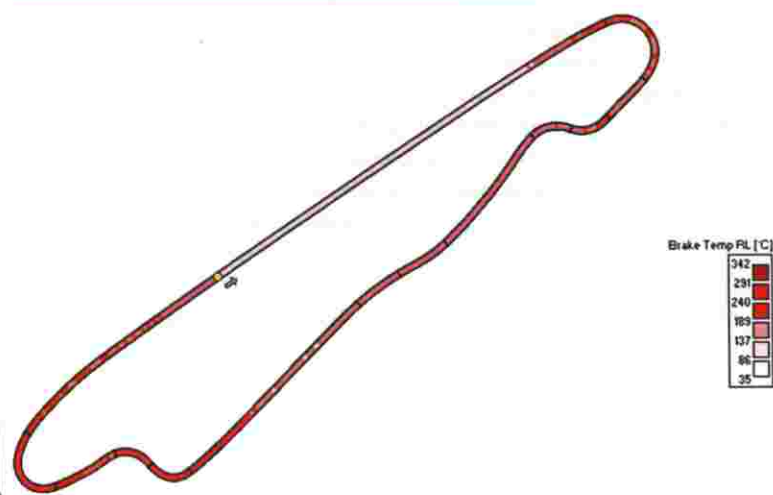
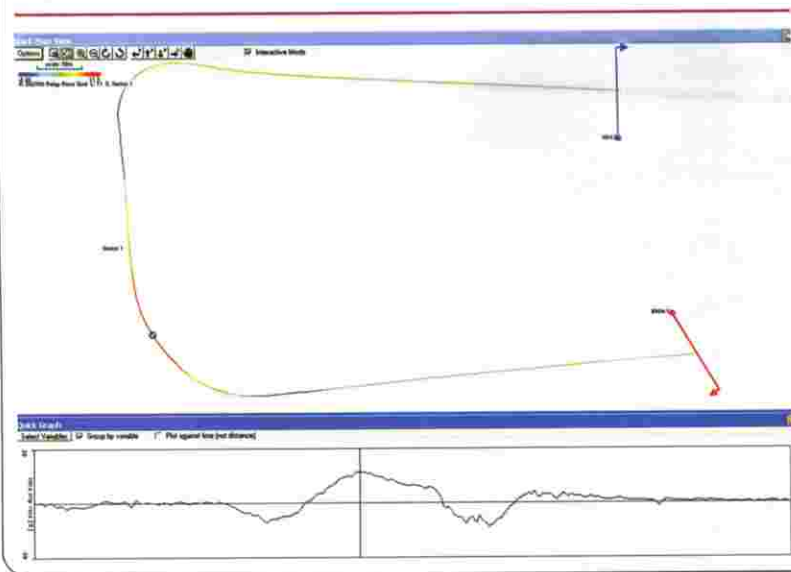


FIGURE 3 RAINBOW MAP – TIME SLIP



in corners at those speeds, so we need to look at the gear charts to find a ratio that would be in the power in that range, and the same goes for the 70 to 90 range.

The tail end of this histogram ties in with the upper ranges of the RPM chart and perhaps indicates that the current top gear is on the low side since the engine is being forced to run beyond its peak power. It would be foolish to rely entirely on the histograms to decide the gearing when strip charts of RPM and speed will confirm the speeds

through the turns and the revs and speed at the end of the main straight. But the histogram gives an instant feel for what is going on with the car.

The throttle chart (the middle of the three) is fairly typical in that it's either full on or full off with little in between. Perhaps this one is a bit more point and squirt than you might expect given the ratio of power to grip, but that in turn raises the question of whether this is related to the chassis set up or the driver.

The fact that the driver is not

spending time on part throttle, mid-corner, could indicate that the chassis is either so nervous that the driver feels inhibited or that it is so good that there is no messing about with half measures. Back to the strip charts and the driver for further evidence. In this case the fastest lap is the black lap and, as might be expected, this is the one where significantly more time is spent on the gas.

### MAPS & RAINBOW MAPS

Track maps were originally nothing more than a means of navigating through the data. At a given point on the circuit these characteristics were present. Now though, they are capable of more than this. The track animations with the fast blob and the slow blob racing each other round the circuit map are all very well for impressing a potential buyer, but don't impart any information that cannot be gained elsewhere.

More significant is the ability to shade the map according to the data. Two rainbow maps are shown. The first (Figure 2) is taken from the sample data provided with the free download of MoTeC's Interpreter software. It shows the range of brake temperatures as the car goes round the circuit and indicates that it stays within a safe working limit even in the heaviest braking zones.

The second map (Figure 3), this time from the DL1, shows the rate of time slip in one sector of the circuit. This refers to the speed difference at any point and compares the current lap with the fastest *sector* recorded that day. A positive number is bad and on the map this is shown at the red end of the spectrum with blues showing time saved. The map shows clearly the cardinal sin of in fast, out slow. The sector shown involves time saved under braking, which then compromised the corner and resulted in losses in time through and out of the bend. The strip chart shows where the time is lost or gained, the rainbow map illustrates it starkly. ▶

**XY CHARTS**

The remaining graphical presentation is the XY chart, which allows the user to plot one variable against another. It's easier to show than to explain. For instance, you can move the friction circle from the textbook into reality simply by creating an XY graph of lateral against longitudinal g. Figure 4 is one such chart. The top half of the chart is acceleration, the bottom half is braking, and right turns are to the right of the chart.

This chart is fairly satisfactory, showing a driver who is quite prepared to turn in under braking and to accelerate while still under strong lateral g. It is equally easy to create a gear chart (Figure 5) by comparing RPM with Speed to mimic the sort of chart provided by the gearbox manufacturer.

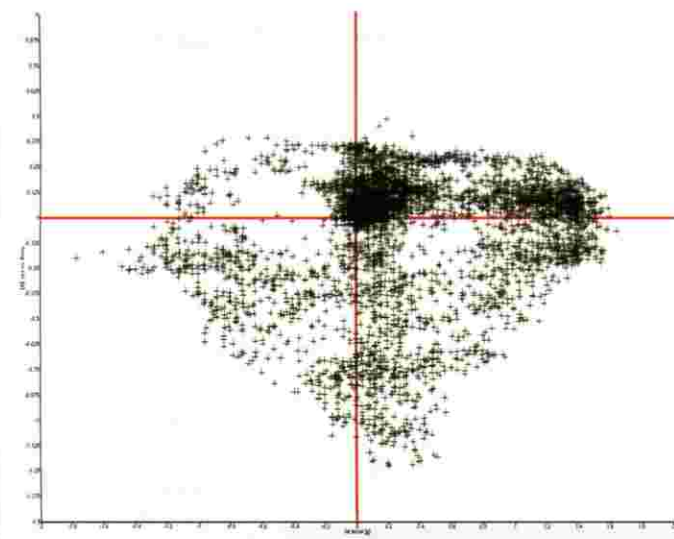
**MATHS CHANNELS**

The data that we can display is not limited by what is physically collected by the logger. Most software packages have some sort of additional maths facility that can be used to create extra channels of data. So if we logged suspension travel and were interested in the amount of body roll, it would be possible to create an extra channel that took the relative damper movements left and right and used them to calculate the amount of body roll. It all depends on what we see as issues needing attention and how much time we have to create the data that would help our understanding.

As an aside, if two maths channels are created, one for front body roll and one for rear, they will almost invariably ▶

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**FIGURE 4 USING AN XY CHART TO PROVIDE A FRICTION CIRCLE**



“ You can move the friction circle from the textbook into reality simply by creating an XY graph of lateral against longitudinal g ”

**FIGURE 5 USING AN XY CHART AS A GEAR CHART**

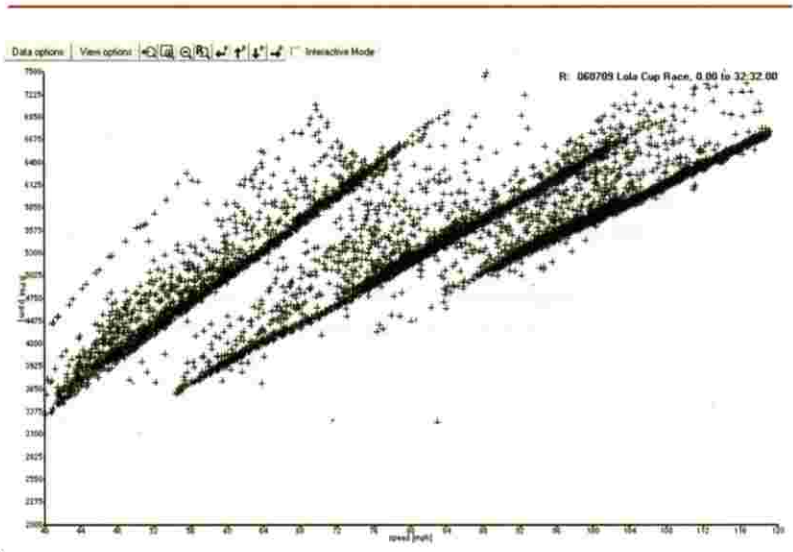
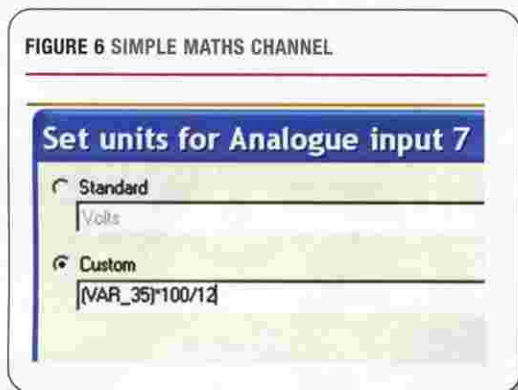


FIGURE 6 SIMPLE MATHS CHANNEL



show different rates of roll. One explanation for this is that the chassis is twisting, but the reality is much more likely to be that the car is working one set of tyres much harder than the other and this appears in the data as differential body roll. If suspension adjustments then bring the calculated rates closer together and lap times improve, we have happened upon an heuristic method of sorting the handling.

Most of the time though, maths channels are not that complicated. One very useful one is a gearing channel and this is easily done by calculating the miles per hour per thousand RPM. This then gives a data set that can show the driver what gear was being used at any part of the circuit and shows the engineer what ratios were in the car when

“ The maths channel will enable us to configure the data into whatever values we want and make good some of the inadequacies of the physical installation ”

the data was taken. The formula would be:  $MPH/1000rpm = \text{Speed (in mph)} \div (\text{RPM} \div 1000)$ .

Maths channels can also be used for calibrating sensors and for putting the raw data into a form that is easy to work with. For example a throttle sensor will merely output a voltage related to position. We can use the maths channel to convert from a voltage to a percentage (in the case of a 12 volt signal) by simply making the variable equal to the:  $\text{Percentage value} = \text{logged value} \times 100 \div 12$ .

The maths channel will enable us to configure the data into whatever values we want so that it can make good some of the inadequacies of the physical installation. If, for example, our installation does not make full use of the available movement of the sensor, the range of readings captured by the logger might only be from 0 to 9.5V rather than 0 to 12V. Obviously a more careful installation would be the best bet, but the maths channel can be used to restore the full 100% range in the data by modifying the previous formula to:  $\text{Percentage value} = \text{logged value} \times 100 \div 9.5$ .

Figure 6 shows a screenshot from the Race Technology analysis program that does just this for the DL1. As always with computers, you have to use the right syntax and in this case VAR\_35 refers to analogue channel 7 which was the input from the throttle potentiometer. You need also to be careful to use the correct evaluation order. Remember that there are two answers to  $2 \times 3 + 1$ , depending on the order in which you do the calculations.

The maths channel will also help adjust the data where we think it is necessary. In the case of steering, the actual angular displacement of the steering wheel will vary for a given cornering force according to the radius of the corner. A fast bend needs much less steering to reach 1.5g than a hairpin would. This then makes the steering traces different when comparing high speed and low speed corners. Some people dislike this inconsistency and use the maths channel to create a 'speed adjusted steering angle' to compensate. The usual formula for this calculation is:  $\text{Speed Adjusted Steering} = \text{Steering} \times \text{Speed} \times \sqrt{\text{Speed}}$ .

**LOOK-UP TABLES**

Another facility provided in some of the software packages is the look-up table. If your software provides this facility, it is not necessary to use a mathematical expression to define the relationship between the signal and its meaning as discussed earlier in relation to the throttle position sensor. Instead you

simply measure the values directly and enter them into a look-up table.

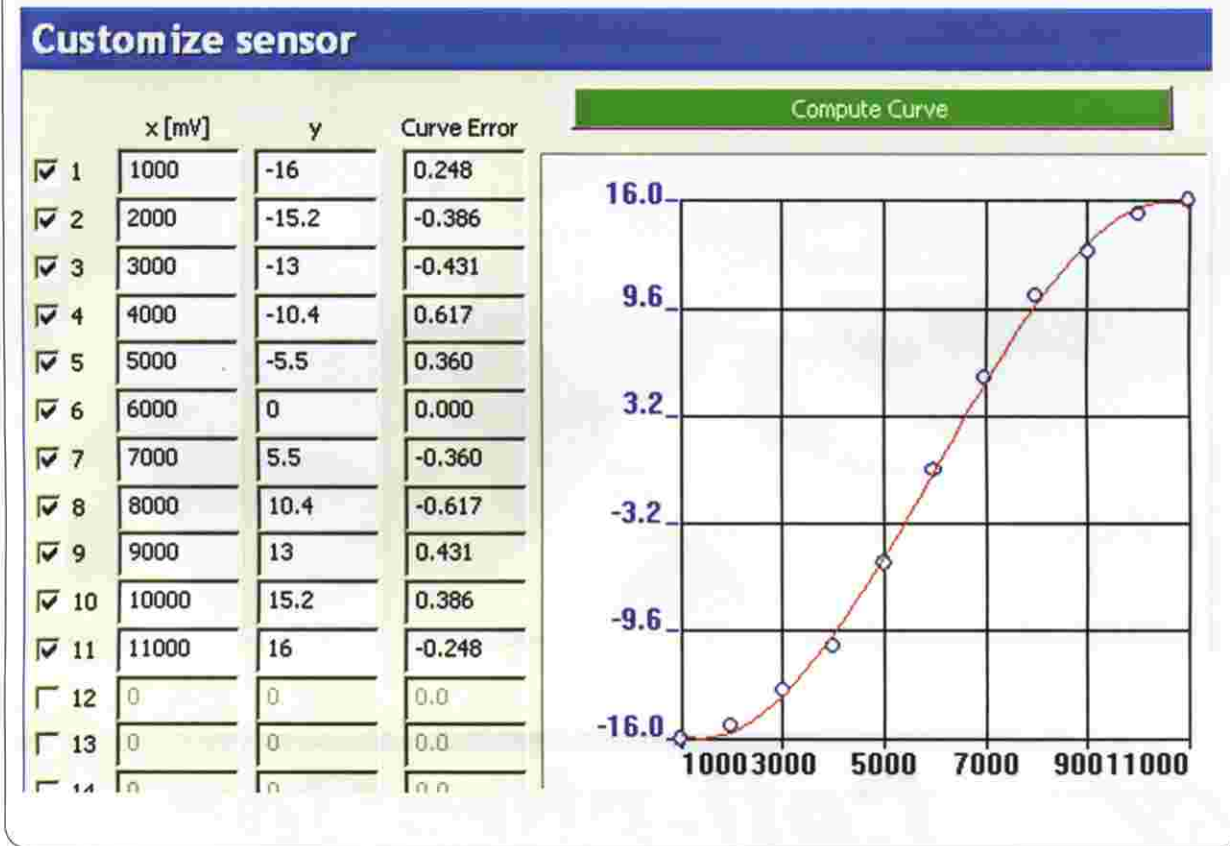
This is not too significant in a simple case, but consider a linear potentiometer used to measure steering

movement. It might be that you are using only 110mm of the available 150mm of travel and, due to the linkage involved, the movement of the steered wheels might not be in a linear relationship to rack travel. Using a look-up table greatly simplifies the setting up of the sensor.

In this case we can cope easily with the non-linear relationship and also the fact that we want zero steering to be shown at 55mm of travel and we want to have negative and positive values depending on whether the steering is to the left or right. A typical look-up table (this one is taken from the AIM software and wants its inputs as millivolts) is shown as Figure 7.

The benefits of this are obvious, but the down side is that the software still has to interpolate between the values that you enter and does this by establishing a mathematical relationship between the input and the required output. Figure 7 shows the software has created a function that smoothes out our measured data in a way that may not always be what we wanted. The smoothing means that it

FIGURE 7 TYPICAL LOOK-UP TABLE



will interpret a signal of 4.25V as 9.4 degrees of left steering when in fact physical measurement put it at 8.8 degrees.

**AVOID BUILDING IN INACCURACY**

This is not of any consequence if all we are looking for is nice values on the strip chart axis. But if we are going to take this number and create another channel with it there might be problems. For example, we might create a channel that shows actual steering vs theoretically required steering (to assess understeer or oversteer) and we would then be building in an inaccuracy that could stack up with others to compromise the information we provide.

At the entry level, the choice of logger commits you to using the manufacturer's own software but that turns out not to be too much of a problem. The format of the data files written by each system is pretty well unique and few people possess the skills required to translate data from one format into another. Software invariably comes with the ability to export the data into a spreadsheet so if you need to look at the data in some way not provided for by the logger software it is possible.

One shortcoming of the maths channels, generally, is the

inability to compare one data point with the others. For example, if your software shows time slip but not the rate of time slip there is no way of comparing the speed on this lap to the speed at this point on the fastest lap.

“ The export facility enables the true data geek to import data into a spreadsheet and work on it in whatever way is required ”

Maths channels are just that – if you can formulate an equation, it's OK, but there is no ability to carry out logical tests (eg is this greater than or less than... or use maximum values in your calculation). You can merely operate on a specific data point to provide the data in a new form. This is where the export facility comes into its own because the true data geek can import data into a spreadsheet and work on it in whatever way is required. ■