STAYING THE COURSE

Like the idea of data logging but worried about the hassle involved? Graham Templeman offers practical tips on how to make life easier

IT IS a sad fact that a significant number of data loggers are installed, used for a while and then abandoned. The reasons are often more to do with hardware problems rather than any dissatisfaction with the process of logging.

These are complex systems relying on exposed and delicate sensing devices and lots of external wiring and removable connectors. Small wonder, then, that in a harsh motorsport environment they cease to function.

Many competitors then abandon the whole business of data logging because it just seems like too much trouble. This is a pity, because with proper installation and reasonable care, there should be no problem keeping the thing alive.

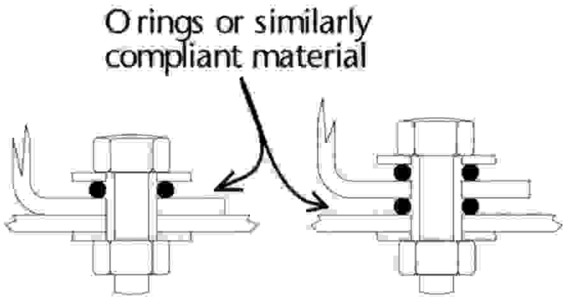
THE SYSTEMS UNIT

Manufacturers give ample instructions on how and where to mount the unit but a couple of things are often overlooked. In the case of a modern lightweight logger, the anti-vibration mounts have to be much softer than you think, since the mass of the unit is so low that conventional rubber mounts would just be too stiff. If using bolts, be sure that the bolts really do isolate the logger from vibration (see Figure 1).

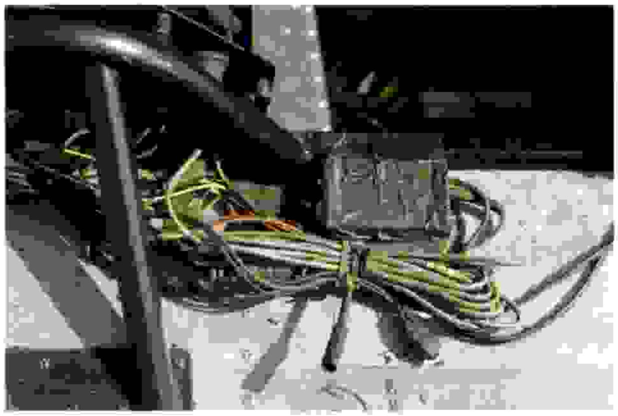
One solution that is often offered is that of Velcro. It meets the anti-vibration criterion (at least for a lightweight unit) but if it is used for accelerometers it can cause a calibration problem. Leaning on the unit shifts the Velcro, changes the installed angle of the device and influences the readings that it will give.

In cars with open cockpits, rain can be a nuisance. One cheap and effective solution is to mount the systems unit in an ordinary plastic lunch box. The locking lid keeps out the rain and the box itself can be isolated from vibration. It causes great hilarity in the pit lane – 'Ho, ho. Will you be stopping for lunch?' – but it gets the job done.

FIGURE 1 ANTI-VIBRATION MOUNTS



BELOW This shows the spare cable that seems inevitable with pre-fab connectors



WIRING

The cabling of the unit also needs attention. There is a lot of electrical noise in the environment and care should be taken to minimise its effects. Runs of cables, tied neatly together, may look great but there is a danger of electrical noise creating spurious signals.

Although it doesn't look as good, let each cable take its own route and only meet the others close to the logger. Using shielded twisted-pair cable will minimise the noise effects although it has to be said at least one logger manufacturer uses ordinary 5 Amp household flex – brown for the feed, blue for the signal and yellow/green for 0 Volts.

When it comes to connection methods, manufacturers are split between plug-in sensors and terminal blocks. For the sort of home-brewed system discussed below, terminal blocks seem to win hands-down.

Both have advantages and disadvantages. Terminals are user-friendly if you are developing and experimenting but might lead you into having to create an external terminal block to tidy things up. The problem is that the logger will provide just one terminal for the system voltage and you end up trying to fit several wires into the same point.

Systems which use pre-fabricated connector cables with their own plug and socket systems avoid this problem but can be messy. The cables never seem to be the right length and you end up with coils of over-generously provided cable hidden all around the car.

An additional problem with plugs and sockets can be self-inflicted by clumsy handling that can push the pins out of register. This can be difficult to trace. Just because your manufacturer uses plugs, doesn't mean that you can't go down the add-your-own sensor route. The plugs are proprietary items and a few minutes on the appropriate electronics supplier's website will generally find you what you need. In the UK, companies like Farnell, Rapid Electronics or RS all provide detailed catalogues on their websites and are happy to deal in small quantities.

SENSORS

Many of the sensors are vulnerable to accidental damage so it seems like a good idea to protect them as much as possible. The first essential is to keep the sensor out of the way of potential physical harm. Anything mounted on to suspension is inevitably susceptible to flying debris and to accident damage. Not only are the sensors at risk, so is the wiring and it also needs to be protected.

Vibration and misalignment hurt sensors. For example, a throttle position sensor (TPS) needs careful set up to ensure that it is not taken beyond its mechanical range. A typical rotary TPS has a travel of 120 degrees to measure 90 degrees of movement so it needs to be carefully positioned in the middle of its range of travel. Damage occurs easily if the pot is forced to travel further than its physical limits.

Vibration is inevitable and invariably shortens lifespan. Wherever possible, some comfort should be provided through linkages that allow for a degree of misalignment and vibration absorption. For example, a rotary TPS can be connected using a short length of small-bore rubber hose as a flexible coupling.

The range of dedicated sensors is enormous and is aimed at professional teams or those with deep pockets. For instance, all sorts of technologies are available for sensing position.

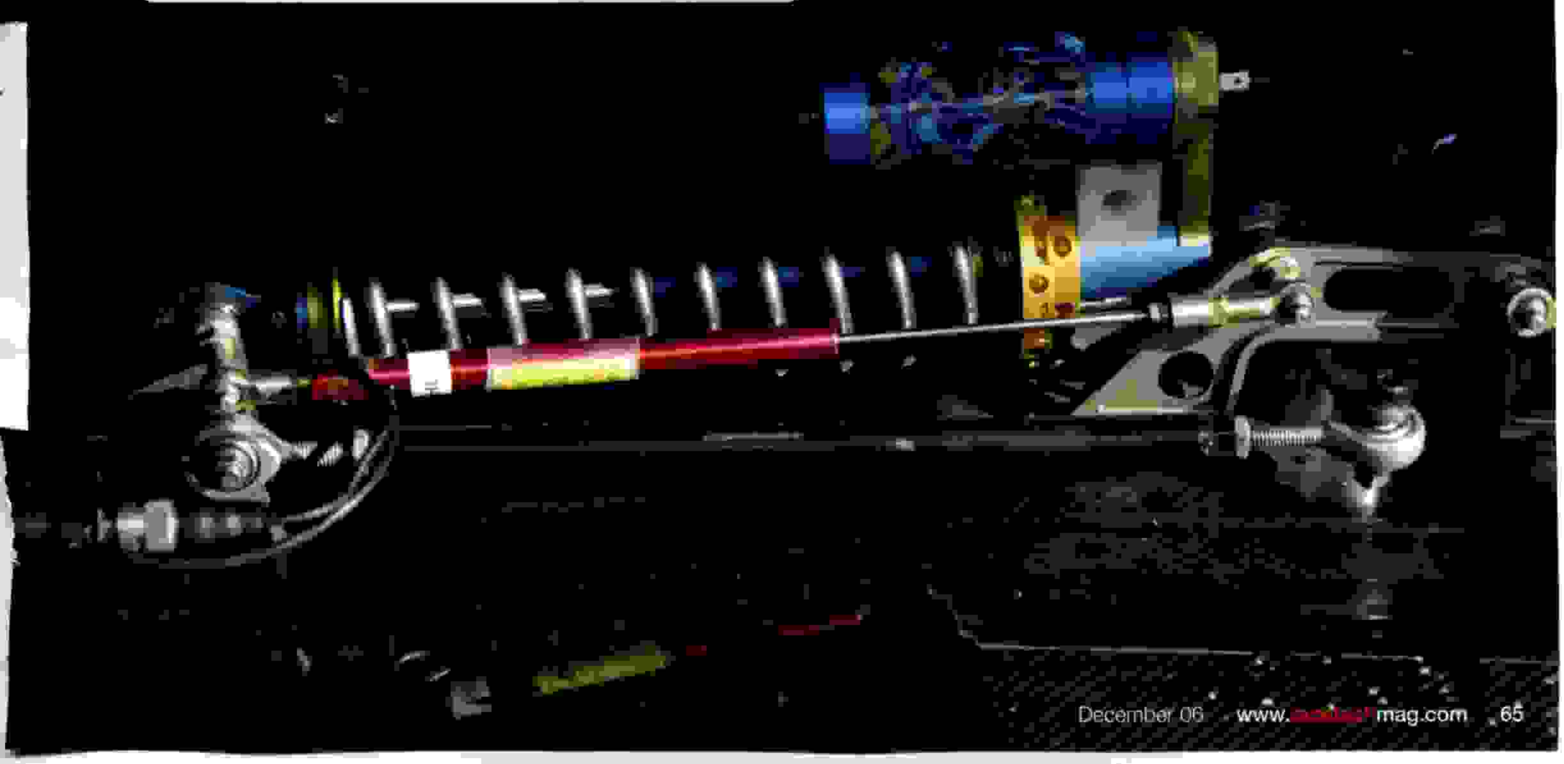
There are LVDTs (linear voltage displacement transducers)

> “With proper installation and reasonable care, there should be no problem keeping the thing alive”

which are highly accurate but require the signal to be processed further before it can be used. There are also non-contact Hall effect devices that measure either rotary or linear movement and are capable of millions of cycles before failure. You can also buy beautiful linear potentiometers that come in virtually any stroke length and are equipped with exquisite miniature rod end joints to make installation simple.

As this is the Practical Racer section, we ought to look at ways of making our own. The cheapest and most popular method to measure displacement is by using a variable resistor configured as a potential divider. A supply voltage (12 or 5 volts depending on your logging system) is fed into one end, the other end is connected to ground and the signal is available by measuring the voltage between the ▸

BELOW This is the professional way, as demonstrated by a displacement transducer on the rear suspension of a DTM car – accurate, easy to fit and, if your mechanics earn a wage, not too expensive



LEFT Cheap, high-quality rotary units are available at a breakers yard near you

BOTTOM A flexible coupling and plenty of adjustment mean that this recycled TPS can be properly aligned and should last for more than just a few races

third (wiper) terminal and ground.

Finding out how the system is wired is straightforward enough. If your system uses pre-fab cables, there will be a three pin plug and a multimeter can safely be used to identify the power supply pin and the 0 Volts pin. When the meter hits the correct pair of pins, the supply voltage will show on the meter. If it has a positive sign, the meter's leads are connected the right way round and the red lead is on the supply pin. The signal line will be the one that's left and will ultimately need to be connected to the wiper of your potentiometer.

If your system uses screw-in terminals, you are looking for a power supply (+12 V or +5 V), a ground (0 V) and a signal terminal. They should be clearly marked.

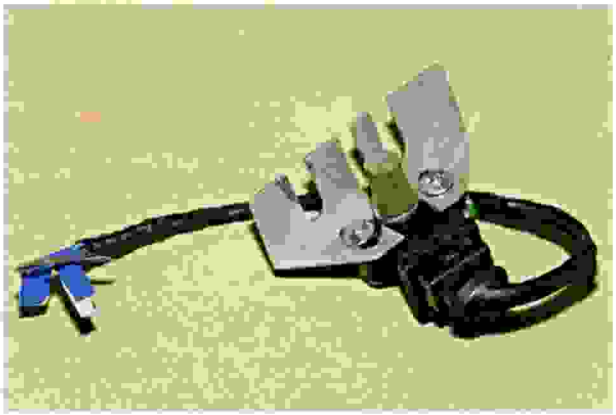
Variable resistors come in all sorts of shapes and sizes, so you should be able to find pretty much what you want. An obvious starting point is the throttle position sensor found on just about any post-1990 fuel injected road car. They are top quality (expected to last the life of the car without trouble) and readily available.

A recent visit to my local car breakers yard provided me with four for less than a fiver. The photograph shows the collection that I turned up in half an hour of ferreting around. The haul offered enough variety of shapes and sizes to fit any installation.

If this doesn't appeal, the usual electronic supply houses will provide good quality variable resistors (potentiometers) at reasonable prices. Avoid the wire-wound type – they lack accuracy – and focus on the resistive film variety.

> “ One cheap and effective solution is to mount the systems unit in an ordinary plastic lunch box ”

Slide type potentiometers are available but are not really suitable since their mechanical construction is not robust enough for motorsport. Rotary potentiometers seem to be the better bet. They are usually available as 90 and 270 degrees or three or 10 turns. The level of resistance is not too important but 5000 Ohms is okay.



USING YOUR CAR'S OWN SENSORS

The manufacturers are understandably cagey about the use of sensors that don't come out of their own catalogue. They market their own sensors because doing so reduces the chance of accidental electrical damage to the logger and enables them to make provision in the software for easy and accurate calibration. Just what the customer wants. ▸

Sometimes, though, for reasons of expense and convenience the end user might want to go it alone. A good example would be a temperature sender that once drove a now-defunct dashboard gauge but now becomes a very tempting sensor for a logging system.

Borrowing sensors in this way is okay, but be careful when sharing sensors between two or more systems. You are likely to find that the host system (especially in the case of an ECU) already has a second resistor built in so that you can shortcut much of what follows about deciding on the value of a second resistor and fitting it. It will simply be a matter of connecting the signal voltage that the sensor provides, directly to the logger.

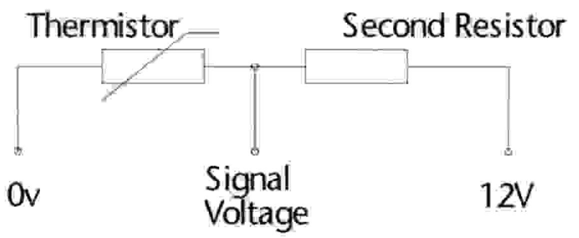
Whatever happens, you need to be wary of interactions between the two systems and be convinced that allowing the logger to freeload off the input for another device will not affect the safe and efficient operation of the host equipment. That's easy to test if you are sharing a temperature sensor between the logger and the dashboard, but it needs a bit more care if you are borrowing from the anti-lock braking system or fly-by-wire throttle.

RESISTIVE SENSORS

Temperature and pressure sensors are normally resistive. That is, their resistance varies with changes in whatever is being measured and calibrating this type of sensor is a bit of a fiddle. Their variable resistance acts on the current in the circuit, not the voltage. But we need to provide the logger with a variable voltage, which we can do by using the same potential divider concept as for measuring displacement.

In this case, instead of having a variable resistor that changes as it is moved mechanically, we can add a second resistor into the system so that we now have a home made potential divider that can provide us with the necessary signal. Figure 2 shows this using a thermistor in conjunction with a second resistor.

FIGURE 2 THERMISTOR AND RESISTOR



In practical terms, the starting point is measuring the resistance of the sensor over its working range. The first two columns in the fragment of an Excel spreadsheet (top right) show the data that was collected using a multimeter, a thermometer and a pan of hot water. The third column was created using the formula below to calculate what the output voltage would be, assuming a second resistor value of 1000 Ohms.

$$\text{Voltage Out} = \text{Voltage In} \times \frac{R2}{R1 + R2}$$

The value chosen for the second resistor will depend on the measured value of the first. The figures in the fragment of the spreadsheet (Figure 3) show the working range to be from 270 to 1790 Ohms, so a resistor in this range will give a reasonable signal. The 1000 Ohms used in this case gives a range of about 5 Volts out of 12 and this would give an adequate resolution on even an 8 bit system.

If your software has lookup tables, the job is almost complete.

LEFT This professional Penny and Giles linear displacement transducer has the added benefit of being waterproof

FIGURE 3 SPREADSHEET FRAGMENT

D7 =-0.0574*B7^3+1.8959*B7^2-5.5618*B7+24.423

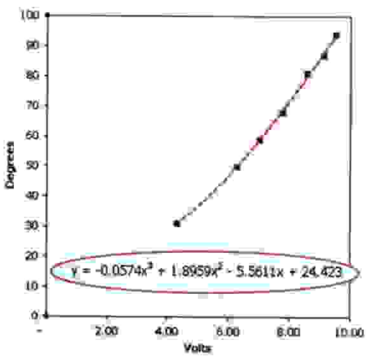
	A	B	C	D
1	Supply Voltage	12		
2	Second Resistor	1000		
3				
4				
5	Ohms	Calculated	Temperature	Check
6	(As Measured)	Output (Volts)	Degrees C	Value
7	1790	4.30	31	31.01
8	913	6.27	50	49.97
9	712	7.01	59	58.82
10	545	7.77	68	68.70
11	400	8.57	81	79.89
12	315	9.13	87	87.93
13	261	9.52	94	93.72

You simply need to wire in a second resistor of an appropriate value and arrange a feed at the appropriate voltage in order to be able to check the signal output over the operating range. These can then be entered into a look-up table for the software to read and your system will translate the output from Volts into degrees.

Without a look-up table, there are a couple more steps. Excel is used to create a mathematical function that the software can read. The process is to draw a scatter diagram of the recorded values (the blue data points on the chart in Figure 4) and to use Excel to show the trend line.

This trend line has several formatting options, one of which is to print out the mathematical expression that describes the shape of the line on the graph. This is highlighted in the red ellipse on the chart.

FIGURE 4 VOLTAGE v TEMPERATURE



> "Sometimes, for reasons of expense and convenience, the end user might want to go it alone"

This expression can then be typed into the software to describe the behaviour of the sensor. This goes a long way to overcoming the problem of not having the look-up table facility.

In the case of the graph shown, the expression is:

$$y = -0.0574x^3 + 1.8959x^2 - 5.5611x + 24.423$$

This can be seen in the edit line of the spreadsheet where an extra check column was created.

For the technically-minded, a third order polynomial expression defines the line best. For those of you that are not Excel fans, e-mail me (gtempleman@gmail.com) for a copy of the spreadsheet and more detailed instructions.

All that remains now is to use this hard-won formula in the logger software. You can now create a user-defined variable, measuring degrees Celsius, where the temperature is calculated as:

-0.06* Voltage cubed + 1.9* Voltage Squared - 5.56* Voltage +24.4

The rounding off is permissible, given that we do not need enormous precision in this case.

If you don't have look-up tables, this fairly drawn-out process is important because it provides a method for calibrating any type of sensor. You can measure the variable that interests you and the output that your home-brewed sensor provides and use Excel to identify a maths function that best describes the relationship that you can use to create a user-defined variable.

For example, it provides a method to calibrate steering in degrees left and right through a process of taking voltage readings every one or two degrees of steering displacement and creating a mathematical expression in exactly the same way.

Armed with a decent set of data for steering, we could be well on the way to measuring tyre slip angles v grip to feed our simulation program better information or move on to further insights about understeer or oversteer. Stay tuned. ■