

## KC5525: KIT – GPS TRACKER/LOGGER 11/13

Silicon Chip Magazine Nov 2013 (p24 to p35)

Rev 1

Batch No:

### PLEASE READ BEFORE COMMENCING CONSTRUCTION

The guarantee on this kit is limited to the replacement of faulty parts only, as we cannot guarantee the labour content you provide. Our Service Department does not do general service on simple kits and it is recommended that if a kit builder does not have enough knowledge to diagnose faults, that the project should not be started unless assistance can be obtained. Unfortunately, one small faulty solder joint or wiring mistake can take many hours to locate and at normal service rates the service charge could well be more than the total cost of the kit. If you believe that you may have difficulty in building this kit (which is simply a complete set of separate parts made up to a list provided by the major electronics magazines) and you cannot get assistance from a friend, we suggest you return the kit to us IN ITS ORIGINAL CONDITION for a refund under our satisfaction guarantee. Unfortunately, kits cannot be replaced under our satisfaction guarantee once construction has been commenced.

#### CONTACTS:

For queries with regards to the design aspects of this project please contact the Project Designer. It is recommended to check the designers/publishers website for further updates since this document was issued. Silicon Chip Publications, POBox 139, Collaroy Beach, NSW 2097, Tel: +61-2-99393295, Fax: +61-2-99392648 [www.siliconchip.com.au](http://www.siliconchip.com.au), [silchip@siliconchip.com.au](mailto:silchip@siliconchip.com.au)

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- Product Number
- Batch No
- Details of Quality Issue

#### Notes and Errata (at time of print):

Jaycar Electronics:

- uses netlists to confirm that the PCB artwork matches the schematic(s) and parts list(s) published. Observed variations are verified and incorporated into the kit but may not be published by Silicon Chip.
- upgrades the original PCB design to use component footprints, possible component shape, value and lead configuration alternatives and aligned polarized components where possible. You may wish to bend component leads and use component pads further apart.
- has updated the project article with relevant notes and errata. It will therefore differ from the original article published in the magazine.
- recommends to check the designers/publishers website for further notes and errata since this document was issued, before starting construction.
- Documentation is up to date at time of kit release.

## KC5525: KIT – GPS TRACKER/LOGGER 11/13

Rev 1

#### Possible Substitutions

Original Part	Original Part Desc	Subst Part	Subst. Part Desc.

#### PARTS LIST

Please note that catalogue numbers refer to suitable products from the Jaycar product range. Quantities listed refer to the actual number of items required. When purchasing items separately, take pack quantities into account.  
<sup>1</sup> See section about Substitution <sup>2</sup> See section about Notes & Errata <sup>3</sup> Processed Panel not part of Case listed  
 Catalogue numbers starting with "E" or listed as "Special Order" (incl. processed panels) are Kit specific and may not be readily available.

For queries with regards to the design aspects of this project please contact the Project Designer at Silicon Chip (tel: +61-2-99393295 or email: [silchip@siliconchip.com.au](mailto:silchip@siliconchip.com.au)).

#### RESISTOR(S)

Cat.#	Qty*	Description	Component Ident And/Or Location
RR0540	1	RES 0.5W MTL 47R 1%	Yellow Purple Black Gold Brown
RR0546	3	RES 0.5W MTL 82R 1%	Grey Red Black Gold Brown
RR0594	1	RES 0.5W MTL 8K2 1%	Grey Red Black Brown Brown
RR0596	3	RES 0.5W MTL 10K 1%	Brown Black Black Red Brown
RR0606	1	RES 0.5W MTL 27K 1%	Red Purple Black Red Brown
RR2526	1	RES 1W CARB 10R 5%	Brown Black Black Gold

#### CAPACITOR(S)

Cat.#	Qty*	Description	Component Ident And/Or Location
RC5316	2	CAP CER NPO 22P 50V 10% P=5MM	22pF
RC5490	5	CAP MONO 100N 50V P=5MM	0.1uF / u1 / 100n / 104
RE6244	1	CAP ELECT RB 4700U 25V 105C P=7.5MM16X35	4700uF / 25V
RU6705	1	CAP SUPER 1F 5.5V P=5MM	

#### SEMICONDUCTOR(S)

Cat.#	Qty*	Description	Component Ident And/Or Location
EZ9383	1	MODULE GPS UP501-150M-ITX-3570	
EZ9386	1	IC PROG (KC5525) PIC32MX250F12 DIP28	EZ9386 KC5525 IC1
PI6501	2	SKT IC TIN/G 14PIN	to make the 28pin IC socket
RQ5287	1	CRYSTAL 8MHZ HC49US	X1
ZD0100	1	LED 3MM RED 5MCD	LED3
ZD0120	2	LED 3MM GRN 6MCD	LED1, 3
ZR1004	1	DIODE 1N4004 400V 1A DO41	1N4004 D1
ZR1020	2	DIODE 1N5819 SCHOTTKY 40V 1A	IN5819 / SOD 81 D2, D4
ZR1100	1	DIODE 1N914/1N4148/BAW76 DO35	1N914/1N4148/BAW76 D3
ZR1416	1	DIODE ZENER 1N4745 16V 1W	1N4745 (16V) ZD1
ZT2466	1	MOSFET IRF540N 100V 33A	IRF540N Q1

#### HARDWARE / WIRE(S) / MISCELLANEOUS

Cat.#	Qty*	Description	Component Ident And/Or Location
EL9384	1	CHOKE 15UH 2.1A 20% P=5MM 10X9	L1
EP0517	1	HEADER SKT VRT SGL P=2.54 6WAY	
EP9385	1	SKT MEMCARD SD SMT	REMOVE RETAINER BEFORE SOLDERING
HM3172	1	TERMINAL PCB SCREW 2WAY BLU P=5MM	
HM3212	6way	HEADER SGL VRT P=2.54MM	for mounting the GPS module
HM3413	1	HEADER STRT LOCK SGL 3WAY P=2.54MM	
HP0550	4	SCREW S/TAP #4X6MM PHIL P/HD	to secure PCB to case
NS3015	1m	SOLDER 60/40 1MM	
PS0920	1	SKT PCB USB B 4P/4C	
SP0600	1	SWITCH PCB TACT SPST N/O 6X6XA0.7MM	S1

#### HARDWARE / WIRE(S) / MISCELLANEOUS - LOOSE

Cat.#	Qty*	Description	Component Ident And/Or Location
EC8380	1	PCB (KC5525) PTH SM NTN W/SMD	double sided, plated through hole, with SMD Caps and Reg preloaded
EH0257	1	LABEL (KC5525) ADH GWV W/BLK TXT 89X75	
HB6034	1	ENCL MOULDED 150X80X30MM	

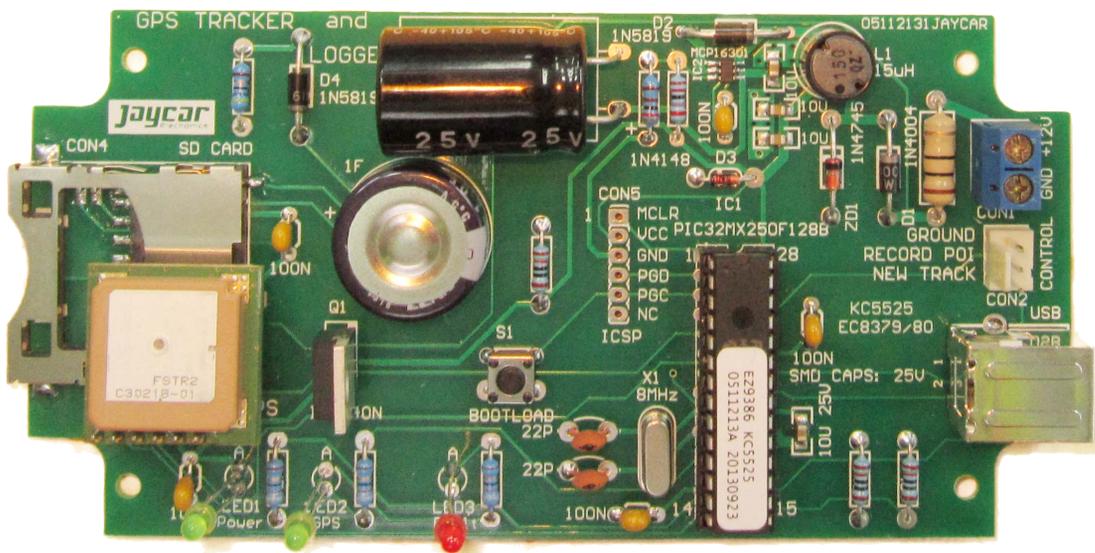


**Precisely record & plot  
your journeys with this**

# **GPS Tracker**

**By GEOFF GRAHAM**

**This little gadget will precisely record where your car, boat or aeroplane has travelled over time. Using software such as Google Earth you can then see your trips mapped onto the surface of the Earth with a resolution of just a few metres. It's a great device for off-road drivers, sailors, farmers and grey nomads and can record a lifetime of travelling onto a single SD card.**



All the parts mount on a single PCB. The GPS module can be seen sitting over the SD card socket on the left, the power supply is on the top right of the board and at the far right are the connectors for power, the optional inputs and the USB socket.

**T**HIS PROJECT was originally created for a couple who were going to do the “grey nomad” trek anticlockwise around Australia in a 4WD and caravan around Australia. Why anticlockwise? Because it’s shorter, as you are driving on the left side of the road and on the inside of a circle!

During their journey, they wanted a foolproof method of recording their route without the complications of keeping a log or constantly running a laptop computer with a GPS dongle. This GPS Tracker is the result.

Basically, it’s a small box that can be wired to the vehicle’s ignition and then forgotten. Each time the vehicle is used, the GPS Tracker automatically records the time, date and the route taken on its SD card. This SD card can be removed later and inserted into a computer so that the stored history can be displayed in Google Earth or some other mapping software.

If you are not a grey nomad, this device can be used for many other tasks – from farmers wanting to know which paddock they ploughed (and when) to boaties or fishermen who would like to know where they have been in the past. It could even be installed in the family car – imagine being able to see precisely the route taken on a particular day some time in the past!

But there’s more! The GPS Tracker can also record points of interest (POI) and automatically build a spreadsheet that records a diary of your vehicle’s business and private use in a format that (hopefully) not even the tax department could argue with.

A lifetime of detailed travel data can

## Main Features

- Records the route, time & date on an SD card each time the vehicle is used.
- Stored SD card data can be displayed in Google Earth or other mapping software.
- Records points of interest (POI) at the press off a button. In Google Earth, each POI marker is displayed as a yellow pin with an associated time & distance from the start.
- Record formats: Google Earth KML, GPS Exchange, raw NMEA data & two Microsoft Excel compatible formats.
- Can record POI locations in a spreadsheet called LOG.XLS and can record a travel diary with private & business entries in a spreadsheet called DIARY.XLS.
- When diary recording is turned on, pressing the POI button during a trip means that the distance travelled (in km) is recorded in the “Business” column of DIARY.XLS.
- Powered from the vehicle’s 12V battery and can be permanently wired into circuit.

be recorded on a single standard SD card, so the entire history of a vehicle could be recorded for posterity. This data could be useful at some time in the future, especially for a business vehicle.

### File formats

The GPS Tracker can record data in five different formats: Google Earth KML, GPS Exchange, raw NMEA data and two Microsoft Excel-compatible formats.

The Google Earth formatted file has an extension of .KML. If you have Google Earth installed on your computer (PC, Mac, or Linux) you only need to double click on the file and it will automatically open in Google Earth and display the track, with markers showing the start, end and points of interest (POI).

Google Earth is free and has many features that assist in displaying your track. These include the ability to

zoom in and see detail, combine many separate trips into one overall view and turn visual features on and off.

The second file format is the GPS Exchange Format (ie, file extension .GPX). This is an open XML data format for the interchange of GPS data (waypoints, routes, and tracks) between applications. Many open applications available on the internet use this format.

Google Earth also supports this format but its main use is with software that can automatically work out where you have taken photographs and insert the latitude and longitude into the EXIF data area of the photographs. The software does this by comparing the date and time that your photograph was taken with the date and time in the GPX format file.

The third file format supported is the raw NMEA (National Maritime Electronics Association) 0183 data which is stored in a file with a .TXT

	A	B	C	D	E	F	G
	Date	Time	Track	POI #	Latitude	Longitude	
1							
2	11/09/2013	7:08	11-#02	1	-31.083957	116.082489	
3	11/09/2013	9:08	11-#02	2	-31.089995	116.088409	
4	12/09/2013	16:53	12-#02	1	-31.094627	116.092971	
5	12/09/2013	7:10	12-#04	1	-31.122228	116.120086	
6	13/09/2013	11:10	13-#04	1	-31.125244	116.123046	

**Fig.1: the GPS Tracker can be configured to record POI (point of interest) locations in a spreadsheet called LOG.XLS which makes them easy to reference later on.**

	A	B	C	D	E	F	G	H	I	J	K
	Date	Time	Track	Start Latitude	Start Longitude	End Latitude	End Longitude	Duration	Private	Business	
1											
2	13/09/2013	7:08	13-#01	-31.065174	116.064025	-31.077001	116.075653	0h 15m	10.3		
3	16/09/2013	10:21	16-#01	-31.079551	116.078155	-31.097412	116.095703	0h 11m		5.3	
4	16/09/2013	14:10	16-#02	-31.100194	116.098434	-31.114574	116.112564	0h 05m	1.6		
5	17/09/2013	10:13	17-#01	-31.117124	116.115066	-31.135448	116.133071	1h 45m		29.8	
6	17/09/2013	17:13	17-#02	-31.117124	116.115066	-31.356845	116.265478	1h 05m		21.1	

**Fig.2: for the tax man, the GPS Tracker can also be configured to record a travel diary in another spreadsheet called DIARY.XLS. In this mode, a trip is deemed to be business if the POI button is pressed during the journey.**

extension. This consists of the RMC (latitude/longitude co-ordinates) and GGA (GPS fix) data records as generated by the GPS module. This format is also used by many applications that can process and display GPS data in interesting ways.

You can configure the GPS Tracker to record the data in one, two or all three of these formats, with a specified interval between records. By default, the GPS Tracker records KML data once every five seconds and GPX data once every minute but this, along with other parameters, can be easily changed (more on that later).

## The POI button

As well as recording the track in the three formats listed above, the GPS Tracker can also record data in two different Excel spreadsheets based on the POI input. This input would normally be connected to a switch that would short the input to ground when pressed. The switch could be mounted on the lid of the GPS Tracker itself or more likely, the dashboard of the vehicle or boat.

Pressing the switch causes up to three actions to be carried out. The first is to insert a marker in the KML track. In Google Earth, this marker

is displayed as a yellow pin symbol with an associated time and distance from the start. This could be used, for example, to record the location of a likely camping spot or the place that you dropped your lobster pot.

You can also configure the GPS Tracker to record the date, time, latitude and longitude in an Excel spreadsheet (named LOG.XLS) each time the POI button is pressed. This is handy if you want to keep a convenient list of specific locations (see Fig.1).

For example, if you are a farmer driving around your property, you could press the POI button every time you came across a patch of weeds. You could then later print out the spreadsheet and give it to a contractor as a starting list for weed spraying.

## Business vs private diary

The second type of spreadsheet file that can be linked to the POI button is a business/private travel diary. As anyone who uses their car for business knows, you have to keep a diary of your business and private use for the tax man. This can be very tedious to say the least but it is necessary so that you can justify the tax deduction.

Diary recording can be turned either on or off and is off by default. When

it is enabled, the data is saved in an Excel spreadsheet called DIARY.XLS (see Fig.2). This spreadsheet includes the date/time of each trip, the start and end latitude/longitude, the trip duration and the total kilometres.

If the POI button is pressed during the trip, the kilometres travelled will be recorded in the business column; otherwise they will be recorded in the private column.

So, all you need do is press the POI button sometime during each business trip and your complete travel diary will be automatically created, ready to be attached to your tax return.

## Design

Because of its intended use, the GPS Tracker was designed to be as simple and foolproof as possible. As shown in the photos, it's housed in a small ABS case with a power cable (+12V from the vehicle's ignition) feeding in at one end and a slot to insert the SD card at the other. There are also three indicating LEDs on the front panel and that's it.

The firmware is designed to be as forgiving as possible and will automatically recover from events such as loss of the GPS signal and power failure.

## Circuit details

Take a look now at Fig.3 which shows the complete circuit. It consists of three main sections: a microcontroller (IC1), a GPS module and a switching power supply.

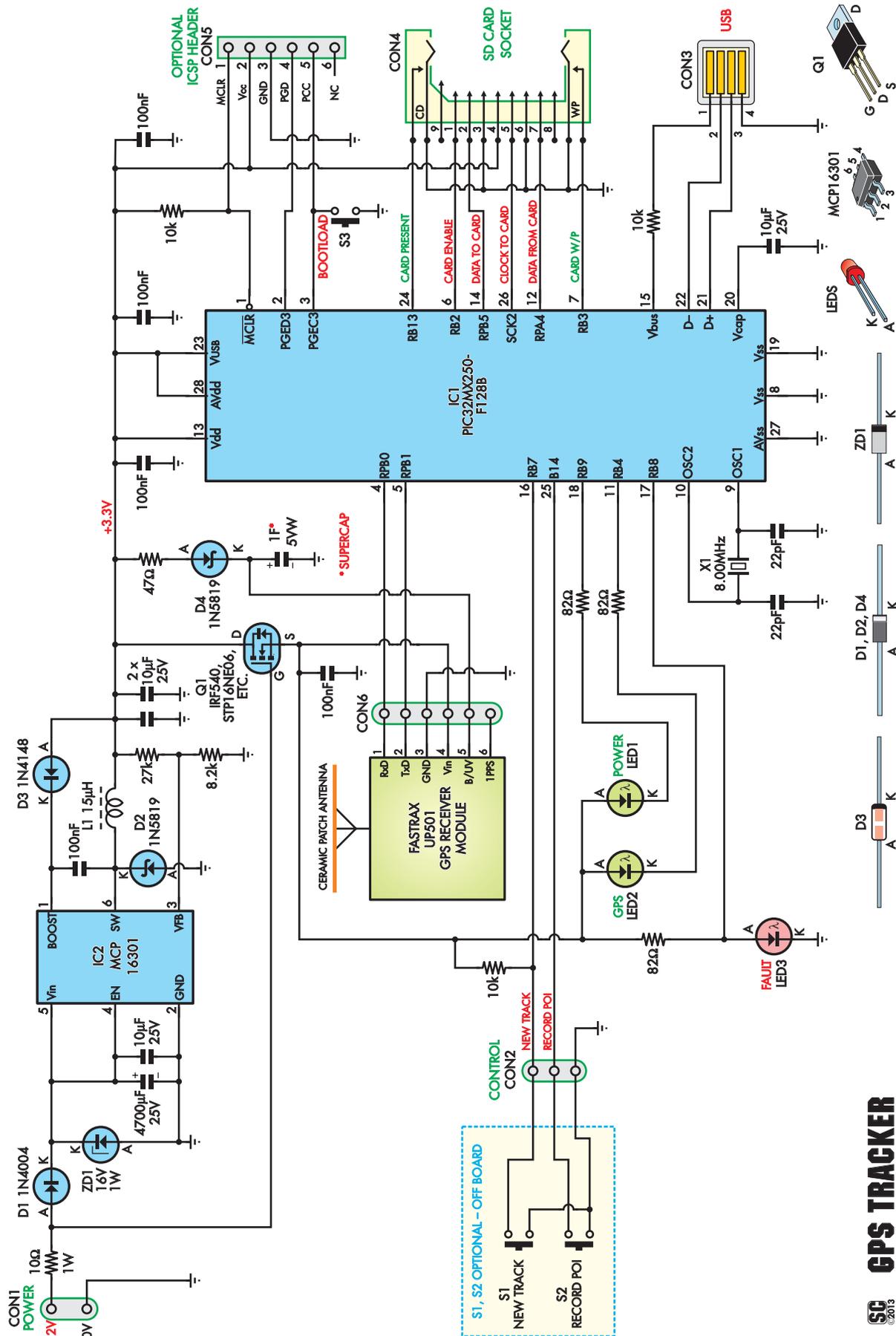
The microcontroller used is a PIC-32MX250F128B, the latest variant from the Microchip PIC32 stable. This was chosen because of its performance – it has a 32-bit processor, the clock runs at 40MHz and it has a large integrated flash memory (128KB).

When you think of it, the microcontroller has quite a heavy workload. Primarily, it must implement a full FAT16 or FAT32 file system on the SD card, with the ability to create subdirectories and navigate through them. It also must be fast enough to close any open files and flush the data to the SD card if the power fails.

But the best features of this high-performance chip are that it is cheap and comes in a standard 28-pin DIP package that can plug into an IC socket.

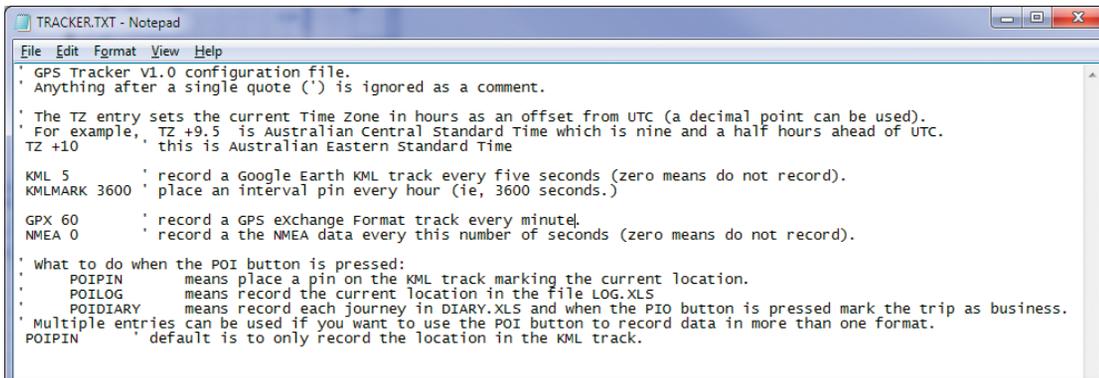
## Power supply

The GPS Tracker is intended to be



## GPS TRACKER

Fig.3: the GPS Tracker consists of three main sections – a microcontroller (IC1), a power supply (IC2) and a GPS module. The power supply is designed to provide a regulated 3.3V supply for up to two seconds after the 12V supply has been removed.



**Fig.4:** this is the default configuration file created by the GPS Tracker if a blank SD card is used. You can use any ASCII editor (Notepad in this example) to change the settings to your preference.

We suggest to take a short trip to confirm that the settings in the configuration file result in the corresponding data files being recorded. Do not eject the SD card while the project is powered up.

powered directly from the vehicle's ignition supply. It can either be hard-wired to the fuse block or it can be powered from a cigarette lighter socket (ie, via a flying lead fitted with a cigarette lighter plug).

In practice, the power supply must protect the microcontroller and the GPS module from spikes and reverse voltage. It must also keep supplying power for a short time after the external supply is removed, to allow data to be written to the SD card. As a result, it's more complicated than a simple 3-terminal regulator circuit.

Transient protection is provided by a 10Ω resistor and 16V zener diode ZD1. These serve to clip any transients while diode D1 (1N4004) provides reverse polarity protection and isolates the main filter capacitor (4700μF) from the vehicle supply when power is removed.

IC2, an MCP16301, is an efficient step-down voltage regulator. This supplies the microcontroller, the

GPS module and the SD card with a regulated 3.3V rail. When power is removed, the charge on the 4700μF input capacitor will decay and the regulator will track this falling voltage while still delivering a stable 3.3V output.

In operation, IC2 can keep its 3.3V output stable for almost two seconds after power has been removed.

The microcontroller needs only about 0.3s to flush its data and close the files on the SD card, so using a 4700μF capacitor sounds excessive. However, there's sufficient space on the PCB to accommodate it and using such a high value provides a wide safety margin that will accommodate the inevitable reduction in its capacitance due to heat and aging.

When power is removed from the unit, we need to minimise its current drain so that the 3.3V supply can be maintained for as long as possible. This is achieved by Q1 which immediately disconnects the power to the LEDs and the GPS module (which is

not required during shut-down) when the power is removed.

As shown, Q1 is an N-channel Mosfet which has its gate connected to the supply rail (ie, before reverse polarity protection diode D1). When the ignition is on, this holds Q1's gate at about +9V with respect to its source and therefore Q1 is turned fully on.

When the ignition is subsequently turned off, Q1's gate voltage immediately falls to zero. As a result, Q1 quickly turns off and in turn removes power to the LEDs and the GPS module.

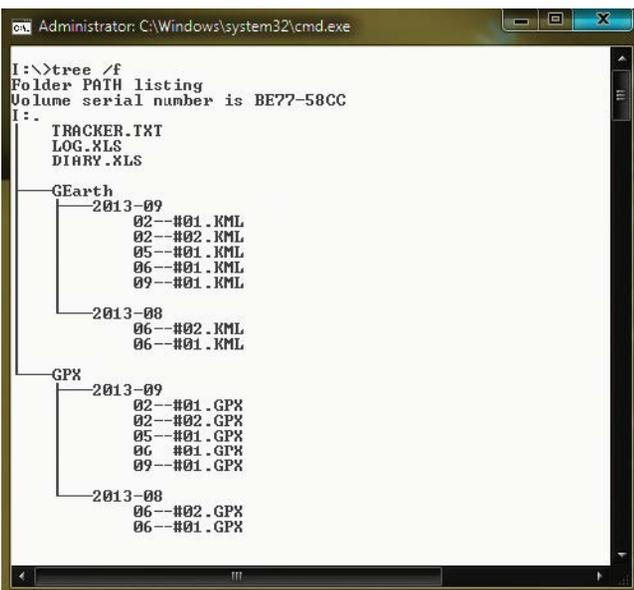
The main requirement of Q1 in this role is that it should have a low drain-source resistance when turned on. There are many SMD FETs that have this feature but it is easier to use a commonly-available power FET, even though we are only switching about 50mA.

## New track input

When the input power is removed, IC1 detects this on its RB7 input (pin 16) and immediately commences its shut-down routine. This involves terminating the current track and writing the cached data to the SD card.

RB7 of IC1 is also connected to CON2 to provide the "NEW TRACK" input but note that a new track is also automatically started if the unit loses power. Shorting this input to ground signals that the current trip has finished. When the short is released, the unit will then start recording a new track.

This facility is provided so that the Tracker can be permanently connected to power if required. The advantage of this is that there will be no delay in it recording the current location, as would otherwise initially occur when power is first applied. Also, because of the efficient power supply design, the GPS Tracker only consumes about



**Fig.5:** this is the directory structure created to hold the data. It consists of three top level directories (GEarth, GPX and NMEA) with sub directories for each month. A file is created within these subdirectories for each trip.

50mA and that level of permanent drain is acceptable in a vehicle that's driven regularly.

LEDs1 & 2 (green) indicate power and correct GPS operation respectively. These are connected between Q1's source and the microcontroller which pulls its RB9 & RB4 outputs low to turn them on.

LED3 (red) is the fault indicator and its drive arrangement is a little different. As shown, it's connected between the RB8 output and ground. Normally, the microcontroller turns LED3 off by pulling its RB8 output low, which shorts out the LED. This means that the LED is off as long as the microcontroller is working normally. However, if anything goes wrong with the microcontroller, the LED turns on to indicate a fault.

The firmware also monitors other components such as the GPS module and the SD card and if anything is wrong, it will turn on the fault LED. That way, the user is immediately warned that data is not being recorded – important in a device that is supposed to work automatically.

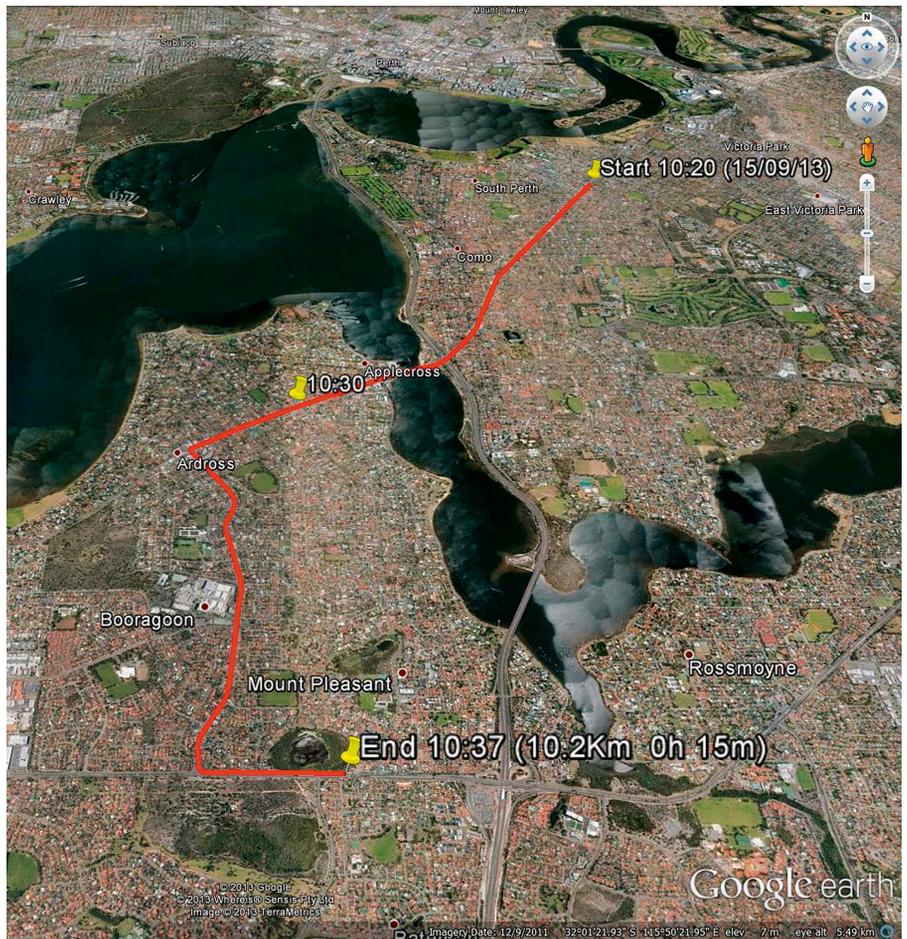
## GPS module

The GPS Tracker is primarily designed for use with the UP501 GPS module from the Finnish company Fastrax. This amazingly small module is cheap, available from many sources and plugs neatly into the PCB. However, if you want to use an alternative, the firmware will also work with the Globalsat EM-408 module that's been used in many of our projects in the past.

The advantage of the EM-408 is that it is a little more sensitive and it has an MMCX connector for attaching an external antenna. However, it is more expensive than the UP501 and is difficult to mount securely inside the case.

The UP501 needs a back-up supply to keep the internal memory of the module alive when power is removed. This is important because it can take a long time for the module to get all the data it needs from the GPS satellites. Provided the back-up supply is maintained above 2V, the module will remember this information and can get a fix on the satellites and your location more quickly.

Therefore, a 1-farad super-capacitor has been included to keep the module's memory alive for up to a week. As shown on Fig.1, this is connected



**A typical track as displayed in Google Earth. You can zoom in to see the detail of the track or you can zoom out as in this image to see the whole route. The start marker records the start time and date, while the end marker records the end time, the distance travelled and the duration of the trip.**

between the GPS receiver's  $V_{DD\_B}$  pin (pin 5) and ground. On the other hand, the EM-408 has an internal super-capacitor, so the external super-capacitor, diode D5 and the associated  $47\Omega$  resistor can be omitted if this module is used.

## USB port & ICSP

IC1 provides a USB port at pins 15, 22 & 21 (Vbus, D- & D+ respectively). This is used only for debugging, as discussed later.

The PCB layout also has provision for an ICSP (in-circuit serial programming) connector (CON5) which is not normally fitted. However, if you purchase a blank microcontroller, you can fit this connector and use a programmer such as Microchip's PICkit 3 to program the chip in circuit.

## Configuring the tracker

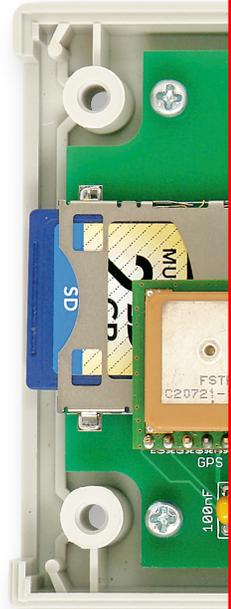
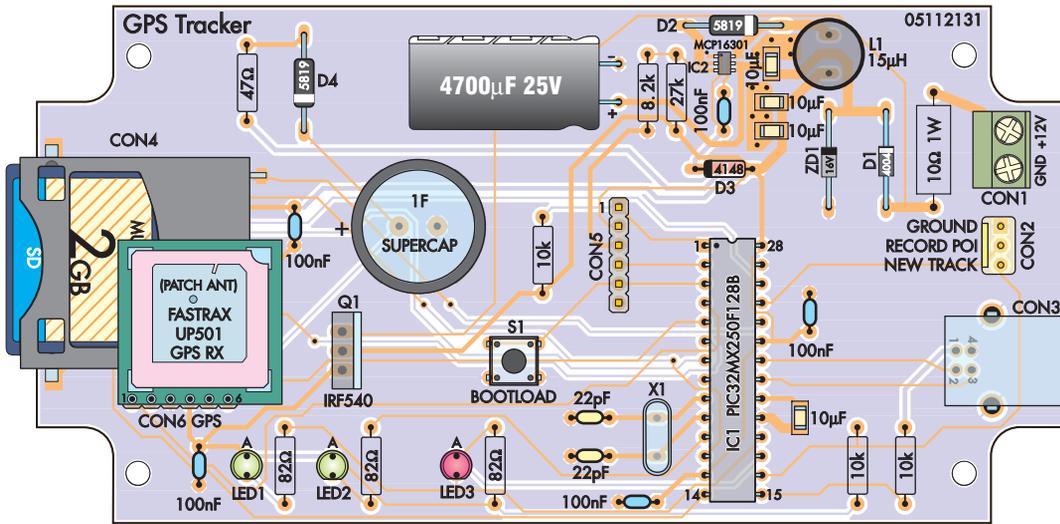
When the GPS Tracker starts up, the first thing the firmware does is read its configuration settings from a file called

“Tracker.txt” in the root directory of the SD card. If that file is not found the firmware will automatically create it using its default settings.

Fig.4 shows the typical contents of this file and as you can see, the comments make the file reasonably self-explanatory. In fact, the best way to create a custom configuration for the GPS Tracker is to insert a blank SD card and let the firmware create the default configuration file. You can then edit that file to suit your preferences.

The main parameter that you might want to change is the time zone that you are operating in. The GPS Tracker gets an accurate time from the GPS satellites but it needs to know your time zone so that it can convert the GPS time to local time for time stamping its records.

Another parameter that you might like to adjust is how often the GPS data is recorded on the SD card. This can be independently set for each of the three main data formats (KML, GPX



**Fig.6: follow this parts layout to build the PCB (note: if you are using the EM-408 GPS module, you can leave out D4, the 47Ω resistor and the supercap). The completed assembly is mounted in the bottom of the case, with the three LEDs at bottom left protruding through holes drilled in the lid.**

and NMEA) and can be as often as once a second for accurate recording all the way up to many minutes if you want to keep the data files small.

The KLMARK parameter controls how often (in seconds) a timed marker is placed on the KML track. This can be handy for long trips as it gives you an indication in Google Earth of your progress during the trip. A setting of zero will disable this feature.

The parameters POIPIN, POILOG and POIDIARY are associated with the POI input and don't have an associated value. Just their presence in the configuration file means that that feature will be turned on.

POIPIN means that a marker pin will be placed on the KML track when the POI input is pulled low. POILOG

means that the date, time, latitude and longitude of the current location will be recorded in the log file (LOG.XLS) when this happens.

Finally, POIDIARY means each trip will be recorded in a travel diary (DIARY.XLS). If POIDIARY is enabled and the POI input is pulled low at any time during a trip, it will be recorded as a business trip.

### Directory structure

Over time, the GPS Tracker can accumulate a lot of data, so a directory structure is used to make it easier to locate a particular trip. Fig.5 illustrates this structure.

Starting with a blank SD card, the firmware will create three directories called GEARTH, GPX and NMEA – one for each of the three data formats to be recorded. Within each directory, it will create a subdirectory for each month. The format of the subdirectory name is year-month. For example, the directory “2013-12” will contain the records for December 2013.

Finally, within these subdirectories,

each trip will be recorded as a separate file. The file name starts with the day of the month followed by a sequence number for that day. So a file with the name “12--#03.KML” is the third trip recorded on the 12th day of the month.

If required, the Excel spreadsheet files (LOG.XLS and DIARY.XLS) will also be created in the root directory of the SD card. They just accumulate data so if you want to reset them, it's just a matter of deleting them and the firmware then recreates these two .xls files with zero size the next time it starts up.

The firmware keeps these and other files open while it's recording a journey. This means that you must not remove the card while it is being used, as that will result in a corrupted file system. Instead, you must always make sure that the power has been removed for a second or two (or the NEWTRACK input pulled low) before removing the card.

The firmware will work with most SD cards up to 32GB in size and formatted with FAT16 or FAT32. Larger

### Capacitor Codes

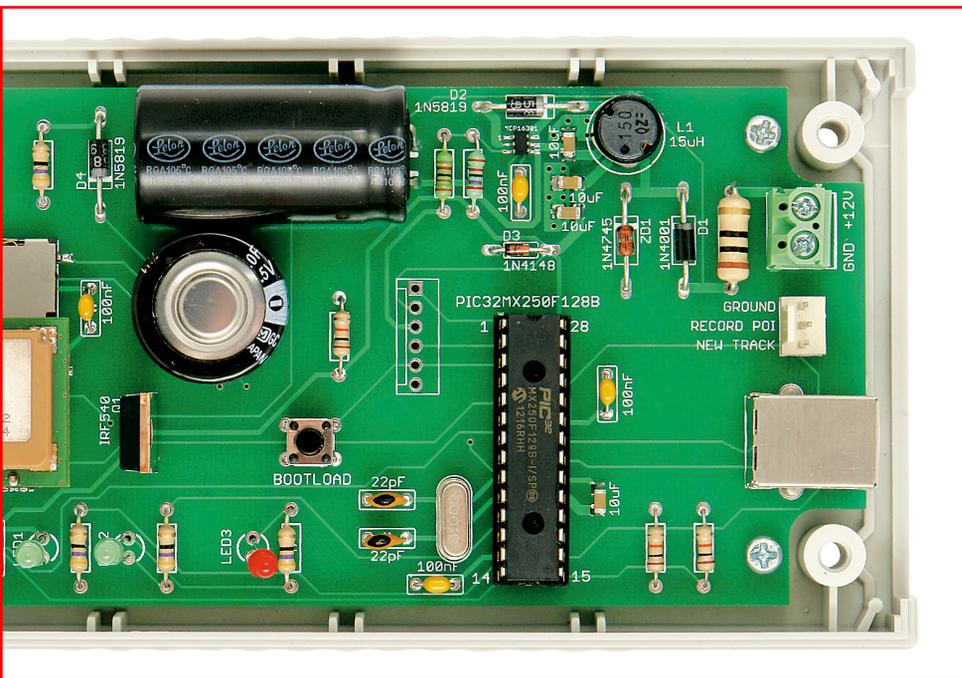
Value	µF Value	IEC Code	EIA Code
10µF	10µF	10u	106
100nF	0.1µF	100n	104
22pF	NA	22p	22

### Resistor Colour Codes

No.	Value
1	27kΩ
3	10kΩ
1	8.2kΩ
3	82Ω
1	47Ω
1	10Ω

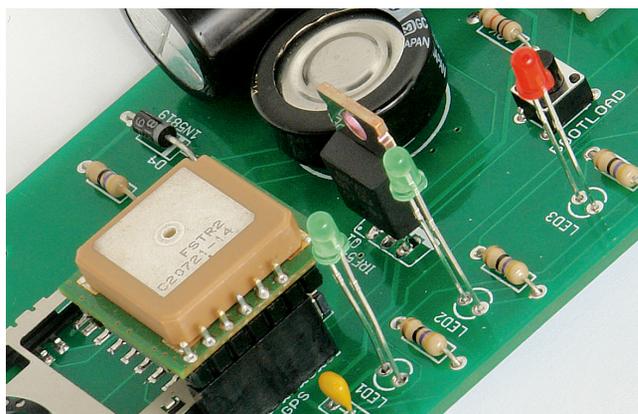
4-Band Code (1%)
red violet orange brown
brown black orange brown
grey red red brown
grey red black brown
yellow violet black brown
brown black black brown

5-Band Code (1%)
red violet black red brown
brown black black red brown
grey red black brown brown
grey red black gold brown
yellow violet black gold brown
brown black black gold brown



This close-up view shows how the UP501 GPS module and the three LEDs are mounted. The LEDs must be 20mm proud of the PCB so that they protrude through the case lid.

SMD IC and capacitors are pre-loaded.



cards may also work but we haven't tested them. However, we expect that larger cards will work if reformatted using the FAT32 file system.

Typically, a track that is recorded once a second will require about 2MB of storage per 1000km travelled, although this can vary considerably depending on your driving patterns.

These days, an 8GB SD card can be as cheap as \$10. So, using 8GB as the benchmark, you will be able to record all three data formats at the rate of once a second for over 1,000,000km. Obviously, storage capacity is not an issue!

## Construction

The GPS Tracker is built on a double-sided PCB coded 05112131 and measuring 137mm x 68.5mm. Fig.6 shows the parts layout.

Most of the parts are through-hole devices, so the assembly is fairly straightforward. However, voltage

regulator IC2 and the four 10µF capacitors are surface mount devices (SMDs) and these parts must be fitted first.

To mount each SMD, first apply plenty of liquid flux to its PCB pads. That done, place the component in position and hold it down with tweezers or a matchstick while you put some solder on the tip of your iron and tack-solder one pin (or end). Adjust its position by remelting the solder and nudging it slightly if necessary, then solder the remaining pin(s).

Finally, return to the original pin and add more solder, to ensure it is soldered correctly. Don't worry if you get a solder bridge between two pins when soldering IC2. The bridge can be easily removed after the device has been fitted using solder wick.

Note that, for performance reasons, the components around the voltage regulator are closely packed. Check Fig.6 carefully to ensure that each

device is correctly positioned. In particular, when fitting IC2, take care to ensure that you identify the faint dot marking pin 1 of the package.

Once the five SMDs are in place, continue by fitting the remaining parts, starting with the low-profile components (resistors, etc) and then moving on to the taller components. Crystal (X1) should be installed sitting about 2mm above the PCB, so that its metal case doesn't short against the solder pads underneath. This can be easily achieved by pushing the crystal down onto a thick cardboard spacer which is then removed after the leads have been soldered.

Note though that the PCBs supplied by SILICON CHIP should have a solder mask layer over these pads on the top of the board, so in this case the crystal can be pushed all the way down.

A 28-pin DIL socket is used for microcontroller IC1. Be sure to install it with its notched end positioned as shown on Fig.6.

## Fitting the SD card socket

Another part that needs special treatment is the SD card socket which is surface mounted. It has two small plastic posts on the underside that mate with matching holes in the PCB to ensure it is correctly positioned.

In particular, make sure that you find and solder all the SD card socket's solder tabs – there are 15 in total. Two of these are very close together on the front lefthand corner of the socket (viewed from the front) and both should be soldered to the same solder pad.

## Other parts

As shown in Fig.6, the 4700µF capacitor is mounted side-on against the PCB. That means that you have to bend its leads down by 90° before fitting it, so that they pass down through the PCB pads. Take care to ensure it is orientated correctly and place a dab of hot-melt glue or neutral-cure silicone under the capacitor before pushing it down into place. This will ensure that it is held against the PCB and prevent it later fracturing its PCB pads due to vibration (the unit is intended for use in a vehicle after all).

LEDs1-3 are mounted 20mm proud of the PCB, so that they later protrude through their respective front-panel holes. To set the correct height, cut a 20mm-wide strip of thin cardboard



This is the level of detail that you can see in Google Earth. The red line is the track of the vehicle and in this case you can even see what traffic lane it was travelling in.

and slide it between the legs of each LED while you solder it into position. Make sure the LEDs are all correctly orientated, ie, with their cathode (K) leads towards the edge of the PCB.

### GPS module secure properly after final testing.

The UP501 GPS module plugs into a 6-pin header socket which positions the module over the SD card socket (see Fig.6 and photos). If you are using this GPS module, simply solder a 6-pin header onto the module. It's subsequently plugged into the socket

on the PCB after the initial testing.

Alternatively, if you are using the EM-408 GPS module, you need to cut off one connector from the supplied cable and solder the leads to a 6-pin header as shown in Fig.7. This header is then later plugged into the header socket on the PCB.

As discussed earlier, if you are using the EM-408, you can leave out the super capacitor, diode D4 and the associated 47Ω resistor. However, these parts should be fitted for the UP501.

A problem with the EM-408 is that

there's no easy method of mounting it securely. One way around this is to sit the module (with its integrated aerial facing up) on top of a block of soft foam which in turn sits on top of the PCB. Then, when the lid is screwed down, you will have a "squashed sandwich" arrangement which will push the module against the lid of the box, thereby holding it in place.

Alternatively, you may be able to secure it to the top of the SD card socket using double-sided adhesive foam. Make sure that the adhesive cannot come into contact with the SD card when it is inserted though.

The assembled PCB fits neatly into the specified plastic instrument case and is secured at all four corners using short M3 or self-tapping screws. Fig.8 shows the drilling details for the lid (to accept the three LEDs), plus the location of the cut-out required in one of the end panels to accommodate the SD card.

The USB connector is used only for debugging, so there's no need to make a cut-out for it in the opposite end panel. However, you will need to drill a hole in this panel for the power lead.

A vehicle is a high vibration environment so both the microcontroller and the GPS module must be secured to prevent them from vibrating loose. The best way to do this is to cut two pieces of high-density foam (the type used to package heavy appliances) and glue them to the lid, so that they press down onto these devices when the lid is later fastened into place.

### Testing

Before plugging in microcontroller IC1 and the GPS module, you should first test the operation of the power supply. To do this, connect the PCB to a 12V supply and check that there is 3.3V (3.1-3.45V range) between pins 13 (+) and 19 (-) of the IC socket. At the same time, the red fault LED should illuminate.

Next, remove the power and check that the 3.3V rail remains for a few seconds (this indicates that the 4700µF capacitor is doing its job). Wait for this rail to drop to almost 0V, then complete the PCB assembly by inserting the microcontroller and GPS module into their sockets.

### Using the tracker

Using the GPS Tracker is as simple as applying power, inserting the SD

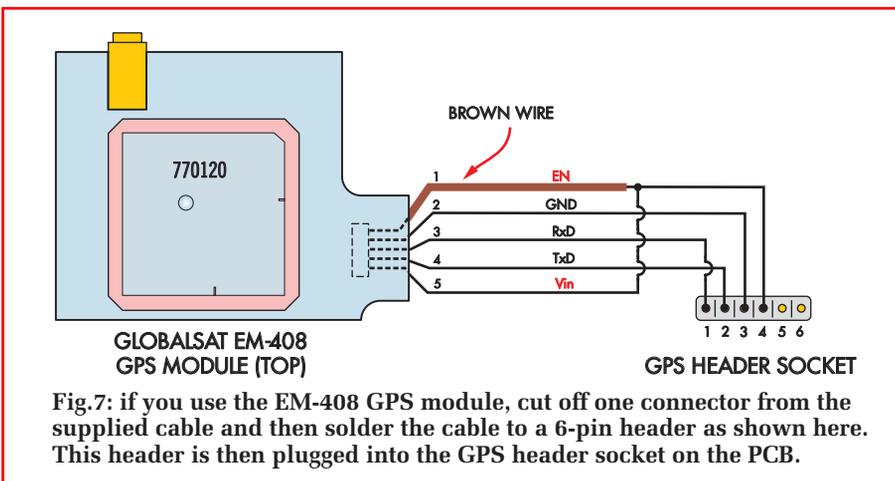
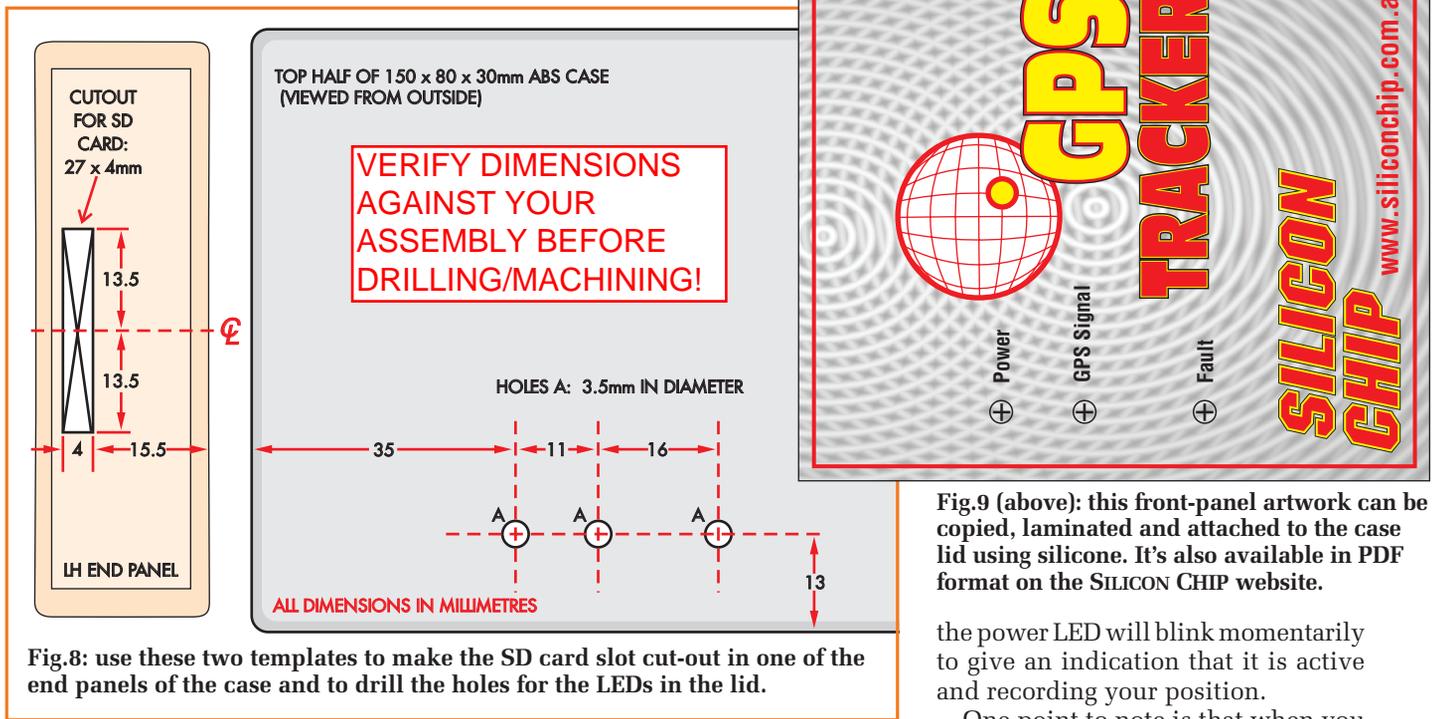


Fig.7: if you use the EM-408 GPS module, cut off one connector from the supplied cable and then solder the cable to a 6-pin header as shown here. This header is then plugged into the GPS header socket on the PCB.



card and checking the three indicator LEDs. The first of these is the power LED and it only comes on when the microcontroller has completed its self test routine, indicating that both the power supply and the microcontroller itself are OK.

The second is the GPS signal LED. This will be off if the GPS module could not be detected (ie, disconnected), flashing if the module is in communication but has not got a fix on sufficient satellites, and steadily illuminated if it has a fix and a valid latitude and longitude.

Note that you need to be a little patient when you first power it up, as it can take up to 15 minutes for the GPS module to get its first fix. So place the device somewhere where it has a clear view of the sky and give it some time.

The third LED (red) is used to signal a fault. As explained earlier, this LED will come on if a fault is detected, including a faulty or disconnected GPS module, a faulty or unprogrammed microcontroller or a problem with the SD card. Note that a loss of the GPS satellite signal is not counted as a fault because you may be travelling through a tunnel and the GPS Tracker will resume recording when you exit and the signal is restored.

If the red fault LED is illuminated, you can deduce the general location of the fault from the other LEDs. For example, if the fault LED is on and both

the green LEDs are on, this indicates that the microcontroller and GPS are OK and therefore something must be wrong with the SD card.

Typical problems with the SD card include not being inserted correctly, having the write protect switch in the on position and a corrupted and/or incorrect file system on the card. Any of these will light the fault LED.

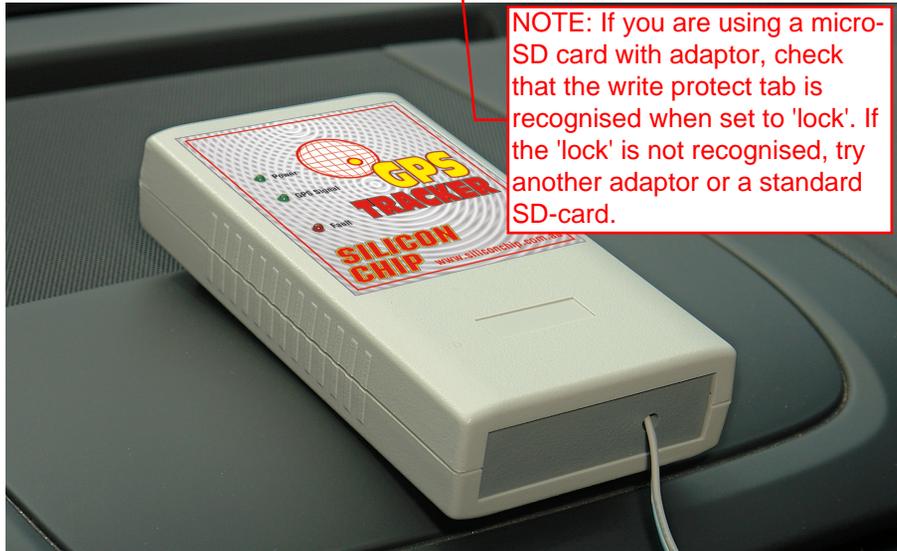
When the GPS Tracker is running normally, the fault LED will be off and the green power and GPS signal LEDs will be on. Whenever the tracker saves an item of information to the SD card,

the power LED will blink momentarily to give an indication that it is active and recording your position.

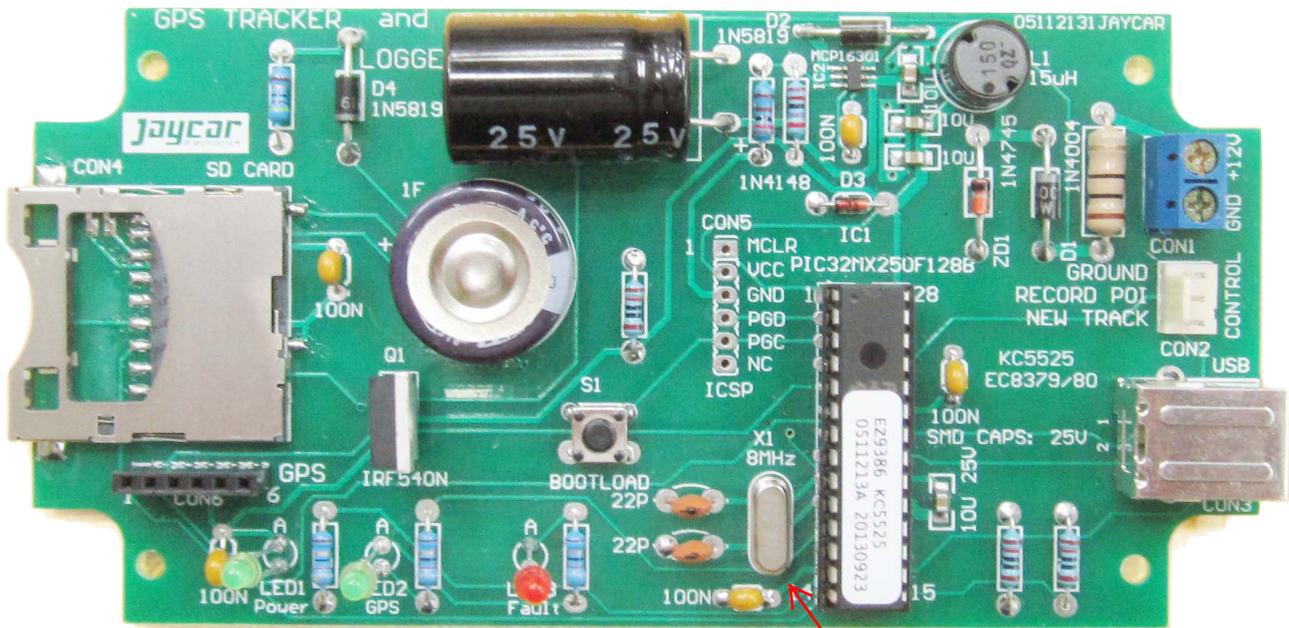
One point to note is that when you are testing the unit on the bench, you will find that it does not record any data. That's because it will only record trips that cover more than 100 metres. This feature was included to avoid recording trivial vehicle movements, like moving a car from the driveway to the garage.

**Installation**

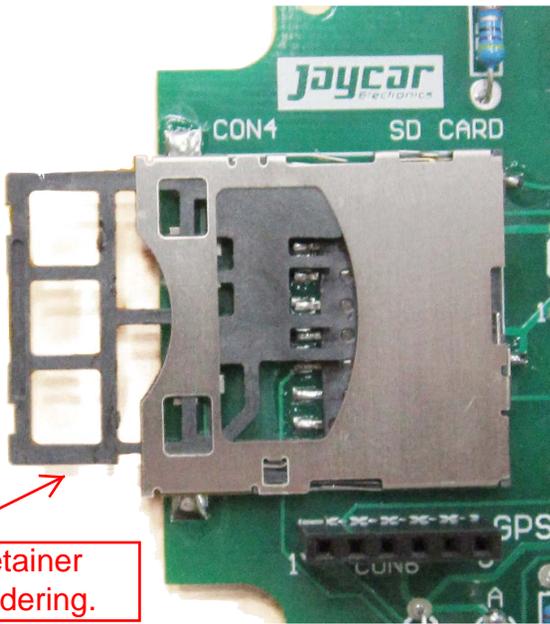
Installing the GPS Tracker can be as easy as securing it to the top of the dashboard using Velcro (or similar hook & loop material) and using a cable with a cigarette lighter plug for power. For a more permanent instal-



**The GPS Tracker sitting on the dashboard of a vehicle. It can be held in place using hook & loop material (eg, Velcro).**



Mount crystal raised to avoid short circuit.



remove retainer before soldering.

If the signal level is inadequate, you could remotely mount the GPS module in a location with a better signal and connect it to the PCB using a 6-core cable up to 2m long. Note that the aerial is on the top of the GPS module and this needs to be aimed straight up at the sky for best reception (ie, the module should be horizontal).

If you are using the EM-408, you can go further and purchase an external antenna with an MMCX connector and plug it into the module. These are available cheaply on eBay and other on-line sources and they will provide a strong signal, even in adverse situations. They are also waterproof and have a magnetic base, so the antenna can be mounted externally on the vehicle with a good view of the sky.

**If you are using the two optional inputs (POI and NEW TRACK), then you will have to add momentary pushbutton switches to short them to ground.** The maximum voltage on these inputs is 3.3V so don't connect them to the vehicle's 12V system (**note: if these switches are mounted remotely from the case, it may be necessary to connect them using shielded cable to prevent glitches.**)

Alternatively, the NEW TRACK input can be connected to the vehicle's ignition circuit in order to automatically create a new track each time the

lation, it could be placed on the rear parcel shelf, in the glove box or under the dashboard and permanently wired to the vehicle's ignition supply (ie, the 12V supply that's available when the engine is running).

In some locations, such as under the dashboard, it's possible that there will be insufficient signal for the module to acquire or maintain a reliable satellite fix. To assess this, you can carry out a simple test. First, place the GPS Tracker on top of your vehicle with a clear view of the sky (no trees, tall

buildings, etc) and leave it for half an hour or so to get a solid fix and charge the super-capacitor.

That done, remove the power, swiftly place it in its intended location and reconnect the power. If the signal level is excellent, the GPS module should regain a fix (indicated by a solid green GPS LED) within 10 seconds. If the signal is marginal, it might take up to a minute or more with the LED blinking before a fix is found. Anything between these two is an indication of the signal strength.

ignition is switched off (only necessary if the unit's power supply is not switched with the ignition). This involves connecting a diode between CON2 and the ignition line, with the diode's anode going to CON2. This pulls the NEW TRACK input low each time the ignition is switched off but prevents 12V from being applied to this input (which would damage it).

## Fault finding

If you have a problem with your GPS Tracker, the first thing to do is check the indicator LEDs. If no LEDs are illuminated it indicates a power supply problem and you should check the input supply for 12V and the regulator output for 3.3V.

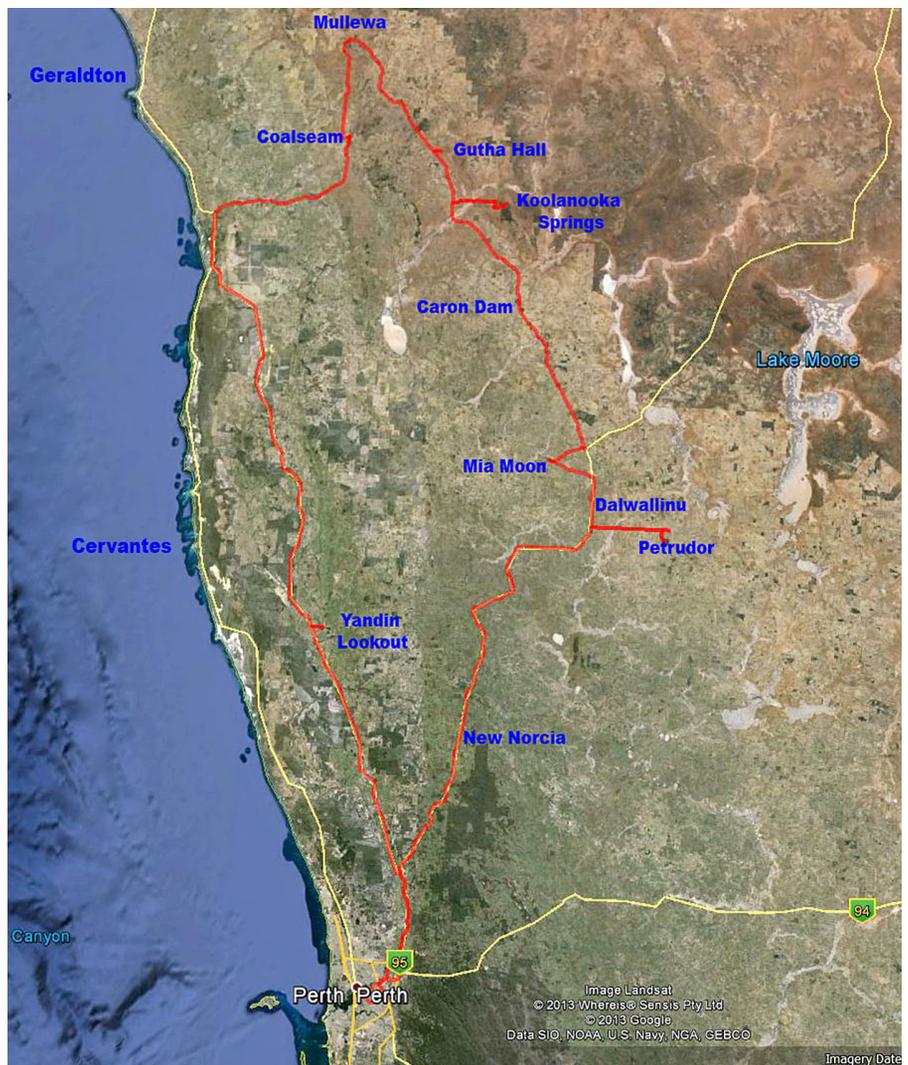
If the red fault LED is on but no other LEDs are illuminated, this indicates that the microcontroller has a problem. Most of the time, this will be because it has been inserted the wrong way around. If so, reverse it and pray that it survived. Another possibility is the 10 $\mu$ F capacitor connected to pin 20 of the microcontroller. It must be a low-ESR ceramic device; anything else could prevent the microcontroller from starting up.

If the GPS signal LED does not come on at all, it indicates that the GPS module is not communicating. This could be because it is not plugged in correctly, the super-capacitor is missing, it is configured for the wrong baud rate or it is faulty (unlikely).

If you suspect the module, use the USB connector to connect the GPS Tracker to a desktop computer. For Windows, you need to install the SILICON CHIP USB Serial Port Driver (available on the SILICON CHIP website) but this isn't necessary for Mac and Linux computers which have built-in drivers. The installation instructions are included with the driver.

Next, use a terminal emulator to open the virtual serial port over USB, as created by the GPS Tracker on your computer. When you do, you should see the NMEA data stream as it is produced by the GPS module. There are many free applications that you can download that can use this data to diagnose your module. If you are a 4WD off-road enthusiast you could connect the tracker to a laptop via USB and use an application like *ExploreOz* which will use the NMEA data stream to pinpoint your position on a map.

You can also use this facility to



This view shows a week long camping trip as recorded by the GPS Tracker. If you are on a long tour, you can use Google Earth to aggregate many individual tracks over many days to provide a "high-level" view of your progress across the surface of the earth.

send commands to the module but you should avoid changing its baud rate as that parameter will be stored in its internal memory and will be recalled on power up. That could make it impossible to communicate with your module, even after the power has been cycled.

If the NMEA data is missing and everything else is OK (including the supply rail to the module), then the module is probably faulty.

## Firmware updates

For firmware updates, you should check the author's website (<http://geoffg.net/tracker.html>). To load a new firmware image, hold down the BOOTLOAD button while applying power to the GPS Tracker. The power LED will then flash slowly, indicating that the unit is in bootloader mode.

Next, copy the new firmware file (it must be called TRACKER.HEX) to

the root directory of an SD card and insert it into the SD card socket. The power LED will then flash rapidly as the image is read from the card and programmed into the microcontroller's flash memory. The whole process only takes about 10 seconds and when it is finished, the GPS Tracker will automatically start running the new firmware.

If an error occurs, the power LED will resume its slow flash and the red fault LED will come on. Possible causes include: (1) a missing or incorrectly named hex file, (2) a hex file that is corrupted in some way and (3) a marginal or noisy power supply. After you have identified and corrected the issue, you can run through the bootload process again.

So, there you have it – a versatile gadget that can record a lifetime's worth of travelling. Where are you going to go with it? **SC**

## COMPONENT IDENTIFICATION

This section will help you to match some of the symbols used in schematics (electronic circuit diagrams) to the physical component used in the actual product. You will see the symbol on the left and the component on the right.

### RESISTORS

Symbol	Component
	<p>4 or 5 Band ¼ or ½ Watt</p>
	<p>1 Watt</p>
	<p>5W or 10W Ceramic</p>

### VARIABLE RESISTORS

Symbol	Component	Symbol	Component

### CAPACITORS

Symbol	Component
	<p>Non-Polarised</p> <p>Ceramic</p> <p>MKT</p> <p>Greencap</p> <p>Non-Polarised Electrolytic</p>
	<p>Polarised</p> <p>Electrolytic</p> <p>Tantalum</p>

### DIODE / ZENER DIODE

Symbol	Component

### BRIDGE RECTIFIER

Symbol	Component

## COMPONENT IDENTIFICATION

### LED's

Symbol	Component

### INTEGRATED CIRCUIT (IC)

Symbol (example)	Component

Pin 1 (to the left of cutout or mark on IC)

### TRANSISTORS

Symbol	Component
	<p>(FET)</p> <p>TO-3</p> <p>TO-5</p>
	<p>TO-92 Body has pin assignments depending on the sub type indicated in brackets.</p> <p>TO-92 (72)</p>
	<p>TO-18</p> <p>TO-220</p> <p>TO-220(A)</p>

## COMPONENT IDENTIFICATION


## COMPONENT IDENTIFICATION

### VOLTAGE REGULATORS

#### VOLTAGE REGULATORS

Component	Symbol
<p>Top view</p> <p>COMMON</p> <p>OUTPUT</p> <p>INPUT</p>	<p>POSITIVE REGULATOR</p> <p>TO-220 PACKAGE</p> <p>78XX, LM340, LM2940</p>
<p>Top view</p> <p>INPUT</p> <p>OUTPUT</p> <p>COMMON</p>	<p>NEGATIVE REGULATOR</p> <p>TO-220 PACKAGE</p> <p>79XX, LM320</p>
<p>Top view</p> <p>INPUT</p> <p>OUTPUT</p> <p>ADJUST</p>	<p>POSITIVE ADJUSTABLE REGULATOR</p> <p>TO-220 PACKAGE</p> <p>LM317, LM350</p>
<p>Top view</p> <p>INPUT</p> <p>OUTPUT</p> <p>ADJUST</p>	<p>NEGATIVE ADJUSTABLE REGULATOR</p> <p>TO-220 PACKAGE</p> <p>LM337</p>
<p>Bottom view</p> <p>COMMON</p> <p>INPUT</p> <p>OUTPUT</p>	<p>POSITIVE REGULATOR</p> <p>TO-3 PACKAGE</p> <p>78XX, LM340</p>
<p>Bottom view</p> <p>INPUT</p> <p>COMMON</p> <p>OUTPUT</p>	<p>NEGATIVE REGULATOR</p> <p>TO-3 PACKAGE</p> <p>79XX, LM320</p>
<p>Bottom view</p> <p>OUTPUT</p> <p>ADJUST</p> <p>INPUT</p>	<p>ADJUSTABLE REGULATOR</p> <p>TO-3 PACKAGE</p> <p>LM317, LM350</p>
<p>Bottom view</p> <p>OUTPUT (2)</p> <p>INPUT (1)</p> <p>COMMON (3)</p>	<p>POSITIVE REGULATOR</p> <p>TO-92 PACKAGE</p> <p>78LXX</p>
Bottom view	SOT-30

### OHM'S LAW

The most basic law in electronics. The relationship between resistance, voltage and current is determined by Ohm's Law (\*). If you know two out of the three values you can work out the third.

$$V = I \times R$$

$$I = V / R$$

$$R = V / I$$



The formulas are:

V is Voltage  
I is Current in Amps and  
R is resistance in Ohms

**Jaycar**  
Electronics

No 1 for Kits

kits@jaycar.com.au

COMPONENT REFERENCE CHART

Ver 1.2 - 24.03.2010

## RESISTOR COLOUR CODES

	3rd Digit	Multiplier	Tolerance
BLACK	0	0	
BROWN	1	1	1%
RED	2	2	2%
ORANGE	3	3	
YELLOW	4	4	
GREEN	5	5	
BLUE	6	6	
PURPLE	7	7	
GREY	8	8	
WHITE	9	9	
		GOLD	5%
		SILVER	10%

Examples:

(5 BAND)  
yellow-purple-black-brown-brown  
= 4 - 7 - 0 - 1 - 1% = 4K7 1%

(4 BAND)  
orange-purple-yellow-gold  
= 3 - 7 - 4 - 10% = 370K 10%

## CAPACITOR CODES

Microfarads (u)	Nanofarads (n)	Picofarads (p)	EIA code
-	-	100pF	101
-	0.22nF	220pF	221
0.001uF	1nF	1000pF	102
0.0047uF	4.7nF	4700pF	472
0.01uF	10nF	-	103
0.047uF	47nF	-	473
0.1uF	100nF	-	104
0.47uF	470nF	-	474
1uF	1000nF	-	105

## ZENER DIODES (1 WATT UNLESS SPECIFIED)

Part no.	Voltage	Part no.	Voltage
1N4728	3V3	1N4744	15V
1N4729	3V6	1N4745	16V
1N4730	3V9	1N4746	18V
1N4731	4V3	1N4747	20V
1N4732	4V7	1N4748	22V
1N4733	5V1	1N4749	24V
1N4734	5V6	1N4750	27V
1N4735	6V2	1N4751	30V
1N4736	6V8	1N4752	33V
1N4737	7V5	1N4753	36V
1N4738	8V2	1N4754	39V
1N4739	9V1	1N4761	75V
1N4740	10V	1N5349B	12V 5W
1N4741	11V	1N5352N	15V 5W
1N4742	12V	1N5374	75V 5W
1N4743	13V		