Data Logging Receiver Supply Voltage Monitor

Introduction

There seems recently to have been something of an explosion in receiver pack NiCAD checkers of various sorts, each with its own feature set. Many are based on the National Semiconductor LM3914 IC and can, therefore, indicate only the current battery voltage while others offer the same indication of current voltage with an additional feature or two. None of these offer any data logging capability and therefore none can offer the ability to log the actual battery voltage during a flight. This Project Article describes a small, lightweight diagnostic unit designed to do just that.

It is intended that the unit be either installed permanently in the model or only used when needed, perhaps in the event of unexplained erratic model behaviour. The unit monitors the battery voltage and determines the values for various voltage parameters and displays them on its 10-segment LED bar-graph display.

When power is applied the unit resets all its internal registers and takes an initial sample of the battery voltage. It then enters its normal operating mode sampling the battery voltage 100 times a second calculating, and recording, the four parameters listed in the box to the right.

It thus provides a more comprehensive range of monitoring facilities than any of the similar commercial devices known to the author and also has the advantage of being able to log, and display, some aspects of the history of the battery voltage rather than merely its current value.

Consisting of a single IC, an LED bar-graph display and a few other parts it is both easy to build and, requiring no calibration, easy to use.

Features

- Wide Supply Voltage Logging Range
- Averages over >1 Million Samples
- Small Size
- Low Power Consumption
- Simple to Build and Install
- Data Download to PC Capability

Recorded Parameters

- Maximum Value of battery voltage measured since power-up
- Minimum Value of battery voltage measured since power-up
- Mean Value of all battery voltage samples taken since power-up
- Current Value of battery voltage

The information contained in this Project Article is believed to be correct.
However no responsibility is assumed for its use.

Description

At the heart of the circuit is a small microprocessor from the popular PIC range; the PIC16C71. It samples the battery voltage, i.e. its own supply voltage, 100 times a second and recalculates and updates the values stored in the four Value Registers as required. Due to this relatively high sampling rate momentary dips in battery voltage caused by servo demands are sure to be detected. The unit will operate over the supply voltage range 3.5V to 6.0V and is suitable for 4 cell receiver packs whose working voltage will typically vary from 4.9V to 4.0V. The Value Registers store measured and calculated battery voltage values over the full supply voltage range to a resolution of approximately 20mV. However because the on-board bar-graph display has only 10 segments it is arranged to display a subset of the full range as detailed in Table 1.

LED	Battery Condition
1	Battery Voltage less than 4.1V
2	Battery Voltage greater than 4.1V and less than 4.2V
3	Battery Voltage greater than 4.2V and less than 4.3V
4	Battery Voltage greater than 4.3V and less than 4.4V
5	Battery Voltage greater than 4.4V and less than 4.5V
6	Battery Voltage greater than 4.5V and less than 4.6V
7	Battery Voltage greater than 4.6V and less than 4.7V
8	Battery Voltage greater than 4.7V and less than 4.8V
9	Battery Voltage greater than 4.8V and less than 4.9V
10	Battery Voltage greater than 4.9V

Table 1: Local Display Details

The highest and lowest values of the displayable range may appear to be a little low to some people. They have been deliberately selected to allow the presentation of precise information regarding the battery state when it is partially discharged as it is felt that detailed information concerning battery voltage, when above 5 volts, is of less value.

The unit is therefore capable of displaying over the most useful range of voltage for a 4 cell NiCAD pack with the 4 parameters being simultaneously displayed as illuminated segments.

On initial power-up, after the initial sample has been taken, all 4 Value Registers contain the same value and this shows, apparently, as a single lit segment. In fact, in order to minimise the current drain, the 4 values are displayed, one at a time, in a timed sequence but, because they all illuminate the same LED, it appears with greater than normal brightness. As the battery pack discharges its terminal voltage falls and when it has fallen to a value that can no longer be represented by the illuminated LED the next LED down will light. Two LEDs will then appear illuminated; the initial one will show the maximum value ever recorded and the new one will show the minimum value ever recorded. One of these LEDs will appear to 'flash' slightly and this is because, in order to distinguish it from the others, the Current Value LED flashes. When the battery voltage has fallen considerably, either due to time or heavy current demands from the servos, a typical unit would have 4 distinct LEDs lit with one flashing. The end two LEDs will display the maximum and minimum voltages detected and the flashing one the current measured battery voltage. The fourth LED displays the calculated mean value of all the samples taken so far and can be used, with the other LEDs, to detect certain types of battery condition (see **The Unit in Use** below).

Theory of Operation

Applying the power resets all the Value Registers to zero and causes the unit to take an initial sample of the battery voltage, the value of which it stores in all 4 of the Value Registers and thus this initial value is used as the starting point. An internal timer is then started which expires every 10ms and each of these time-outs is the trigger for another sample to be taken. The measured battery voltage value is then compared with the current values stored in the Maximum Voltage and the Minimum Voltage registers and if larger than the current Maximum Value, or smaller than the current Minimum Value, the relevant Value Register is updated. The newly taken sample value is simply loaded directly into the Current Value register.

Additionally the mean, or average, value is calculated for all sample values taken so far and this calculated value is loaded into the Mean Value register. There is a time limit to this calculation process as the Mean Value is calculated as the 'sum-of-all-samples-taken' divided by the 'total-number-of-samples-taken'. As mentioned above the unit takes 100 samples per second so these two numbers become quite large very quickly. The software is capable of performing this calculation when working with up to 1 million samples. After the 1 million sample limit, which is reached in just under 3 hours, the unit stops taking additional samples. It continues to display the values that were present at the time the 1 million limit was reached and, in order to indicate that the limit has been reached, the software flashes all 4 of the LEDs.

An unusual feature of this unit is the method used to assess the battery voltage in as much as, compared with more normal techniques, it operates 'in reverse'. Any analogue to digital conversion, such as that performed by this unit, relies on comparing an unknown quantity, in this case voltage, with another known voltage referred to as the reference voltage. The normal method used in the PIC16C71 is to use the supply voltage as the reference voltage and feed the unknown voltage into one of the ADC input pins. This technique wouldn't work in this application because it is what would normally be considered the reference voltage that we are interested in measuring. The unit reverses this and feeds a known stable voltage of 2.50V, provided by U2, into the ADC input pin. As the supply voltage changes, and thus the 'reference voltage' changes, the digital code produced changes... the only difference being that if the supply voltage decreases the digital code takes on a larger value rather than the normal smaller value.

The Unit in Use

After a period of use the unit will normally display 4 distinct LED segments as mentioned above. Some typical displays and examples of their interpretation are shown below.

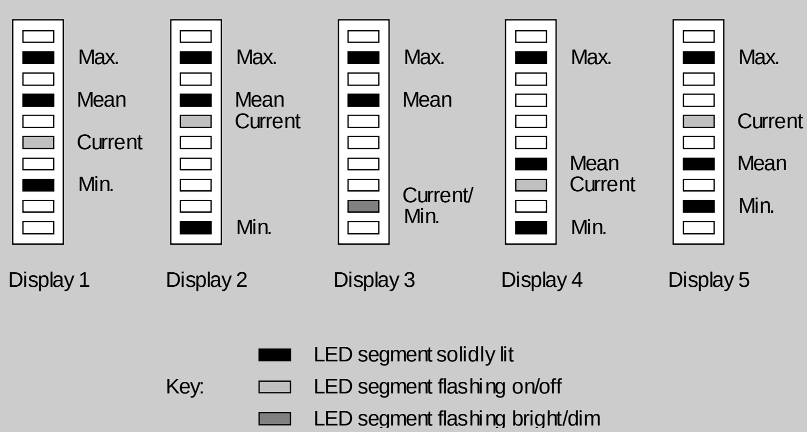
Display 1: This is an example of a normal display. The battery voltage has fallen to its CURRENT value and has dipped on occasions to the MIN value. The MEAN value is midway between the CURRENT and MAX values indicating that the battery voltage has been falling steadily. If the MEAN value was higher than midway it would indicate that the battery voltage has recently started to fall more rapidly suggesting that the pack is beginning to run flat.

Display 2: In this display the MIN value is considerably lower than the others. This indicates that the battery pack has either a poor connection or a slightly higher than normal internal impedance causing an excessive voltage drop under load. An alternative possibility is that very heavy current demands are made by one or more servos.

Display 3: This display indicates that the battery pack is nearly flat. The CURRENT and MIN values are the same, causing the LED segment to flash bright and dim, and considerably lower than the others. Note that any display with these two values the same, or close together, but separated from the others indicates the battery pack is running low.

Display 4: This display can suggest a very heavy use of the servos, as perhaps in aerobatic flight. It can, however, also indicate that the battery pack has a significantly higher than normal internal impedance. This latter condition may be checked for by switching the system on and watching the LED display for a period of time while NOT operating any servos. If the CURRENT value falls rather quickly this indicates a high internal battery impedance.

Display 5: This is an unusual one because the CURRENT value is higher than the MEAN value. It indicates a prolonged period of heavy servo usage, causing the battery voltage to drop, followed by a period of low servo activity that has allowed the battery pack to recover somewhat.



Assembly

Assembling the parts onto the PCB is straightforward. However some of the components must be inserted in the correct orientation and the notes below should help:-

U3 This component is a CMOS device and should be treated accordingly. It will have a semi-circular 'notch' in the end that marks pin 1. The IC should be inserted such that pin 1 connects with the square pad.

U1 With the PCB orientated such that U3 is toward the top-right and the resistor networks are along the bottom this component should be fitted such that the corner with the slight chamfer on it, denoting pin 1, connects to the square pad.

U2 U2 should be fitted with its 'D' shaped body orientated as shown on the component placement drawing.

RNx The two resistor networks also require to be fitted with the correct orientation. They will both have a 'dot' marked on their bodies denoting pin 1. Fit each one such that pin 1 connects with the square pad.

X1 This 3 leaded device is not orientation sensitive and may be fitted either way round.

J1 This 'connector' is not fitted. If the unit is to be connected permanently into the models wiring any suitable hook-up wire may be used to make the connections between J1 and the model or, alternatively, a suitable servo lead may be used with the free ends stripped and tinned prior to soldering through the PCB. Note that only the +5V and 0V connections are made...the third lead should be cut short and dressed to ensure that it does not come into contact with any other components. This lead is referred to as the 'Input Lead'.

J2 This 'connector' is also not fitted but wired as for J1 above if required...see the section headed **Download Capability** below.

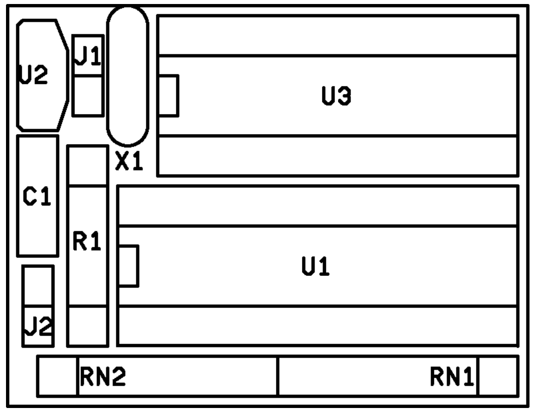


Fig. 1: Component Placement Drawing

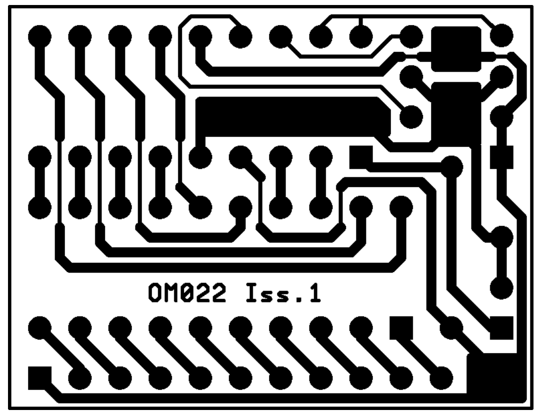


Fig. 2: PCB Copper Trace Detail (Underside View)

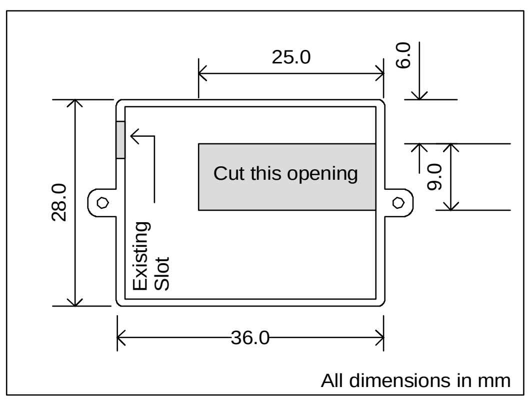
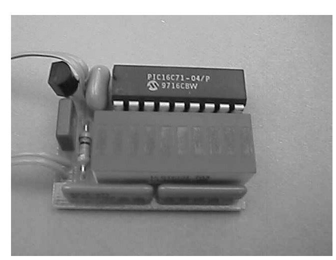
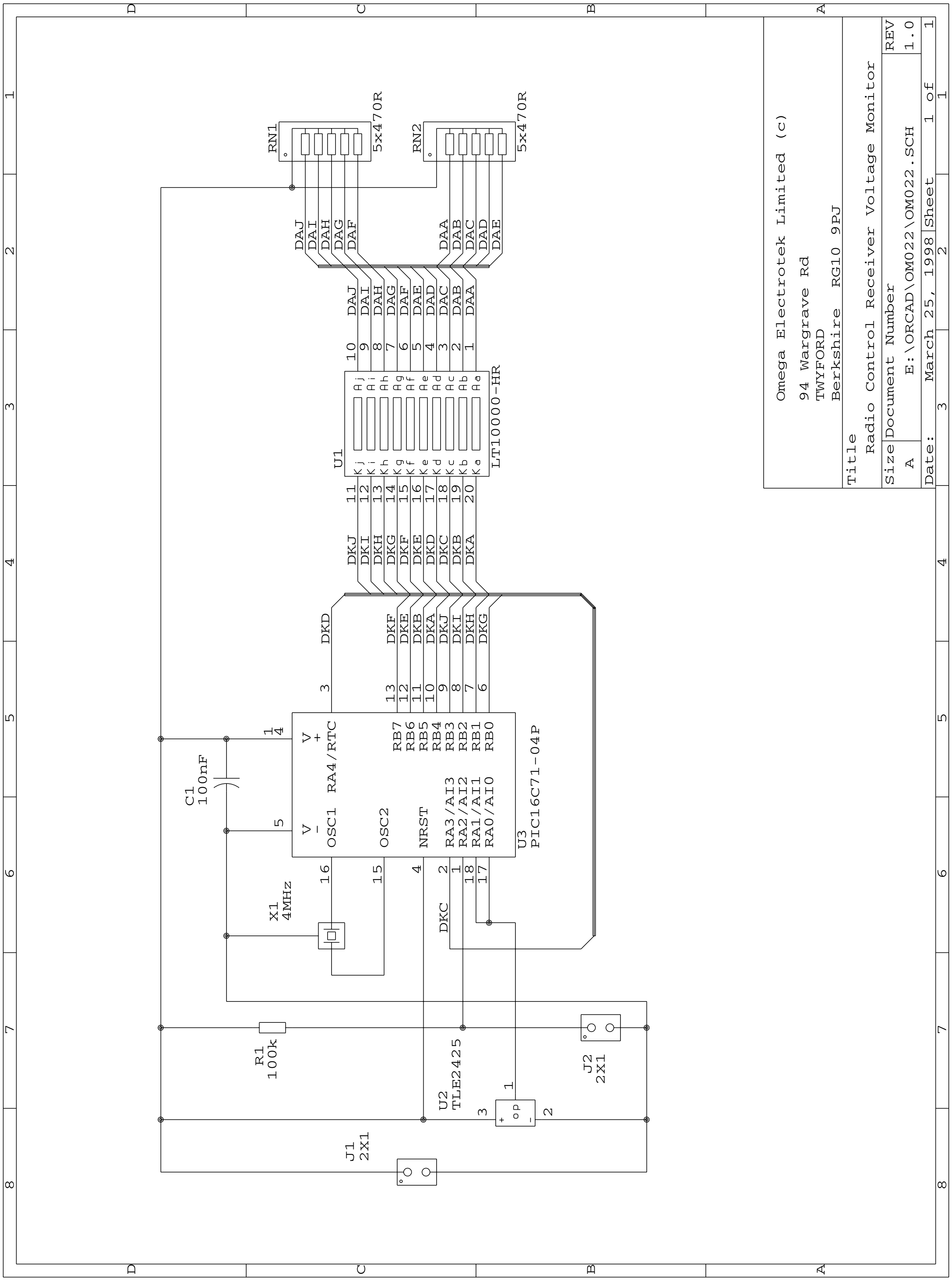


Fig. 3: JX56L Rework Drawing (Underside View)

Fig. 4: Assembled PCB

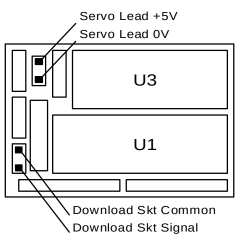


Schematic Diagram



Initial Checking and Power-up

Having carefully checked that all the components are correctly located, orientated and soldered, and in particular the flying leads, the assembled unit may be tested.
The diagram below shows the two 'connectors' and their pin functions.



Viewed from Component Side

NOTE: There is no reversed polarity protection provided and connecting the unit with the wrong polarity will probably destroy it.

The testing procedure is very simple, as no manual calibration is required. The following procedure will check that the unit is functioning correctly:-

1. Connect the unit to a receiver using the input lead and power up the receiver.
2. Check that only one, or perhaps two, LED segments are initially illuminated.
3. Operate one of the transmitter sticks and observe that the MIN value may become distinct indicating that the battery voltage has dipped due to the extra load of the servo operating. If a single stick movement fails to illuminate a distinct MIN LED try operating two sticks simultaneously.
4. Over a period of about 15-20 minutes occasionally perform multi-stick movements and verify that the display tends towards that shown in Display 1 above.
5. Should the displayed LED segments more closely resemble any of the other examples shown it may suggest some remedial action is required.

This completes the testing procedure and, in order to secure the Input Lead connections, a blob of Araldite may be applied around the wires on the component side of the PCB to increase the mechanical strength.

Wiring into the Model

The finished unit may either be wired permanently into the model or only installed when required. If being permanently installed it may be connected into the models wiring using lengths of suitable hook-up wire, ensuring that the connection to the circuit is made after the receiver on/off switch. Alternatively it may be simply connected to a spare servo channel.
For temporary use the unit should be installed in the model and connected to a spare servo channel.

Download Capability

This project, along with other projects available from the Model Electronics Company, is part of a series having a 'data download' capability built into their software. As described above the Data Logging Receiver Supply Voltage Monitor software maintains four Value Registers whose stored values are displayed locally, over a limited range, using the on-board 10-segment LED bar-graph display. The full range of recorded values may be extracted from the unit using a simple cable connected to J2.
To make use of this download facility it is intended that J2 be connected to a small jack socket, or similar, mounted in a convenient location on the model.

Another project is available that allows the values to be downloaded to an IBM, or compatible, PC using a simple interface that plugs into the parallel port. The PC, fitted with the interface and running the custom software, may be used to download and display the contents of the four Value Registers along with a fifth value containing the number of battery voltage samples taken so far. Using the software the information may then be stored in a disk file and, optionally, printed.

Downloading the stored data does not change the values stored in the Value Registers or upset the logging process, which continues as normal after the download is complete. In this way multiple downloads are possible if it is required to perform a frequent check on battery condition using this method.

Components

Complete kits of the components required to build this project are available from the Model Electronics Company. Alternatively just the PCB and pre-programmed microprocessor may be purchased and the remaining parts obtained from other sources using the Parts List table as a guide.

For those people not wishing to undertake the assembly of the PCB this is available pre-assembled and tested. Please see the price list for details.

Item	Manufacturer	Specification or Part Number
C1	N/A	100nF 63V 10%
R1	N/A	100k 0.25W 5%
RN1	Bourns	470R 0.2W 5%
RN2	Bourns	470R 0.2W 5%
U1	LED Technology	G10000RRR
U2	Texas Instruments	TLE2425CLP
U3	Pre-Programmed	PIC16C71-04P
X1	Murata	CST4.00MGW

Table 2: Parts List

Note that where manufacturers part numbers are given their continued accuracy cannot be guaranteed.

Notes

This Project Article is issued by :-

The Model Electronics Company
94 Wargrave Road
TWYFORD
Berkshire RG10 9PJ

For information on placing an order for this project please see our price list which gives details of prices and payment methods. The price list may be obtained from the address above or from our web-site.

http://www.omegaco.demon.co.uk/mechome.htm

© The Model Electronics Company