Briefing Note 0001 – Batteries and Charging

Issue 1: 18th September 2016

Contents

Introduction

After the delivery of the Nicola 3 radios to the British Cave Rescue teams, there have been issues with the batteries summarised as:

- Several of the radios were delivered with the batteries discharged
- This was traced to an issue with the ‘turn on’ implementation
- There was a further problem with the ‘turn on’ supervisory circuit discharging at a greater rate than anticipated

Turn On Implementation Issue

The Nicola 3 radio is designed to cut off when the battery level (of both batteries) drop to about 6 volts. This is to protect the Li-ion batteries, which are susceptible to failure if individual cells drop below ~3 volts. This works correctly when in operational mode i.e. when being used the radio will switch off when the battery level drops.

The Nicola 3 radio can use the Left keypad button to latch on the power in addition to the physical plug that can be used to power up.
It turns out that this keypad turn-on circuit is located to the 'wrong side' of the battery monitoring and thus the batteries continue to discharge when they drop below 6 volts total.

Turn On Circuit Discharge Rate

This problem was exacerbated by the discharge rate of the supervisory circuit.
In this standby state, it was expected there would be a leakage of about ½ milliamp, giving a shelf life with the 2400 milliamp hours batteries supplied of about 6 months. It turns out that the standby current of the sets is about 1 milliamp, rather than the expected ½ milliamp, thus discharging at twice the expected rate. *(Sorry about the technical description here.)*
This gives a shelf lifetime of about 3 months compared to the 6 months originally expected.
This problem can be overcome by changing the solid state switch to one discharging at 0.05 milliamp.

Discharged Batteries

The consequence of the above items mean that the batteries in the delivered radios were discharging at a greater rate than expected. This together with the delivery of the radios later than planned with the battery in an unknown state led to a number of the batteries dropping below the critical voltage and indeed some dropping to below a level where damage can occur to said batteries.
When the sets were delivered from the supplier it would seem that the lithium cells did not hold a full charge and some had rather less than a half charge, so that the shelf life was weeks rather than months.

Mitigation

Since the discovery of the problem, a number of notes have been circulated to mitigate the problem; these are summarised here.

Maintaining the Batteries

Charging the Batteries

It is important that teams should have means of charging the N3Z radios.

As mentioned above, the expected shelf life of the radios is some 3 months rather than the 6 months designed. Thus it is recommended the radios should be charged every 3 months; indeed every month might be a good policy to follow.

Teams not having a battery charger

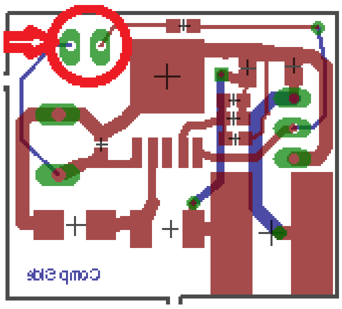
If teams do not have access to a charger, then either:

i) The batteries should be isolated from the set to prevent slow discharge. The lid of the box can easily be removed by unscrewing the 4 screws in the corners of the device. The batteries can then be isolated by taking a 50mm length of sellotape (2") and folding in two to stick the sticky sides together and then sliding down the + end of each battery by pressing the metal clip away from the battery slightly with a finger. The + side of each battery is at the end nearest the banana antenna sockets – care must be taken not to use a metal object to perform this operation to avoid the possibility of a short circuit.

ii) The sets should be kept on trickle charge using the PCB provided with XT60 and 3 way connector to the N3Z. A lead will need to be made up with an XT60 connector. These are readily available e.g. at https://www.amazon.co.uk/dp/B00V3F7PQ8?psc=1 . The bare ends should be connected to a 12V supply (or anything between 10 and 30V) respecting the polarity, i.e. red = Positive, black = negative. It should be noted that this PCB is a regulator producing 7.8V to maintain the state of the charge of the batteries and is NOT a battery charger in itself. The trickle charge at 7.8V will not unduly stress the batteries and will provide the current required by the standby current of the set.

Recovering the Batteries

If the batteries do fall in voltage close to zero, most Lithium batteries will refuse to charge the cells and the batteries may be irreversibly damaged. It may however be possible to recover cells in some cases by passing a current (~0.5A) for about a minute to bring the cell voltages up to about 3V at which point a conventional charger will continue to charge the batteries. The battery maintenance PCB may be used for this purpose, however it is inhibited if the centre pin is below 2-3V (ie if the lower battery is significantly discharged). The circuit can be forced on by shorting the pins on the PCB as indicated below:



A pushbutton switch could be attached allowing the supply to be ‘forced’ for about a minute to attempt to bring the cells up to about 3V each so that the circuit will then become enabled. If the cells do not come up after 2 minutes of ‘forcing’, it should be assumed that the cells are irrecoverable and should be replaced.

Continuous charging of batteries

There should not be an issue keeping each N3Z unit attached to the small voltage regulator PCB continuously as it would provide 3.9V per cell and the current will drop to zero in the cell and the supply will provide only the drain current allowing the cell voltage to be maintained. At 3.9V, the cell should not be unduly stressed. I can however understand people’s nervousness in doing this given the recent Samsung incident (and others).

Replacing the Batteries

Cheap 18650 cells (~£2 each) are available on eBay, however the capacity is likely to be no better than 2000mAH (distrust anything that claims more than 3000mAH!).
Better batteries will be closer to £7 each.

Protected Cells

Graham has ordered some 'Protected cells' with a view to testing them for suitability. Although these may allay some people's fears, they would not alleviate the need to keep the units 'topped up'. Protected cells also tend to be about 3-4mm longer than standard cells and so are not currently held properly in the current design. Graham has some protected cells with the same dimensions, but is still in the process of testing them.

Operation with External Batteries

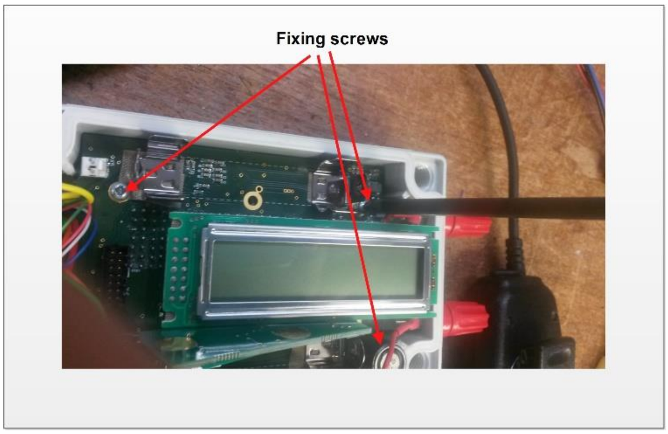
Some teams have asked whether it is possible to remove the internal batteries and use an external battery pack. Originally Graham had suggested that this would not be a good idea as the external regulator PCB would not be good at providing the rather large surge currents during the transmission of very 'peaky' voice. The current from an external source is also limited to about an amp by internal thermal fuses (which were intended to protect the internal batteries from potential short-circuits). Having thought about this some more, it may be possible, provided that the external source provided the correct voltage and current characteristics so that the external regulator was not needed and the internal fuse was shorted out to allow the surge currents to pass. Provided the leads were not too long and of sufficient gauge, this may work.
Tests of this option have been performed successfully (11th September 2016). The idea would then be to use an external pack with 2 X 18650 lithium batteries in series, or a commercial pack such as http://www.ebay.co.uk/itm/Floureon-Rechargeable-Lithium-Ploymer-2S-7-4V-5000mAh-20C-Lipo-battery-Pack/272042069483?_trksid=p2045573.c100507.m3226&_trkparms=aid%3D555017%26algo%3DPL.CASSINI%26ao%3D1%26asc%3D20151016114640%26meid%3D4a13f693fd38403f8618cc26fdce5685%26pid%3D100507%26rk%3D1%26rkt%3D1%26

The latter would require a modification of the provided charger lead to change the XT60 connector from female to male to allow the battery to be connected directly. This battery could also be charged directly from the iMax B6 charger.

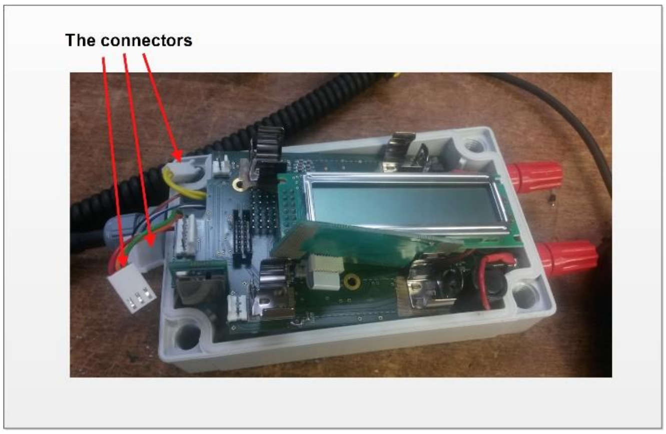
Modification Procedure

The following procedure will short out the thermal fuse and allow the use of the correct external battery packs – but with the internal batteries still fitted.

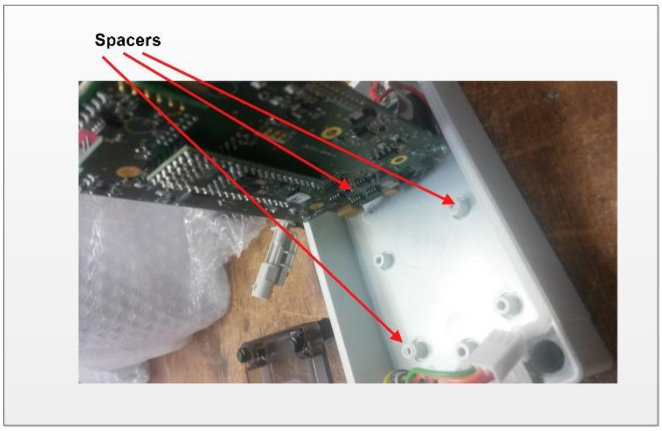
1. Remove the plastic lid; carefully release the 4 nylon screws and remove the lid.
2. Remove the internal batteries.
3. Remove the 3 screws holding the circuit boards to the box.



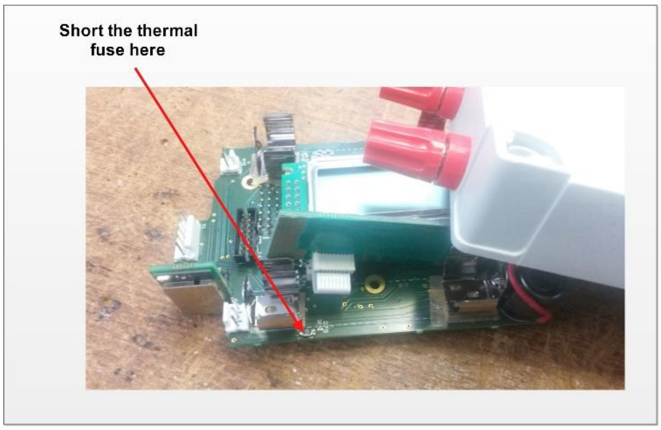
4. Remove the 3 microphone/power connectors.
5. Carefully ease the circuit boards out of the box.



6. Make sure the spaces under the three screws are not lost (noting one is hidden under the circuit board in the photo).



7. Locate the thermal fuse; solder a short circuit across this component.



8. Re-build the radio by reversing the above procedure:

- Replace the circuit boards in the box making sure the nylon spaces are correctly fitted
- Re-fit the screws holding the circuit board
- Re-fit the microphone and power connectors
- Optionally replace the internal batteries
- Replace the lid

The finished product

Operating with Batteries removed

To operate with the batteries removed, an alternative procedure must be followed to add a larger fuse, thus allowing a greater peak current when transmitting.

Refer to the video prepared by Graham at https://youtu.be/mnt_Rwv0RCM. This is some 10 minutes long and requires good soldering skills to implement.

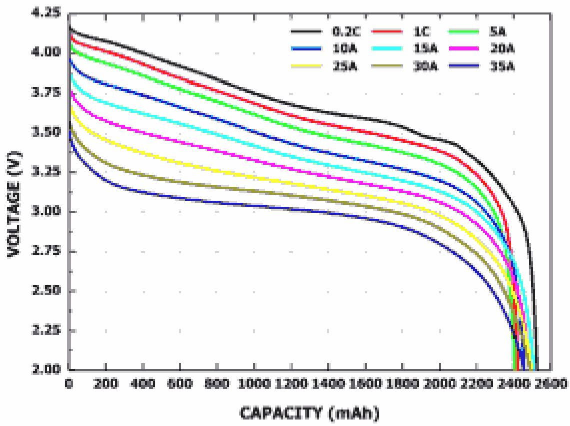
The video identifies the part as 2383297 LittelFuse 1206L200PR from Farnell – see http://uk.farnell.com/littelfuse/1206l200pr/resettable-fuse-6vdc-100a-1206/dp/2383297 .

Technical Note

It is important that the Lithium cells do not discharge below 3V per cell – ie 6V total. At this voltage there is only a very small amount of charge left and the voltage will fall rapidly even with a small drain current (see below for typical discharge characteristics).

- **Test Conditions**
  - Charge (CC/CV) : 0.5C charge to 4.2V, 100mA cut-off
  - Discharge (CC) : 2.0V cut-off

LG 18650HE2



Discharge Current	Capacity (mAh)	% of 1C Capacity
0.2C	2526	-
2.5A	2423	100.0
5A	2406	99.3
10A	2456	101.4
15A	2510	103.6
20A	2494	102.9
25A	2496	103.0
30A	2493	102.9
35A	2455	101.3

The units contain a safety circuit that will turn the set off to protect the cells from the high drain current during operation. At this point an external battery should be connected (using the provided PCB) to maintain operation, or following an operation the sets should be returned to the depot and attached to a commercial charger or the charge maintenance board as indicated in ii) above (though note that this should only be used to maintain the voltage not as a charging device). Unfortunately the safety shut off does not stop the standby current and so the sets will continue to drain slowly and so it is important that the sets are not left in this state for more than a day (and preferably within a few hours). This wasn't originally appreciated hence the need now to take action.

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