REAL WORLD INTERFACES

Memory Backup for the Devil Fish modified TB-303

Robin Whittle 10 February 2019 www.firstpr.com.au/rwi/dfish/

From 2018, with versions 5.0 onwards, TB-303 Devil Fishes have their memory backed up by a user-replaceable 2032 non-rechargeable, long-life, lithium coin cell – Option C as described below. Prior to 2015, we used Option A – a high capacity, very long life, non-rechargeable cylindrical lithium battery. In 2015, Australia Post regulations regarding lithium batteries in airfreight required us to use Option B, which involves shipping the machine without a lithium battery, and the user then installing a 2032 cell, to make it Option C. In 2018 Australia Post regulations do allow us to ship machines with a lithium battery installed.

Contents

0 - What this manual does not apply to

In Devil Fish TB-303s with a **Quicksilver 303** system, the memory which stores patterns, tracks etc. is FLASH memory within the Quicksilver microcontroller chip. The TB-303's static RAM memory chips are removed as part of the Quicksilver installation. FLASH memory does not require batteries for data retention. It is a form of electrically erasable programmable memory, in which electrons are removed from and returned to small islands of silicon, which are surrounded by silicon dioxide (quartz) insulation. **TT-303 Bass Bots** also use FLASH memory, and so require no batteries for data retention. This will remain the case for Devil Fish modified Bass Bots in the future.

For TB-303s and TR-303s with the **Sonic Potions** CPU replacement system, the situation is the same: the machine's memory is part of this system as FLASH memory, so no battery is required

In all three of these types of machine, the four C-cells which can be installed in the battery compartment are purely to run the machine, and are not required to retain memory contents.

The first 18 Devil Fishes, serial number -001 to 016 (Version 1 Devil Fishes, 1993 to 1994) had no lithium battery. None of these machines had the 32 Bank Memory system. They used the standard TB-303 memory backup arrangement (as described in Section 2 below) which depends on the four C-cell batteries.

1 - This Devil Fish has one of three approaches to battery backup

In the printed version of this manual, one of the boxes below is marked with an **X** to indicate whether Option A, B or C is used in this Devil Fish.

Option	Memory backup system Care and maintenance
[ ] *A* **Page 5.**	**Permanently installed cylindrical lithium metal non-rechargeable battery (0.30 grams of lithium).** **Have a technician check the voltage after 10 years, and then every 5 or so years after that. The battery will probably last for decades.**
[ ] *B* **Page 7.**	**C-cell batteries with under-voltage protection, large capacitor and 2032 lithium metal non-rechargeable battery (coin / button cell with 0.07 grams of lithium) holder *without* a 2032 battery. By removing the back panel of the Devil Fish, such a battery can be installed by the user.** **Keep four C-cell alkaline batteries in the machine at all times, unless you install the lithium battery, which involves taking the back off the machine.** **The alkaline C-cell batteries will last for years, except to the extent that you drain them by running the machine without a power adaptor. It is best to install fresh C-cell batteries every 3 to 5 years.** **If you have installed a lithium battery, have a technician check the battery voltage after 10 years, and every 5 years after that. Since the coin-cells are inexpensive, it is probably best to install a fresh one every 10 years or so.**
[ ] *C* **Page 14.**	**As above, but with a 2032 battery already installed. All new TB-303 Devil Fishes from 2018 onwards have this option.** **Have a technician check the battery voltage after 10 years, and every 5 years after that. Since the 2032 coin-cells are inexpensive, it is probably best to install a fresh one every 10 years or so.**

Determining whether a machine has Option A, B or C

If you have a machine without its original documentation, you can determine which memory backup option it uses by reading the section above *0 - What this manual does not apply to*, and if it is a machine which has one of these options, looking for the VRAM wire which is pictured next to the positive end of the battery compartment, in the section below: *Testing the VRAM voltage*. (This applies to conventional Devil Fishes with the original ABS plastic case. In an AluCase Devil Fish, the VRAM test-point is labelled as such on the main TB-303 board, and is only visible if the bottom of the AluCase is removed.)

If the machine lacks this wire, its memory backup arrangement is Option A. If there is such a wire, then the arrangement is either Option B or C. One of the few machines we shipped with Option B may have since had a lithium coin-cell added, which means it is now Option C. Alternatively, an Option C machine may have had its coin-cell removed, or this coin-cell may have insufficient charge to power the memory, in which case it is effectively has Option B. To distinguish between Option B and C, remove the back of the machine as noted in the section below *Testing the voltage of the 2032 coin-cell battery* to see if there is such a battery, and to measure its voltage if there is one.

Machines modified during and after February 2015, starting with serial number 289, generally have Option B if they were for an overseas customer and Option C if they were for an Australian customer. However, machines which were modified earlier than this may have been returned here for further work, and we may have changed them from Option A to Option B or C then.

2 - The TB-303's original Memory Backup System

The TB-303 Bassline contains a 42 pin single-chip microcontroller, which is generally referred to as the "CPU" (Central Processing Unit). This single chip device contains a 4 bit CPU, input-output sections, a limited amount of read-write memory (Random Access Memory = RAM), and a permanently programmed Read Only Memory (ROM). The ROM section of the chip is manufactured with a pattern of ones and zeroes which form the computer program which causes this chip to perform its sequencer functions.

The microcontroller chip connects to three battery backed up low-power static RAM chips, each of which has 1024 locations of 4 data bits. These chips total 1.5k bytes of memory, and are used to store the patterns, pre-scale values, pattern lengths and the track data. Low power static RAM chips retain their data as long as power is applied to them, since each memory cell is a simple flip-flop of six transistors. A flip-flop can be set into either the flipped state (low on the left, on high the right) or the flopped state (high on the left and low on the right) and will remain in this state as long as power is applied. That state can be read, or later changed. (Dynamic RAM chips, as used for the main memory in PCs, are cheaper per bit, but require constant external refresh drive activity to retain their data, which is stored in capacitors.)

The six transistor memory cells used in the TB-303's original memory chips cause these chips to consume a very small current indeed when they are not being read or written to. This is the backup current. The total current drawn by all three chips is typically less than 1/100th of a microamp - less than 1/100,000,000 amp.

With the 32 Bank Memory System, which some Devil Fishes have, we replace these chips with three larger ones, which also use these six transistor cells. With these three larger chips, the backup current is typically 0.02 microamps at cool room temperature, such as 18°C, rising to something like 0.5 microamps at 50°C. Both the old and new chips normally operate from 5 volts, and will retain their data as long as their supply voltage is above about 2.5 volts. In a standard TB-303, the VRAM supply voltage for the memory chips is supplied via two pathways, both involving a silicon diode (a one-way valve for electrons). In practice, one or the other pathway will be active, since the pathway with the highest supply voltage will raise VRAM to that voltage minus the 0.5 to 0.6 volt drop of the diode:

1 - IF power is supplied via an external 9 volt adaptor (which is regulated inside the TB-303 to +6 volts) AND the power switch is turned on, then this will supply VRAM via a diode, resulting in about 5.4 volts, which is fine for read-write operations and data retention between these operations.

If there was no external power supply and the machine was running from batteries, then there is no 6 volt regulator, and VRAM is driven via a diode voltage drop from the C-cell battery voltage, which may be as high as 6.4 volts or so.

2 - IF four C-cell batteries are installed AND either there is no external power supply OR the power switch is off, then the voltage from the batteries (nominally 6 volts, but it can be higher with fresh alkaline batteries) drives VRAM via a diode - so the memory chips get about 0.5 volts less than the battery voltage. (0.5 volts due to the very low current required to drive VRAM when there are no read or write operations.)

With fresh alkaline batteries, each of which have significantly higher than 1.5 volts, both these pathways may drive the VRAM supply above 5.5 volts, which is the maximum operating voltage of the original RAM chips. However, they seem to work fine.

The VRAM voltage is sustained, for a short time, such as a day or so, by a **100uF** (millionths of a Farad) **capacitor**. (A capacitor is like a storage tank for electricity. It is somewhat like a battery, but it has no particular voltage, such as 1.2 volts for a nickel-metal-hydride battery. The voltage rises and falls in direct proportion to the charge which is stored.) Since the current consumption of the three standard memory chips (when there are no read or write operations) is so low, this capacitor would slowly discharge over a period of a day or two (or maybe more in cool conditions) and so keep the memory chips supplied with a high enough voltage (probably 2 volts or more is sufficient, in practice) to keep their data intact.

In practice, depending on the self-leakage of the capacitor and the temperature and characteristics of the original memory chips, this capacitor would retain memory contents, in the absence of C-cell batteries or the machine being turned on, for a few days, and perhaps a week or more. The sole purpose of this capacitor is to retain data while the user removed one set of C-cell batteries and installed a fresh set, without running the machine from an external power supply.

As the capacitor discharged further, the voltage would be too low for the flip-flops to retain their states. So when proper operational power is applied (5 volts or so, when fresh batteries are installed, or the machine is turned on with an external power supply) they assume states which are unrelated to the states they were in as a result of the last write operation. That state depends on the exact physics of each of the cell's transistors, and some cells will tend to flip (binary 0) while others will tend to the flop (binary 1). We think of these states the flip-flops wake up in, when a proper voltage is applied to them, as "random" since we can't control them.

Different brands of memory chip (NEC, Mitsubishi and Toshiba) have different kinds of patterns of flip-flop states, and so no-doubt give rise to somewhat different types of "random" patterns.

The current consumption of the original memory chips is far too low to drain the C-cells in any time period of interest. An alkaline C-cell has a capacity of about 7 amp hours. So even if the memory system drew 1 microamp, it would take 7,000,000 hours to drain the batteries, which is 800 years. The self-discharge rate of C-cells is higher than this.

There are several problems with this original arrangement, for a normal TB-303 or a Devil Fish modified TB-303 (if it had no lithium battery or other arrangements as described below, as was the case for Version 1 Devil Fishes in 1993-94):

1 - If the machine was left running from batteries for too long, the voltage would drop so far that firstly memory data would be lost and secondly, over time, the batteries would leak their electrolyte, causing corrosion to the battery contacts and perhaps to the circuitry itself.

Alkaline batteries have lower self-discharge rates, larger capacities and are less likely to leak. **Do not use ordinary (carbon-zinc) C-cells. Always use alkaline C-cells.**

2 - Memory contents rely on the batteries having sufficient charge, and making good contact with both the positive and negative contacts.

The negative (coil spring) contact cannot be seen unless the machine is dismantled, so the user may not notice corrosion there.

The positive contact may have corrosion, and so make poor contact.

On older TB-303s, the positive contact is recessed so far that modern batteries (of the 1990s and later) do not touch it, due to these batteries having their positive terminal protrude very little, compared to what was common in the early 1980s, when carbon-zinc batteries were most common. (We fix this as part of the Devil Fish mods.)

3 - The user had to keep C-cell batteries in the machine at all times, except for perhaps a few minutes (or in practice perhaps a few days) when removing one set and installing a fresh set.

This leaves the machine at continual risk of being turned on and running from batteries by accident, which leads to the danger of data loss and corrosion of battery contacts and the internal circuitry.

The solution I adopted, in 1996, for Devil Fishes version 2 and above, is described in the next section: Option A – a permanently installed large capacity lithium battery.

3 - Option A - Permanently installed cylindrical lithium battery

All version 2.x, 3.x, 4.0, 4.1, 4.2 and 4.2A Devil Fishes, except those with a Quicksilver 303 system, had a large capacity cylindrical lithium battery installed as part of the Devil Fish modifications. This is the Devil Fishes which were first modified from 2006 to the end of 2014, and a single machine (serial number 287) for an Australian customer in January 2015.

The battery is a Varta CR 1/2 AA, which is a 3 volt cell rated at 950 milliamp hours. It is the same diameter as an AA pen cell, but half the length. It has a stiff copper lead welded on each end, and with these leads the battery is soldered to the main Devil Fish circuit board. The Material Safety Data Sheets at varta-microbattery.com state that these contain 0.3 grams of metallic lithium.

These cells have a self-discharge rate of less than 1% per year, depending on the temperature. With the ordinary memory chips, which draw very small fractions of a microamp, their life would be determined almost entirely by their low discharge rate. Only if the 32 Bank Memory system is maintained for long periods of time at elevated temperatures would the memory chip current drain contribute significantly to the discharge of these batteries.

With the standard memory chips, the two drives for VRAM (the supply voltage of the memory system) are the same as those described on page 4. When the 32 Bank Memory system is installed, the second diode is removed, so the C-cells, if any are installed, have no role in powering the memory system when the machine is turned off. The first diode (which drives VRAM when the machine is turned on) has a second diode added in series, to drop the VRAM drive another 0.6 volts or so. This is to cope with the situation of running from fresh alkaline batteries (whose total voltage may reach 6.5 volts or so) which, with a single diode voltage drop exceeded the 5.5 volt maximum supply voltage specification of the 32 Bank memory chips. This caused them to behave erratically. The first dozen or so Devil Fishes with 32 Banks of Memory, from July 1999 to February 2000 (serial numbers 061 to 079, all of which had 32 banks, except for 063, 070 and 072), did not have this second diode. Please use somewhat discharged alkaline batteries if you are running these machines from C-cell batteries.

The backup current of the 32 Bank Memory system is higher than the very low, and difficult to measure, current of the standard memory chips. I used several types of memory chip, but since mid-2001 have been using a large batch of very low current Samsung chips. Typical backup currents are 0.02 microamps at 18°C, to 0.40 microamps at 50°C.

The 100uF capacitor would not supply the 32 Bank Memory system chips for very long. However, the capacitor is not important for this purpose since, until the end of 2014, we always installed a permanently installed large-capacity cylindrical lithium battery.

In the absence of accurate knowledge of temperature, memory chip current drain and self-discharge rates, the most accurate characterisation I can give of this solution to the memory backup problem is that the battery will last at least ten years and probably for several decades. It would not be surprising if they are still fine in 60 years or more. With the 32 Bank Memory system, assuming it is generally at cool room temperature, say 20C, with a current of around 0.03 microamps, the theoretical life of the battery, not counting self-discharge, would be 950,000 / 0.03 = 3,614 years.

The soldered-in nature of the battery means there are no potential problems with connections to a battery holder. These cylindrical cells seem to be very long lasting, with no evidence of electrolyte leakage, or excessive self-discharge.

For the Devil Fish versions mentioned above it is possible to measure the voltage of the battery with digital volt meter applied to a test point which is accessible if the Mode knob is removed. There is another test point there which, if shorted to ground, will drop the VRAM supply and so erase all the data, allowing the chips to come up with their "random" states. Details of these are in the next sub-section.

There have always been two problems with this arrangement, neither of which I considered worth worrying about:

1 - If C-cell batteries were installed (which are only needed for powering the machine, since they have no role in memory backup) and the machine was left on accidentally for a long time, these batteries could be flattened, and leak – corroding the battery contacts and perhaps parts of the circuitry.

2 - The soldered-in lithium battery can only be replaced by a technician completely dismantling and reassembling the Devil Fish, which is difficult. However, the battery should not need replacing in the next few decades.

This was a generally satisfactory solution to the memory backup problem. However, in 2015, some regulations regarding lithium batteries in airfreight led us to develop a user-installable lithium battery system, which is only practical with coin cells, which are unlikely to last for multiple decades..

Measuring the voltage of the permanently installed lithium battery

This sub-section only applies to Devil Fishes with the Option A arrangement of a soldered-in CR 1/2 AA cylindrical lithium battery.

To test the battery voltage, remove the Mode knob. (Use adhesive masking tape or rubber gloves to grip it, if necessary.) Connect the negative lead of a digital multimeter in voltage mode to the ground of the machine. The best way is to clip on to the ground of one of the 3.5mm jacks at the rear, or to plug a lead into any of the sockets and connect to the ground of that lead. Note that the metal ring on the outside of the 1/4 inch jacks is not grounded. Place the positive lead of the meter on the test point near the Mode Switch. This is the lithium battery voltage via a 3.3k resistor. Any voltage above 3.0 volts is fine.

It is possible to erase memory's data, and allow the chips to power up with data determined by the physics of each cell. This will result in "random" patterns. This can be achieved by turning off the machine, removing the C-cell batteries, removing the Track/Pattern Knob and shorting to ground, for more than a second the test point which is underneath the knob.

To measure the current drain of the memory system, turn the machine off, and remove any C-cell batteries. Connect a micro-amp meter between these two test points. Current will take a while to stabilise due to the presence of a capacitor on the RAM chips' VDD (VRAM) supply. The final current should be less than 1uA.

4 - Option B - C-cells with under-voltage protection, a large capacitor and a user-installed, replaceable lithium coin-cell battery

Most of the following section also applies to Option C, with the 2032 battery installed with the Devil Fish modifications. This is how all Devil Fishes have been modified since 2016 (other than those noted in Section 0 which do not have battery backed up memory.)

This system provides a clip-in battery holder for a 2032 20mm diameter, 3.2mm thick, non-rechargeable lithium coin-cell battery into a battery holder. The Material Safety Data Sheet (MSDS 2.001.005) at varta-microbattery.com state that the 2032 contains 0.07 grams of metallic lithium.

Option A's problem 1 (the C-cell batteries being flattened by accidentally leaving the machine turned on and running from batteries for many hours) is solved by an **under-voltage protection system**. The TB-303 already has a PNP transistor Q44 though which all the +6volt power flows, during ordinary operation. Its purpose is to protect against the batteries or the external power supply being inserted with the opposite polarity, without the loss of 0.6 to 0.7 volts in a diode, which would also offer this protection.

We install a new circuit which disables the drive to Q44 when the supply voltage (from the C-cells, or from an external power adaptor, if one is plugged in) is less than about 5 volts. The TB-303 won't run from 5 volts or less, so this does not affect normal operation. It prevents the C-cell batteries from being flattened if the machine is accidentally left on and running for extended periods. When the C-cell batteries have 5 volts, or as little as 3.7 volts, they will still be able to power the original memory chips or the 32 Bank Memory system, for many years.

Option A's problem 2 (the lithium battery needing significant technician effort to replace) is solved by the optional lithium battery being a coin-cell, which clips into a holder which is loosely but securely mounted inside the machine, just to the right of the battery compartment. Instructions on inserting and replacing this battery follow.

These coin-cell (also know as button-cell) batteries have a capacity of about **230 milliamp hours**, which is about a quarter of that of the 1/2 AA batteries mentioned in Section 2. If not for self-discharge, these batteries would last for decades too. Their self-discharge rate at room temperature (ca. 20°C) is also specified at below 1% per annum. However, coin-cells have a smaller amount of electrolyte than the cylindrical cell, a larger gasket, and possibly not such a good seal in this gasket. So it my impression that coin-cells are at greater risk of failing due to evaporation or leakage of the electrolyte than the cylindrical cells.

We do not want to ship machines with C-cell batteries. This adds to the weight, which affects shipping costs and might cause additional damage if the package is dropped. (One TB-303 which arrived from overseas with C-cell batteries presented a puzzle when it did not run from these batteries, even though each one was measured as having a healthy 1.5 volts. The package had been dropped in such a way that the batteries' inertia impacted them so hard that the batteries became *shorter* – in total shorter than the distance between the battery contacts.)

We install **a large capacitor across VRAM**. The value is **6800uF, which is 68 times that of the original capacitor**. For a 2 volt drop (from about 5 to 3 or so, which is enough to retain memory contents) this capacitor can supply 13.6 milliamp seconds.

Depending on the temperature and self-discharge rate of the capacitor, this may retain the memory contents for months with the original memory chips, 5 days or so for the 32 Bank Memory system at 20°C (0.03 microamps = 45,333 seconds) or for 7 hours at 40°C (assuming 0.5 microamps).

Installing and changing the 2032 coin-cell lithium battery

These instructions are for people who are handy with a screwdriver and prepared to take responsibility for opening their electronic musical instrument, with the consequent risk of damage due to static electricity or other causes. Alternatively, please take the machine to an electronic technician who already knows about these things. These instructions assume a normal plastic (ABS) silver case for the Devil Fish. (AluCase Devil Fishes have their battery holder located between the main TB-303 PCB and the switch PCB, just behind the Run/Stop button.)

1 - Choose a good battery. There are numerous companies making these 2032 lithium batteries. All these batteries should work, but I suggest using a Panasonic or Varta battery, since these are very well established companies.

These are non-rechargeable batteries. Many of these batteries use lithium manganese dioxide chemistry. These should be fine, but Panasonic assert that their lithium polycarbon monofluoride batteries have a longer life in low-current battery backup applications. I suggest you buy one of the following cells, which are available from element14.com, mouser.com, digikey.com and many other electronic component distributors. Be sure to order the plain coin (AKA button) cell configuration, without any extra leads:

Panasonic **BR 2032/BN** (lithium polycarbon monofluoride).
Panasonic **CR 2032** (lithium manganese dioxide)
Varta **CR 2032** (lithium manganese dioxide)

Wash your hands before handling the batteries. Any contamination of the insulating gasket between the positive and negative contacts with salty water or other residues might cause an electrical path which would discharge the battery prematurely.

Small batteries such these are very dangerous if a child or pet swallows them, so please don't leave them lying around.

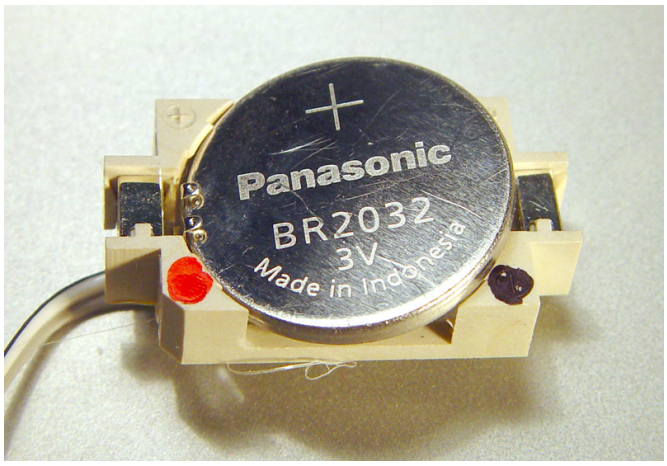
2 - Prepare a static-free work environment.

Don't wear plastic soled shoes, or synthetic socks. Assuming your clothing is cotton, sit only on a wooden chair or one covered with cotton. If the chair is covered in synthetic material, place a cotton towel over it.

3 - If your machine has four C-cell batteries in the battery compartment, remove them. Place the Devil Fish upside-down on a cotton cloth. Plug a 6.5mm audio lead into the Audio Out socket and tuck the connector of the other end of the lead under your leg as you sit on the chair. This helps ensure that no significant voltage difference can develop between your body and the machine you are about to work on.

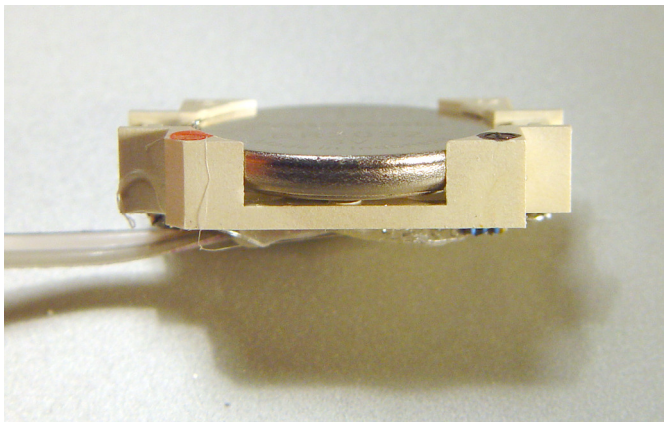
Unscrew the 7 screws in the bottom of the machine and lift the back off gently. Take note which screw came from each hole. Sometimes, these screws are chosen to deal with worn-out holes in the support pillars of the top part of the case.

4 - The 2032 battery holder is tucked into the front-right corner of the machine. Any old battery can be unclipped and a new one clipped in, with the main metallic part of the battery, which is **+**, facing upwards.

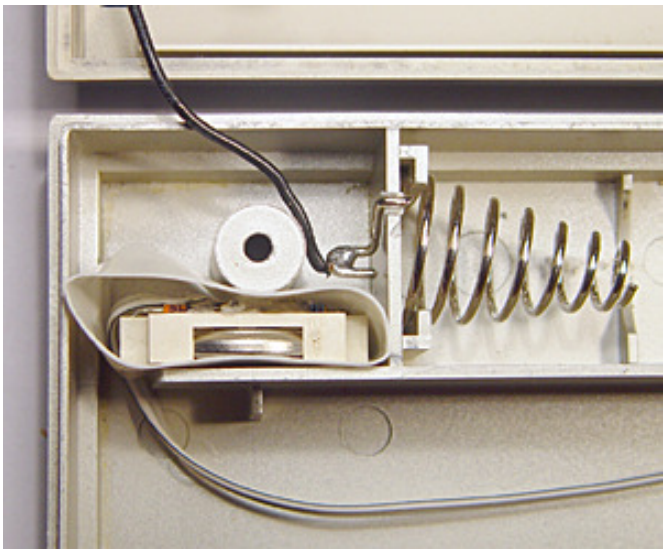


The battery almost clipped into the holder.

Red marks the positive contacts, which hook over the edge of the main body of the battery. On the right, but not visible are two small plastic hooks under which the right edge of the battery clips once it is pushed into place. To remove an older battery, use a fine screwdriver at the right edge of the battery to lever the battery to the left and upwards, out of the grip of those plastic clips.



The battery properly clipped in.



The battery and holder, within a tube of white plastic (which happens to be heatshrink, but has not been shrunk), ready for the machine to be re-assembled.

Alternatively the battery may be adjacent to the pillar, with the diode and resistor at the back of the holder adjacent to the inner panel.

5 - Reassembly is the reverse of the disassembly procedure, but please take care that no wires are caught against the pillars of the bottom part of the case. Please use an ordinary screwdriver, not an electric screwdriver, to tighten the screws. Do not do them up very tight, since this tends to strip what little plastic may be present in the support pillars.

6 - Make a note to yourself, such as inside the lid of the battery compartment cover, about when you installed the battery.

Testing the voltage of the 2032 coin-cell battery

Lithium coin-cells have a smaller electrical capacity and greater chance of electrolyte evaporation or leakage than cylindrical cells. It would not be surprising if a coin-cell was still working fine after 20 or 30 years, but I suggest opening the machine, as described above, and checking the voltage after 10 years, and then every 5 years after this.

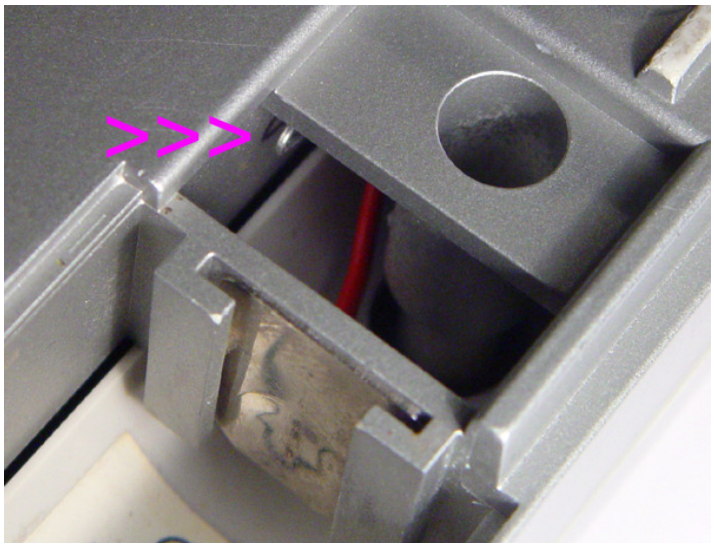
Once the back has been removed from the machine, as described above, the voltage can be measured with a digital volt meter at the metal contacts of the socket, which are visible at either side of the holder in the first picture above. As long as the voltage is above 3.0 volts, and there is no sign of leakage and corrosion, the battery should be fine for another five years or so. **Since 2032 cells are inexpensive, a better approach would be to install a fresh one every 10 years.** Check the old battery and the battery holder for any signs of corrosion.

Testing the VRAM voltage

VRAM is the voltage which drives the memory chips. In machines with Option B or C, this is directly connected to a large electrolytic capacitor – 6,800uF – which is located in the lower part of the case, to the left of the battery compartment. This voltage will be driven high, such as to 5 to 5.5 volts, when the machine is powered on. After that, the voltage will drop slowly. If there are no C-cell or coin-cell batteries installed, then over time (days to months, depending on the internal leakage current of the capacitor, the current drawn by the memory chips and any other sources of leakage, primarily the original 100uF capacitor) the voltage will fall. The chips will probably retain their data down to 2.5 or 2.0 volts.

If you are interested in the rate at which the voltage falls, you can measure the voltage without dismantling the machine. Making two measurements hours, days or weeks apart will enable you to estimate how long the memory contents would be retained in the absence of both the C-cell and the coin-cell batteries.

As shown in the following image, the positive wire of the capacitor is extended so it can be contacted through the gap just to the left of the positive C-cell battery contact, once the battery compartment door is removed. (For AluCase Devil Fishes, the VRAM test point is on the back of the main TB-303 PCB and is labelled as such. This is accessible once the bottom of the AluCase has been removed.)



To do this, use a digital multimeter (DMM), set to its 20 volt or similar scale, and connect the positive lead to this wire, with the negative lead going to ground, such as the metal outer part of the CV Out or Gate Out TB-303 sockets on the rear panel. Assuming the DMM presents a 10M ohm load to the circuit (it may be higher), then if the capacitor is not being driven via the internal diodes from the main power supply, or by the C-cell or the coin cell batteries, then connecting it to the capacitor for will drop its voltage by about 15 parts per million per second. It only takes a few seconds to connect the meter, record your measurement and disconnect it. For instance, at 4.0 volts, a 5 second measurement will drop the voltage by 4 * 15 * 5 = 300 microvolts = 0.0003 volts.

Testing the VRAM current

To measure the **current drain from the C-cell batteries** to the memory backup system (the memory chips, the chip-enable decoder chip, the original 100uF capacitor and the new 6,800 uF capacitor and any other source of leakage) disconnect any power adaptor and run a microampmeter (such as a digital multimeter on 200uA scale) *potentially in series with a silicon diode, such as a 1N4148* between the positive C-cell battery contact and the abovementioned VRAM test terminal.

"*Potentially*" means: if the machine has the 32 Bank memory system and is serial number 080 or later, use the diode, since I installed a two diode path between the battery positive terminal and VRAM. If the machine does not have 32 banks of memory, or does and has an earlier serial number, then do not use the diode, since there is just a single diode in this pathway.

Please allow a few minutes for voltages and currents to settle. The current should be below 1uA.

In Devil Fishes with 32 banks of memory and serial numbers 080 and above, there are two 1N4148s in series inside the machine between these two points, due to the potentially high voltage of four fresh alkaline C-cells in series driving VRAM higher than the 5.5V operating limit of the memory chips. The microampmeter in series with a single 1N4148 diode will raise VRAM 0.5 to 0.6 volts higher than normal, so the current you measure will be slightly higher than during normal operation (the C-cells powering the memory system when the machine is turned off). It will also be significantly higher then the current drawn by the memory system from the optional internal lithium battery alone (when the machine is turned off and there are no C-cells installed) since the lithium battery is typically 3.0 to 3.3 volts.

A single 1N4148 diode is between the lithium battery positive terminal (both Option A and Option B/C) and VRAM, so he highest VRAM voltage when powered by the lithium battery is likely to be 2.5 to 2.8 volts, rather than the approximately 5.5 volts which might be present on VRAM with fresh C-cells and the ~1.0 volt drop of the two diodes.

To measure the **current drain from the 2032 lithium battery**, remove the C cell batteries and any power adaptor. Connect your DMM in current mode, such as 200uA full scale, between the positive terminal of the battery (positive lead of the DMM), which is the top surface and the sides (and so directly accessible when the battery is installed as show above, without the need to move the battery holder) and the abovementioned test terminal (negative lead of the DMM), which is the positive wire of the 6800uF capacitor.

With both types of current measurement, you may need to wait a while for the reading to settle down. Frequently, you will, at first, be *discharging* the 6800uF capacitor, and so get a negative current, which drops through zero and becomes positive. Sometimes, if there has not been a battery in the machine recently, you will be charging the 6800uF capacitor and so have a very high current at first. Generally, you will get a somewhat high current which settles down to the final stable current after some minutes, which is due to the DMM (and *potential* extra diode as mentioned above) causing little voltage drop over part of the circuit which previously had one diode (and so ~0.5V drop) or two such diodes (see *potentially* above).

When these capacitors rise in voltage, there can be transient currents associated with self-healing of gaps in the aluminium oxide insulating layers inside these capacitors. Before becoming alarmed at currents above about 0.2uA for the 32 Bank memory system, **please let the system settle down for an hour or so**.

If, for instance, the memory system (32 bank or the normal RAM chips) is drawing 0.2uA at ordinary room temperature, and if we add a fudge factor for higher currents at warmer temperature, then we assume that the average current consumption is 0.3uA.

This is 0.3 * 24 * 365 = 2,628 microamp hours per year, which is 2.638 milliamp hours. Since the battery capacity is around 230 milliamp hours, this gives a theoretical life, not counting battery self-discharge, of about 87 years. With both the 32 bank memory system and the original memory chips, the current should be below 0.2uA.

Deliberately zeroing VRAM to erase the memory contents

In the original TB-303, it was possible to remove the C-cell batteries, wait a few days, or perhaps weeks, and then power the machine on again, to find that the stored patterns and tracks have been either corrupted or erased. To perform the same operation with a machine with Option B or C, you *must disconnect the machine from its external power adaptor and remove the C-cell batteries*. There is no need to remove the coin-cell lithium battery, since excessive current drain on this battery is prevented by a 100 ohm resistor. Short the VRAM wire mentioned in the previous section to ground, such as to the metal ground of any of the Devil Fish's or original TB-303's 3.5mm sockets. It is probably OK to do this with a wire with close to zero ohms resistance, but don't be surprised if you see a small spark. A more civilised method involves using a 10 ohm resistor in series with the lead, to reduce the current spike.

5 - Option C - C-cells with under-voltage protection, large capacitor and a user replaceable lithium coin-cell battery already installed

This is the same as Option B, except we will install a 2032 battery. We have been doing this in all Devil Fishes which use battery backup memory (see Section 0) since version 5.0 in early 2018.

There is no need to keep C-cells in the machine in order to retain the memory contents.

Please refer to the section above regarding Option B for when and how to test the battery's voltage, and to replace it – which is ideally every 10 years.

Document history

- 2015-02-02 New document.
- 2015-02-04 Added note about DHL accounts only being allowed for businesses which ship to other businesses, not to customers. Added details of the lithium contents of the 1/2AA and 2032 batteries.
- 2015-02-07 Added photos of the battery installation.
- 2015-02-22 Added sections on measuring and zeroing VRAM for Options B and C and on determining which option a machine has.
- 2015-05-10 Added section on testing VRAM current for Options B and C.
- 2015-10-20 Minor revisions and mention that we can use FedEx to ship machines with lithium batteries installed.
- 2015-10-22 Revised details of the battery holder and VRAM test point for AluCase Devil Fishes.
- 2018-03-01 Revised to reflect the use of Option C for all TB-303 Devil Fishes version 5.0 and later.
- 2019-02-10 Added details of dates and serial numbers of 32 bank machines which did not have the second diode installed, and so which should only be used with somewhat discharged alkaline batteries. Provided proper details of how to measure the battery drain with just the 2032 cell installed. Various other improvements including adding a worked example of current drain and theoretical life of a 2032 battery