REAL WORLD INTERFACES

Memory Backup for the Modified TR-808

Robin Whittle 18 February 2019 www.firstpr.com.au/rwi/tr-808/

Option A served well, but in 2015, due to problems with air-freight restrictions on lithium batteries, we devisd a new approach Option B for overseas customers, and a related Option C for Australian customers or for overseas customers who choose FedEx shipping, which is more expensive than the Australia Post Express Courier International service we used at the time. In September 2017, Australia Post does allow us to ship TR-808s overseas with a lithium battery installed, so part of the original impetus for Options B/C no longer exists. Nonetheless, the whole modification, with lithium battery installed (Option C) improves on the original alkaline AA cell arrangement in several ways, so it is still a good idea to install it.

(For a version of this document from 2015, which applies to a few machines modified before September 2017, please see: http://www.firstpr.com.au/rwi/tr-808/TR-808-Memory-Backup-2015-10-20.pdf . This was written on the basis of us not being able to ship with Australia Post any machine with a lithium battery installed.)

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0 - TR-808s this manual does or does not apply to

In the 1980s I modified many TR-808s with Sound Improvement, 4 Level Accent and several types of Memory modifications. Generally, those machines did not have any alteration to the standard battery arrangements for powering the memory chips when the power was turned off, which involve the three 1.5 volt AA batteries in the battery holder which is accessible via a battery compartment cover in the bottom panel of the machine.

However, for all these machines, I did install the write spike modifications, which overcomes a problem which corrupts memory data, which us unrelated to the battery arrangements. I installed a lithium battery (Option A below) and the Write Spike modifications in all – or almost all – of the TR-808s I modified In the 1990, 2000s and early 2010s. This includes one I repaired in March 2014. This manual describes the battery backup arrangements for these machines, none of which have the Option B/C arrangement, which I first installed in May 2015.

1 - This modified TR-808 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 machine.

Option	Memory backup system Care and maintenance	Suitable for customers . . .
[ ] ***A*** **Page 6.**	**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.**	**Suitable for customers located in Australia, but generally we use Option C below for newly modified TR-808s for Australian customers.** **Until March 2015, when I modified a TR-808, I generally used this Option A. This PDF file documents this system for those customers with such machines.** **We may leave this system in previously modified TR-808s we work on and return to customers in Australia.**
[ ] ***B*** **Page 7.**	**A large capacitor and 1/2 AA lithium battery (large capacity cylindrical cell) holder *without* a 1/2 AA battery. By removing the right plastic panel of the TR-808, such a battery can be installed by the user.** **A recessed button and two LEDs in the bottom panel enables the voltages of both the AA alkaline battery and the optional lithium battery to be checked.** **Keep three AA alkaline batteries in the machine at all times, unless you install the lithium battery, which involves taking the side panel off the machine.** **The three alkaline AA batteries will last for years. It is best to install fresh C-cell batteries every 3 to 5 years, and check that the battery compartment contacts are clean.** **If you have installed a lithium battery, check the battery voltage after 10 years, and every 5 years after that. Since the 1/2 AA cells cost about $10, it is probably best to install a fresh one every 10 years or so.**	**Generally, there is no need to install the lithium battery, as long as you check the voltage of the AA batteries regularly. This is easy, with the new switch and LED.** **There is no other drain on the AA batteries than the very low current required by the normal or 32 Bank Memory systems. The life of the batteries is determined by their self-discharge rate, rather than this small current drain. It would not be surprising if fresh alkaline batteries were still good after ten years, but I suggest installing new ones every three years or so.** **The battery test button tests not just the combined voltage of the three batteries, but the fact that their connections to the battery holder are good too. So a poor connection, flat battery, or a battery inserted in the wrong direction, will be indicated by lack of light in the LED.** **The lithium battery has advantages of inherently longer life, and just two connections to a more robust battery holder, so it is likely to be more reliable than the AA cells. Having both AA cells and the lithium battery will be still more reliable.**
[ ] ***C*** **Page 11.**	**As above, but with a 1/2 AA lithium battery already installed.**	**From September 2017, we generally install this when shipping machines within Australia and to customers overseas.**

2 - The TR-808's original Memory Backup System

The TR-808 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 four battery backed up low-power static RAM chips, each of which has 1024 locations of 4 data bits. These chips total 2k 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 TR-808'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 TR-808s 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 0.04 microamps at cool room temperature, such as 18°C, rising to something like 0.7 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.

As described below in the Write Spike mods section, R91 adds an additional drain current of about 3 to 4uA for all TR-808s in their standard state, and all those I worked on before May 2015.

In a standard TR-808, 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 - When the power is on, a diode from +5 volts drives VRAM to about 4.4 volts, which is fine for reading, writing and data retention.

2 - When the power is off, a diode from the combined voltage of the three AA cells drives VRAM. This voltage is nominally 4.5 volts, so VRAM is driven to about 4.0 volts, with the very low current flowing through the diode. The actual voltage produced by the three AA batteries may be higher or lower than this.

When the power is off and the Mode switch is set to Manual Play or Track Play, the R91 current is not active, and:

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 four 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 so (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) to keep their data intact.

Depending on the self-leakage of the capacitor and the temperature and exact natures of the original memory chips, this capacitor would retain memory contents if the power was not 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 AA batteries and installed a fresh set, without the machine being plugged into the mains and turned on.

If the power is off and the Mode switch is set to 1st, 2nd 3rd or 5th position (not Manual Play or Track Play), then the R91 current is active and:

The capacitor will loose enough of its charge in a minute or less to cause memory data to be lost.

As the capacitor discharges further, the VRAM voltage would be too low for the flip-flops in the RAM chips to retain their flipped or flopped states (the musical data written by the CPU in the past, ready to be read in the future when the machine is turned on). So when a proper voltage for memory data retention or operation is applied 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, and for the R91 current, is far too low to drain the AA-cells in any time period of interest. The TR-808 was originally supplied with ordinary carbon-zinc dry cell AA batteries, since alkaline batteries were rare and expensive at the time. An alkaline AA cell has a capacity of about 2.5 amp hours. So even if the memory system drew 1 microamp, it would take 2,500,000 hours to drain the batteries, which is 285 years. The self-discharge rate of AA-cells is higher than this.

There are some potential problems with this original arrangement:

1 - If the batteries are installed the wrong way, or are flat, or if there is corrosion or some other problem with the six contact, there will be no supply to the memory chips. There's no visible way of ascertaining this, if the corrosion is slight, since the user may not know the batteries are flat or inserted incorrectly.

A potential contributor to incorrect connections is that the foam on the battery compartment door was rather soft originally, and so may not have kept the batteries in place initially. Three decades later, this foam is either much softer or has crumbled and been removed. We install firmer foam.

2 - If non-alkaline batteries are installed, they may go flat and leak in a year or two, which is much shorter than what can be expected of alkaline batteries.

3 - If the battery contacts do become corroded, it may be difficult for a technician to find a replacement battery holder.

These battery holders are cheap in cost and in quality. The spring is connected to a rivet, where the compacting force of the rivet presses on the nylon (I guess, or some other inexpensive thermoplastic) body of the battery holder. This may deform over time, reducing the pressure which is required for electrical

connectivity.

Even if the batteries have never leaked, it is possible that in humid or salty environments, over many years, that some corrosion has occurred between the rivets and springs or on other parts of the battery contacts.

Until May 2015, the solution to these problems was Option A, as described in the next section – a permanently installed large capacity lithium battery.

3 - Option A - Permanently installed cylindrical lithium battery

Until May 2015, when I modified a TR-808 the customer usually chose to have a large capacity cylindrical battery installed. This is a separate modification from the 32 Bank Memory system.

This battery may not be retained in the future. If we work on one of these machines and return it to a customer overseas (unless by FedEx), we will remove this battery and install the Option B system mentioned in the next section.

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 has soldered electrical connections (it is not in a battery holder) and is held firmly in place inside the TR-808 or in some cases the battery compartment (meaning that AA batteries could not be installed). 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. The R91 current (as described in the Write Spike mods section below) adds to this current considerably, but it would still not discharge the 1/2AA lithium battery in less than two decades or so. 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.

This battery provides a third drive for the memory supply (VRAM), via a silicon diode and a 100 ohm resistor, which limits the current in the event of a short-circuit.

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 0.03 microamps at 18°C, to 0.50 microamps at 50°C.

The 100uF capacitor would not supply the 32 Bank Memory system chips for very long. However, the capacitor does not play any useful role once there is a lithium battery installed.

In the absence of accurate knowledge of temperature, memory chip current drain, R91 current and self discharge rates, the most accurate characterisation I can give of this solution to the memory backup problem is that the lithium battery will last at least ten years and probably for several decades. 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. However, in all these machines, there is the R91 current (such as 2.7 to 4uA) if the Mode Switch is not in Manual Play or Track Play, so the theoretical life without accounting for battery self-discharge would be much shorter.

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.

There was only one potential problem with this arrangement, which I did not considered worth worrying about: The soldered-in lithium battery can only be replaced by a technician completely dismantling and reassembling the TR-808. However, there's no reason to believe the battery would need replacing in the next few decades.

This was a perfectly satisfactory solution to the memory backup problem. It remains so, except that in 2015 we needed to find a way of shipping machines to customers overseas when Australia Post would not carry packages containing lithium batteries. This prompted the development of the Option B and C arrangements. In 2017, we can ship machines overseas with Australia Post's "International Express" service, so we do so with Option C, with the battery installed. Option B was so we could ship the machines without a lithium battery, and have the customer install such a battery.

4 - Option B - A large capacitor, an optional user-installed replaceable lithium 1/2AA battery and a push-button and pair of LEDs to test the state of the AA batteries and the optional lithium battery

This is the system we were using for overseas customers who choose the standard Australia Post EMS shipping option from 2015 until September 2017.

Compared to the 2032 coin or button cells which we must use, for reasons of space, in the TB-303 Devil Fish and the TR-606, the cylindrical 1/2 AA lithium cells have a larger electrical capacity, a larger amount of electrolyte and a smaller and probably more robust electrolyte sealing gasket between the positive can and the negative contact. This type of battery, in general, has an excellent record of operation over several decades. There have been no reported problems with these batteries (with leads spot-welded to them) which I have been installing in Devil Fishes since 1996. Similar batteries were installed for the memory backup of Jupiter-8s in 1980, and are still functioning well decades later.

We will ship machines with fresh AA alkaline cells in the battery compartment. These will supply the memory system during transit, and will probably continue to do so for the next five years or so. If no lithium battery is installed, I suggest installing fresh alkaline batteries every 3 years or so.

If there is no lithium battery installed, if the machine is not plugged in and turned on, and if the three AA alkaline batteries are removed (or if any of them are removed or are flat, or if the battery contacts are not working) then the memory should be powered for some time by the larger capacitor we install for this purpose. This **large capacitor across VRAM** has a 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, 4 days or so for the 32 Bank Memory system at 20°C (0.04 microamps = 45,333 seconds) or for 7 hours at 40°C (assuming 0.5 microamps). There is no R91 current with Option B or C, since I remove this resistor, as described in the section below on the Write Spike mods.

Testing the charge of the three AA alkaline batteries and the optional lithium battery

In the bottom panel of the TR-808 there is a 6mm hole exposing a white tact switch, next to two 3mm holes, each of which has a red LED. Pressing the switch inside the 6mm hole connects the test circuits to the batteries. The **left LED** will illuminate if the three AA alkaline batteries are connected properly and have sufficient charge to run the memory system for another few years. The **right LED** will do the same for the optional lithium battery. The brightness of the LEDs should not be much dimmer than the LEDs in the TR-808's front panel. If the left LED (for the three AA alkaline batteries) is much brighter, this is fine, since this indicates the higher voltage of fresh alkaline cells. Here is a photo of the test controls:

Installing and changing the cylindrical lithium battery

Once installed, this battery is likely to be good for several decades. However, since they are relatively inexpensive (though not available via ordinary retail outlets), it probably makes sense to replace the battery after ten or fifteen years.

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.

1 - Order the battery - a "1/2 AA" or "1/2AA"size cylindrical lithium metal battery which is non-rechargeable. (The Material Safety Data Sheets at varta-microbattery.com state that these contain 0.3 grams of metallic lithium.) The battery must not have any leads or terminals. (If you accidentally purchase one with leads, these can be cut off and the remains of the leads filed flat.) For instance, from element14.com, catalogue number 836-6206:

These and equivalent batteries are available from element14.com and suppliers such as mouser.com and digikey.com:

Varta **CR1/2AA**
Panasonic **BR-1/2AA**

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.

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

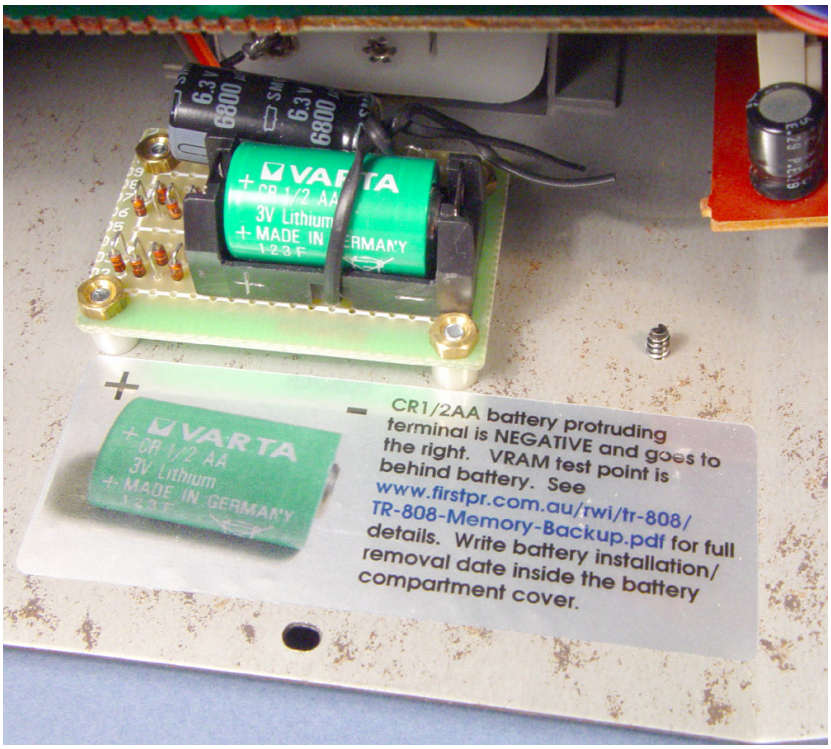
2 - Prepare a static-free work environment.

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 - Unplug the TR-808 from the mains. Remove the three screws on the bottom panel which are close to the right side plastic panel. Remove the two rearmost screws on the top panel nearest the right panel. The front screw there, near the Volume knob, should remain in place. The final screw to remove is underneath, near the back of the machine, beneath the Hi Level Master Out socket.

4 - Carefully remove the right side panel, being careful not to pull any wires to the controls there for the various modifications. While you are doing this, you will be touching the metal front panel, which should reduce or eliminate the chance of static electricity build-up between your body and the TR-808.

5 - The battery can now be inserted in its holder, with the positive end towards the front of the machine, which is to your left. Unlike conventional batteries, these lithium batteries have their protruding terminal as the minus (-) terminal, which should be to your right. A twistable cable-tie is already installed around the battery holder. Twist it around the battery to keep the battery in position even if the machine is subjected to a sudden bump which might otherwise dislodge it. Here is a photo of the battery board:



6 - Press the battery test button as described above. The right LED for the lithium battery should illuminate. Write a note on the inside of the battery compartment door about the date of installation of the internal lithium battery.

7 - Carefully replace the right panel of the machine, being careful not to allow any wires to become pinched or entangled. Replace the screws, with a hand screwdriver, being careful not to do them up too tight.

Measuring the memory system current consumption

For the interest of technicians, here are some notes on measuring VRAM and the current consumption of the memory system.

Behind (in the above photo) the lithium battery holder is a test point which is connected to VRAM. This enables voltage measurements. To check current drain, connect a microampmeter between this point and (if three AA batteries are installed) the positive terminal of the rear-most AA battery, otherwise the positive terminal of the lithium battery. The current should be below 1uA and may be as low as 0.02uA at low temperatures.

5 - Option C - the same as Option B, but with the lithium battery already installed

- This is the same as Option B, except we will install a CR1/2AA battery.

There is no need to keep AA cells in the machine in order to retain the memory contents, but there is no harm in installing them, provided you ensure they are replaced every few years so they don't leak and cause corrosion problems.

Please refer to the section above regarding Option B for how to test the voltage of the three AA alkaline batteries, if you have any installed, and the 1/2 AA lithium battery. The above section describes how to install a new lithium battery, which you should do every ten years or so – though the one battery will probably last for decades.

6 - The Write Spike mods and R91 - for the interest of technicians

The standard TR-808 circuit design has a problem which causes the machine to frequently corrupt its memory. As far as I know, the corruption concerns only Track 1 and the first beat of Pattern 1. The cause is capacitive coupling to the active low Write line to the RAM chips.

The /CE pins of the chips are driven by an apparently adequate circuit involving pull-up resistors (R99, R96, R98 and R95) to VRAM ("BU" in the schematic) and one of them is pulled low by IC5 (4051) according to the CPU pins 14 and 15 address lines and an active high RAM enable pin 31 of the CPU, the drive of which to IC5 is pulled low by the FET Q75 which is turned on by the muting circuit when the machine is powering up and down.

CPU (IC4) pin 30 is the active low drive to the /WR pins of the four RAM chips. There is a 1M (15k in early machines) **R91** pull-up resistor to VRAM on the /WR signal to the RAM chips. This is intended to work together with section b of Mode switch SW1, which connects the CPU pin 30 to the /WR pins except when the Mode switch is set for Manual Play (of patterns) or Track Play. In both of these modes, the CPU should not be writing to RAM, and this disconnection is evidently intended to reduce the chance of memory corruption. Unfortunately, it seems to have the opposite effect since it makes the /WR line more susceptible to capacitive crosstalk.

This rather delicate (1M pull-up to VRAM) /WR signal traipses across the main PCB from the CPU area to the Mode switch. Likewise the CPU pin 30 signal which drives it, but this is a low-impedance output signal from the CPU, so it is not so subject to capacitive crosstalk.

The crosstalk appears to happen when the machine is turned off – perhaps especially so if this is done by the power switch, rather than by unplugging the power cord or turning the power off at the power socket. It is also possible that the crosstalk occurs due to spikes when the power is turned on, or perhaps when there is a high frequency spike on the mains supply. (Turning on the power at the peak of the 240VAC mains cycle could generate a sharp edge voltage from 0 to plus or minus 340 volts, which might also be sufficient to cause memory corruption.)

The crosstalk may occur when the Mode switch is set to other than Manual Play or Track Play, but it certainly does happen (and would be expected to happen more strongly) when this switch is set to one of these two positions.

The source of the crosstalk is high frequency spikes on the wires which go from the primary of the power transformer and (perhaps, or at least to a lesser extent) the wires from the mains input to the power switch. These wires are encased in a clear PVC tube and are often pressed right up against the Mode switch part of the main PCB.

If the Mode switch is in Manual Play or Track Play modes, then the /WR signal is only pulled up to VRAM by the 1M **R91**.

When an inductive device such as a power transformer is disconnected from its power source, it frequently generates a sharp (high frequency) spike in the opposite direction, as if to try to maintain the current which was flowing through it. With 240V (RMS) mains, the peak voltage is plus or minus 340 volts (240 * square-root-of-2) and the power transformer input wires, once disconnected from this drive, could easily generate many hundreds and perhaps a thousand or so volts in the opposite direction to whatever polarity is driving them at that instant.

It doesn't take much capacitive coupling from these mains wires to the /WR line to cause it to go from ~3 or ~4 volts below the negative threshold of the RAM chips (below about 1 volt) for a few tens of nanoseconds or more (these chips have a few hundred ns access time) and so to cause any chip which happens to have its /CE line active low, to write invalid data somewhere.

This problem is probably worse in 240 volt countries than in the USA (~120 volts) or Japan (100 volts).

My fix for this, since I started working on TR-808s around 1982, has been the Write Spike mods:

- Cut the /WR line as it approaches the left RAM chip, and insert a 10k in series, with a 100pF to ground on the driven side (the right, going to the RAM chips). This forms a low-pass filter which seems to be effective at rejecting the high frequency spike caused by crosstalk from the mains wires.

- Connect the two non-connect pins of the S1b (9 and 9 o'clock when the back of the main PCB is downwards and we are looking at the underside) via a 10k resistor to VRAM. The resistor must be mounted behind the switch to avoid more capacitive crosstalk problems, with a wire connecting it to VRAM at a location such as the right end of R95, near IC8. This provides a better pull-up for the /WR line to VRAM than the 1M **R91**, which would otherwise be the only pull-up for /WR when the Mode switch is set to Manual Play or Track Play.

As far as I know this is effective at stopping this memory corruption problem. I have done this to all or almost all of the TR-808s I have worked on – and I will continue to do so.

In May 2015 I realised that there was some unfinished business here. **R91** always pulls /WR to VRAM. The trouble is that when the Mode switch is not in Manual Play or Track Play, the /WR line is connected to CPU pin 30. When the power is off, CPU pin 30 will be at about 0 volts (actually it may be somewhat higher due to a 0.6 volt diode drop), and so this **R91** drains current from VRAM to ground. This is insignificant as long as the memory backup is driven by the three AA cells - assuming they are changed every few years. The current would be about 4uA at most, which is 35mA hours per year.

Nor is this a serious concern if the memory backup power source is the 1/2AA lithium battery (Option A, which I installed in many machines from the 1990s until 2014). After the diode voltage drop, VRAM in this case is likely to be about 2.7 volts, which means 2.7uA = 24mA hours per year. This is unlikely to affect the life of the lithium battery much, since it represents a 1/30th or less of the battery's nominal capacity. However, it might make the difference between the battery lasting 15 years or so and lasting 40 years (if there was no such 2.7uA drain).

This R91 resistor's current drain would be significant when the 6,800 uF capacitor is the only source of memory power, which is the case with Option B or C if there is no lithium battery and no AA alkaline batteries, such as when changing batteries. The RC time constant for this combination is 6,800 seconds - about 11 minutes for a 63.2% drop in voltage. However it probably only takes a 30% drop before data is lost.

Since this 2.7uA or 4uA current drain discharges the lithium battery or capacitor significantly faster than the actual current drawn by the four RAM chips (plus the self-discharge of the 6,800 and 100uF capacitors, and any other leakage) and since we don't need this **R91** circuit due to the Write Spike mod 10k pull-up, **from May 2015 I removed R91**. For machines with the 32 Bank Memory system, I use the R91 position for the 10k series resistor of the write spike mods.

This document generally assumes that R91 is out of the circuit, but this is not the case for the machines I worked on prior to May 2015. None of these machines have Option B/C, so **all TR-808s with Option B/C and so the 6,800uF capacitor and the user-installable lithium battery, will have had R91 removed**.

Document history

- 2015-02-02 New document, derived from the Devil Fish equivalent.
- 2015-02-04 Added the weight of the lithium in the batteries.
- 2015-05-08 Added photos of the battery board and test controls. Added sections on testing memory system current drain and on the Write Spike mods and R91.
- 2015-10-20 Minor revisions and mention that we can use FedEx to ship machines with lithium batteries installed.
- 2017-09-25 Updated to reflect that we can ship TR-808s with a lithium battery via Australia Post "International Express". Removed references to the prospect of a future Quicksilver 808 since it seems unlikely that this product will be developed. Fixed typo which mentioned installing a 2032 (coin cell) battery for Option C, rather than the CR1/2AA. Added link to the 2015 version of this document.
- 2019-02-18 Fixed typo. Mentioned that with the 32 Bank Memory system, the R91 position is used for a different purpose.