NAD C390DD start-up issue

Thanks to all, starting from Ergo in August 2018, for your contributions about this issue. It was a good starting point for me. However, when first reading it, I was a bit skeptical about whether the secondary capacitors of the supply were indeed the real root cause. I bought the C390DD new in mid 2014 and it has had the problem of occasionally not switching on from the beginning. I don't expect these capacitors to have been bad from the start, although I find it very disappointing that NAD is using these low cost (crappy?) Chinese capacitors. I would have expected that for equipment at this price point, decent capacitors would have been used from for example Nichicon, Panasonic, Rubycon, Vishay or Elna. Anyway, back to the problem.

Actually initially I thought this was a software issue ('booting'), because doing a 'hard reset' using the switch on the back always solved the issue. It didn't happen very often so it was not a big issue, although a bit of a nuisance. In 2015 something went wrong in the power supply. When I switched the amp on, my circuit breaker in the house tripped and I had to send the amp for repair (warranty). The SMPS (PSU-A) was replaced, but unfortunately it did not solve the issue of sometimes not switching on. Back then, in 2015, I also searched the web for more information, but did not find anything about this issue with the C390DD. Somewhere in 2019 switching on the amp became increasingly difficult until it didn't switch on at all. Also using the switch at the back did not help anymore. I did a new Google search which almost immediately led me here. Apparently, this is a common problem with this amplifier. Starting from Ergo's contribution, it became clear that the problem is caused by the 12.5V supply on the PSU-B board. But still I was not convinced that the real root cause were the capacitors, and after checking with Wim Janse, this was confirmed. It looked like a combination of those capacitors, and a marginal design which may manifest itself more after aging of the capacitors.

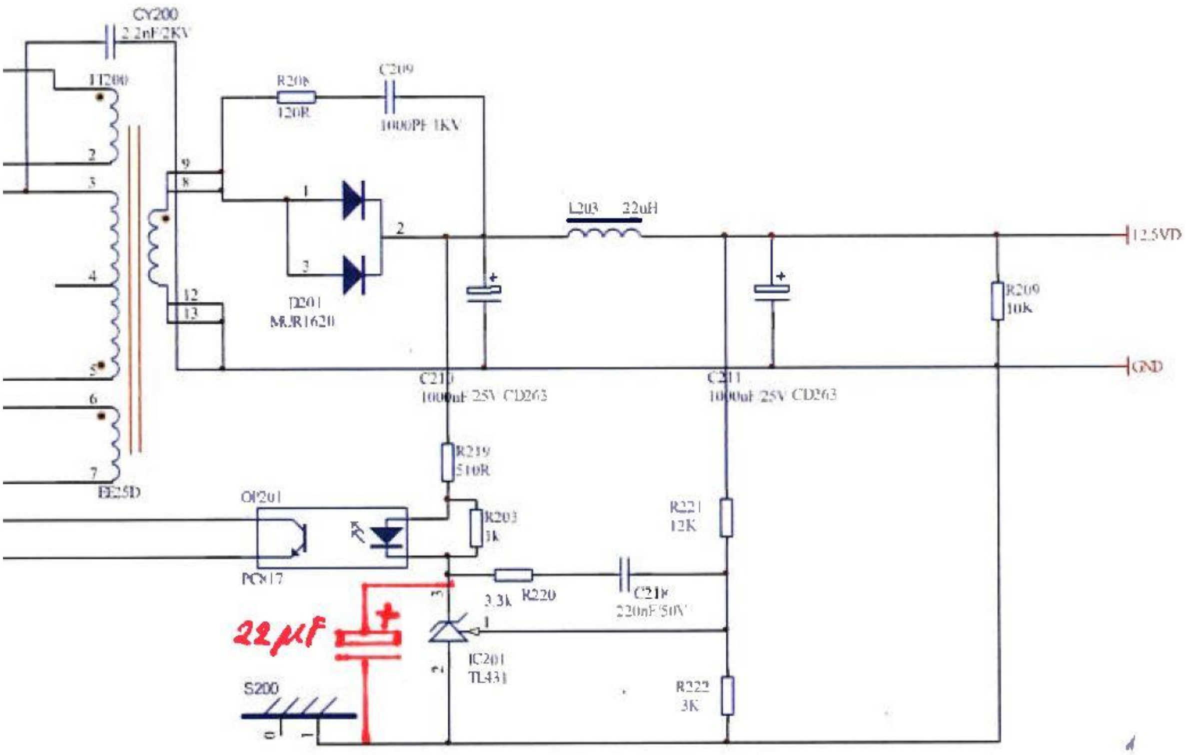
When the on/off button at the front is operated, relay K200 comes in. This means that the 5V standby power supply of PSU-B, built around the TNY274 works properly. See schematic of full PSU-B which is attached.

It is easy to overlook that there are actually two supply voltages which are not the same. There is a 12VD (generated by the circuitry around the TNY274) and a 12.5VD, generated by the circuitry around TOP246Y. The latter is the problem.

Transformer T201, driven by the TNY274, contains a 12V winding (pins 4 and 5). When the signal BSTBY is made LOW, transistor Q200 starts to conduct via optocoupler OP202. Thus the 12V is switched through to create 12VD and relay K200 comes in.

Once relay K200 is in, the upper part of the schematic of PSU-B, built around the TOP246Y should start working. This then will provide the 12.5VD. However, this does not always happen. The 12.5VD supplies, via a number of dedicated linear voltage regulators which provide lower voltages, large parts of the amplifier like the Zetex FPGA board, input selection, USB card and optional plug in cards. It looks as if this supply does not always start up properly. It may depend also on how many plug-in modules are used. In my case, I have the HDMI module and the analog module. These optional modules increase the load on this supply.

TOP246Y from Power Integrations integrates the high voltage power MOSFET, PWM control, fault protection and other control circuitry onto a single CMOS chip. On the Power Integrations (PI) website several application notes and design ideas are available for using this device. I found information about a so-called soft finish capacitor that can be added to the design in order to improve startup behavior. The simplest implementation is to add just one elcap in parallel with the TL431 (IC201), pins 2 (minus) and 3 (positive). This is indicated in red in the schematic below.



The purpose of the soft finish capacitor is to ensure that the power supply actually starts up. From PI: “Soft finish helps our devices to get (already) a feedback signal before soft-start finishes (soft start takes 10 ms) when there is huge output capacitance or heavy load at startup.”
In this case of the C390DD the output capacitance is 2 x 1000 µF. The presence of the soft finish capacitor enables a (additional) current through the LED of the optocoupler during start up. This current charges the elcap, and once the TL431 zener voltage is reached, the soft finish elcap doesn’t have much effect anymore. However, since the elcap ensures an initial current through the LED of the optocoupler, during that time also a current will flow in the control input of the TOP246Y.
This device provides a fully integrated 10 ms soft-start, which limits peak currents and voltages during start-up and dramatically reduces or eliminates output overshoot in most applications. However, if no external feedback/supply current is fed into the CONTROL pin by the end of the soft-start, the high voltage current source is turned off and the CONTROL pin will start discharging in response to the supply current drawn by the control circuitry. This then results in no start-up of the supply, and to prevent this from happening the ‘soft finish’ elcap has been added. I have seen several values being used by Power Integrations, mostly 22 µF but I have also seen designs with 47 µF. I have opted to use 22 µF here.

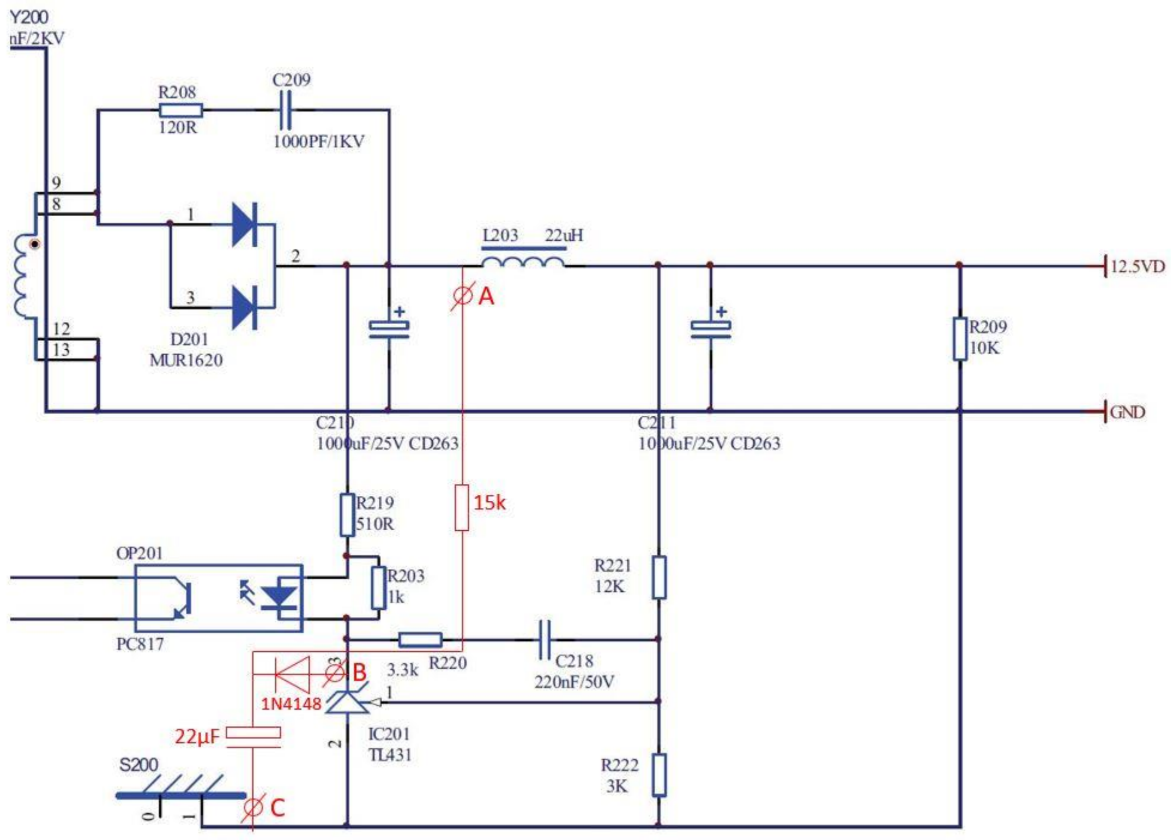
Since I had the PSU-B out of the amplifier, and since the cost of some electrolytic capacitors is not very high, I decided to change them all. I didn’t think that the root cause of the unreliable start up behavior is in the capacitors, because my amplifier showed this behavior from the beginning when it was new. However, I suspect that aging of the capacitors can cause the issue to occur more frequently until at some point the amplifier doesn’t start up at all anymore.
After replacing the capacitors I measured the old ones with the Peak ESR70. Across the line the capacitor values were a bit below the specified values. Only C210 and C211 (1000 µF/25V) had a

value which was more than 10% less than specified. Not a very long lifetime. ESR was ok. **Only one capacitor was clearly at fault and had to be replaced, and that was the primary 47 µF/400 V Lelon.** Therefore, for anyone facing the same problem, the first repair attempt should be just replacing this capacitor.

For C210 and C211 the replacement capacitors are Panasonic 1000 µF/25 from their FP series.
For C204, C205, C213, C217 and the new capacitor I used Panasonic NHG. For the 400V capacitor at the input I used a Nichicon UCY type. An alternative could have been the Panasonic EE series.
After this modification the amplifier always started up. However, I noticed that sometimes some audible noise came from the PSU-B. Not loud, but if this was coming from the circuit around the TOP246Y this would indicate that the supply could be experiencing some stability issues since the regular switching frequency is 132 kHz. Also the relatively large new capacitance across the TL431 was something that had made me wonder before whether this would not affect stability. Checking with PI resulted in the following information:

“Using the single capacitor option for "soft finish" requires use of a general purpose capacitor of value 1-10 uF (generally), depending on the particular application. A general purpose capacitor (examples are UCC KME series, Nichicon VZ series, or Panasonic NHG series) in that capacitance range will have an ESR of several tens of ohms that is swamped out by the cathode-anode impedance of the TL431 (~1 ohm). Use of a high quality low ESR capacitor or a ceramic capacitor for soft finish might cause stability issues unless a series resistor is introduced.”

In some Application Notes or Design Ideas also a more extended version of the soft finish solution was given with an additional diode and resistor. This is the one I ultimately used. The three components for the soft-finish are indicated in red. Letters A, B and C indicate connection points, also on the picture of the PCB further in this document.



This slightly more complicated diode-resistor-capacitor solution does not have this sensitivity to capacitor ESR, as the 1N4148 diode isolates the capacitor from the TL431 cathode during normal operation. The 15k resistor will pull the capacitor to a sufficiently high voltage such that the diode is reverse biased, effectively isolating the capacitor from the TL431 cathode after it has done its job in improving the start-up behavior. The 15k resistor also provides a discharge path for the capacitor once the supply is switched off. In principle there is no reason to use a smaller capacitor than with the simple circuit, but according to Power Integrations 10 µF is enough and indeed I have only seen this value being used in their design examples. However, a first attempt with 10 µF did not fully solve the issue and I went back to 22 µF.

Unfortunately, after mounting these three components, nothing had changed in occasionally noting audible noise from the PSU-B. It may have been there always, but since I had my amplifier in a cabinet, I didn't notice. Of course after making a change in the power supply I pay more attention to such issues, but there is no reason why adding the three component soft-finish circuit would result in stability issues or in a reduced switching frequency. Listening more carefully it also does not seem to originate from the part around TOP246Y, it comes from the supply using TNY274.

Used switching frequencies:
TOP246Y: 132 kHz typ.
TNY274: 132 kHz typ. with a jitter of ± 8 kHz in order to reduce EMI. However, this part can work in burst mode when the load is light. This results in lower frequency components. Some phrases from the datasheet below:

Audible Noise

The cycle skipping mode of operation used in TinySwitch-III can generate audio frequency components in the transformer.

The current limit state machine reduces the current limit by discrete amounts at light loads when TinySwitch-III is likely to switch in the audible frequency range. The lower current limit raises the effective switching frequency above the audio range and reduces the transformer flux density, including the associated audible noise. The state machine monitors the sequence of enable events to determine the load condition and adjusts the current limit level accordingly in discrete amounts.

Therefore the 5V standby power supply around TNY274 is the prime suspect, and the occasional audible noise probably always has been there.

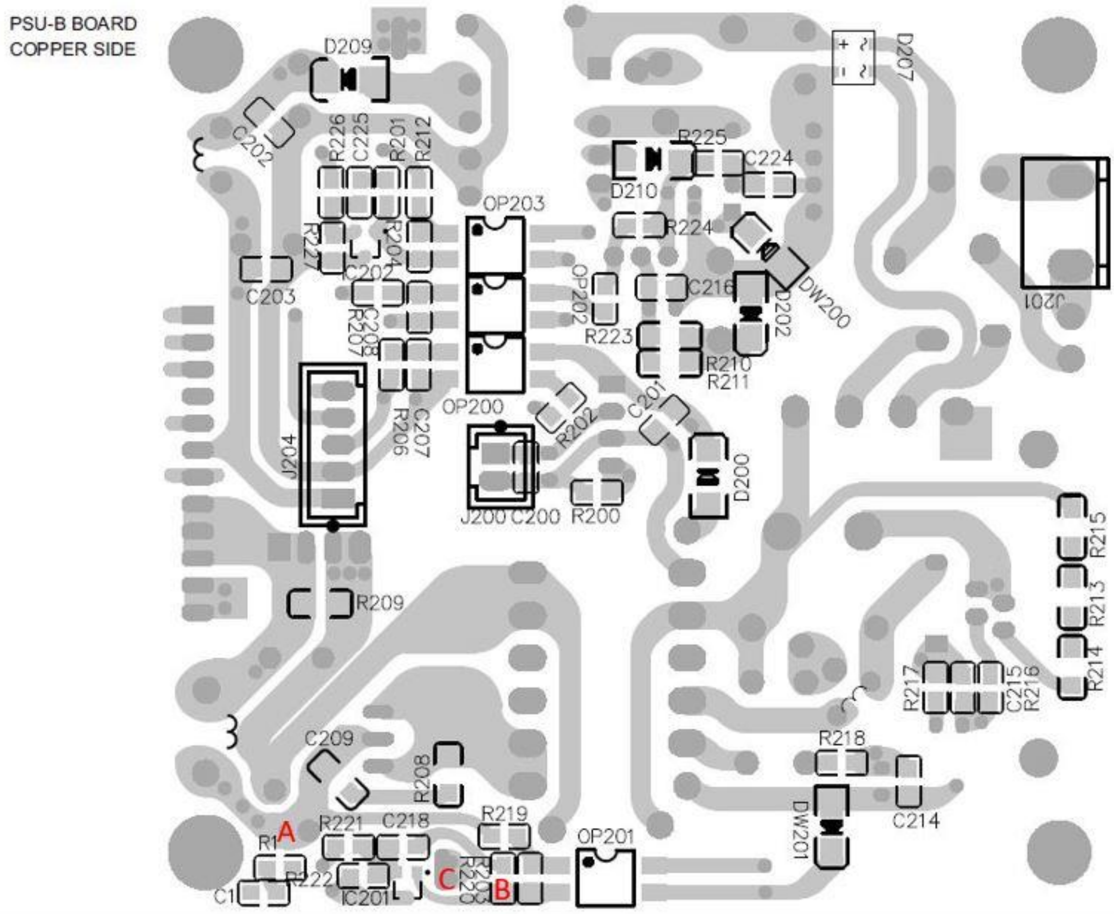
When switching on the amplifier, a number of relay clicks are heard. I noted 7 moments where a relay clicks:

1. K200, which provides power to the supply around TOP246Y.
2. Some small relay on the right, in the MDC module area.
3. Another small relay
4. K100 and K101 on PSU-A, supplied by 5VDS. Main power supply starts operating.
5. Small relay somewhere in the middle.
6. Small relay somewhere to the right.
7. Loudspeaker relay.

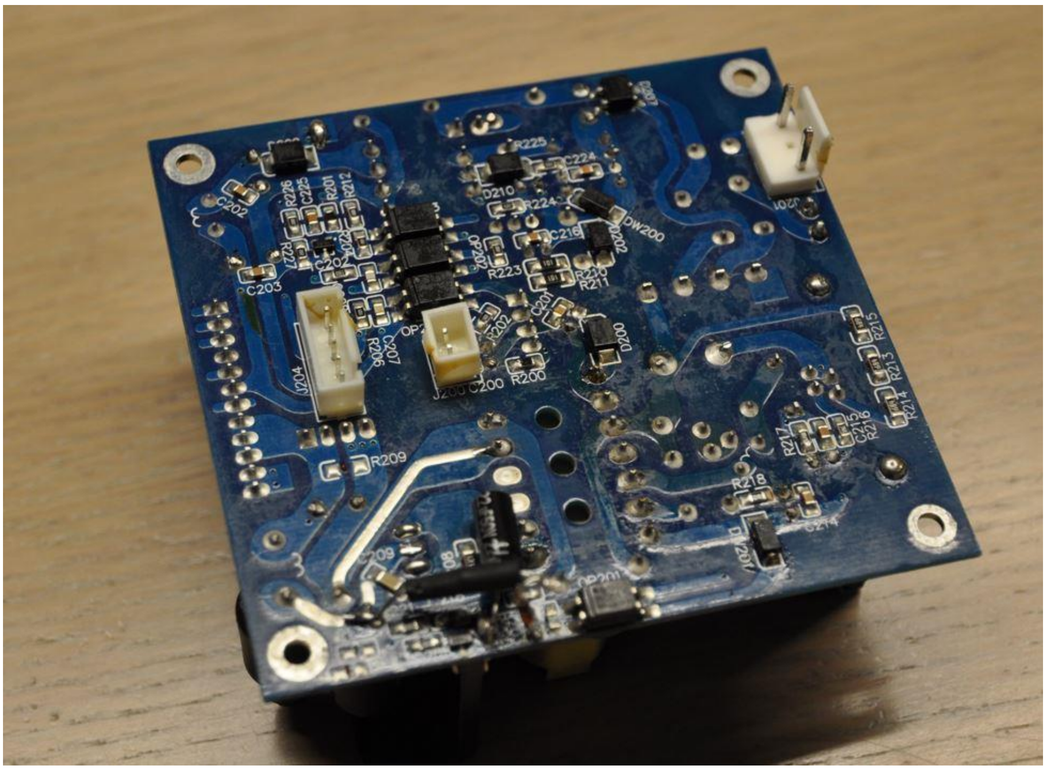
The noise, when it occurs, starts with click number 4, but clearly coming from the small PCB, PSU-B. However, keeping both relays K100 and K101 in does increase the load as they are supplied from the 5VDS which is generated by the supply built with the TNY274, so this is not expected to result in burst mode operation. Also the microcontroller will draw more current when the amplifier is on.

As a result I do not know what causes this sound which happens occasionally. I think it has always been there. In order to check whether something runs too hot in this mode I used a thermal camera to compare the temperatures in normal mode and in the mode when this happens. See below.

In both situations the temperature distribution and actual temperatures are the same. Therefore I have stopped to look further into it.



Bottom of PSU-B PCB with connection points for soft-finish circuit



Picture with components added