"Fixing" the LDG Z100 ATU

25 March 2011

Back on the web page **The Trials and Tribulations of Going Portable (http://www.vk4adc.com/web/index.php/operating-info/43-general/95-trials-tribs-portable-operation.html)** on this site, I revealed an issue with my LDG Z100 auto antenna tuner. Maybe if I didn't operate on the 6 metre band (6m) , I would never have found that there was a problem. The following extracts disclose a bit of the background :

"Ok, the tuner. I then did some transmitter tests with it connected it back in line and using FM to get a constant carrier power & hit the PTT button. The PO bar on the 706 showed 100 watts, as did the SWR meter between the 706 and the Z100, THEN about 10 seconds later, down went the PO bar to around 50% (ie 50 watts), up came the SWR to over 2:1. Hey, these tuners are supposed to tune out impedance mismatches - not create them.

I unscrewed the Z100 top cover, and touched around the toroidal inductors checking for any one hotter than the remainder.. the middle one was - L4. It was very hot. I was then wondering if I had a faulty relay in it. Where would I get another replacement relay ???? There wasn't much I could do there and then - it would have to wait for my return home."

and....

"I also took the opportunity to do some tests on the LDG Z100 in the workshop but this time into a RF power meter/dummy load. I confirmed that effects noted while we were away - some kind of heating effect was occurring with the result that the SWR presented back to the radio rose to > 2:1 on 50 MHz.. The confusing part about this was that it did it even while it was in Bypass mode. I even tried changing over the radio to the older IC-706 (a Mk1) and it showed the same outcomes. Direct to the RF power meter via the SWR meter, the RF power stayed around 100 watts (indicated on the 706 PO display) on 50 MHz FM on either. Via the Z100, the SWR rose and the internal ALC in the 706 throttled back the RF output power, again, on either. I don't have a schematic for the Z100 but have emailed LDG the symptoms and asked for suggestions and a PDF of the schematic.

My conclusions are that there is a component in the inductor/capacitor/relay network that is getting affected by the application of RF at the 100 watt level and either getting lossy or is detuning (changing value) as it heats up. I have to spend a little time investigating the cause (and thus determine a remedy) and am really hoping that it is not RF loss in the PCB material itself. If it is, there is no cure.. To prove what is happening, I will have to either remove at least one toroidal inductor (more likely two) or one relay. Until I get a response from LDG, I am reluctant to do either.

The email back from LDG on their first working day after I sent my email request was quite short :

Hello,

Sounds like a relay going bad.

You may have to burn it up to find the one.

No schematic attached so it looks like I have to do it the hard way.... and that will have to wait for a few days so I have some time to really get stuck into it.

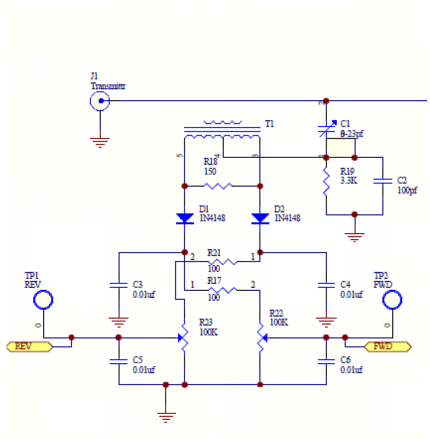
"

It is hard to grab (or retain) respect these days and LDG lost a lot of my respect with their response. It is always the imperative to provide excellent customer service, rather than just some customer service, because you never know what and where your comments may end up. Maybe the person at LDG was not to know that the response would end up on a web page, but anything emailed cannot be regarded as truly private. It may be forwarded, published (the old "copy & paste" process is just so easy) on to a web page (just like I did) and then the word really is "out". That diminishes your future customer base.....

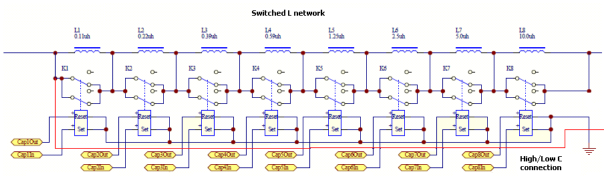
I used to retail the LDG product, and in fact sold quite a few Z100's over several years. Maybe it is not a current product line but the basic design is undoubtedly still used in their most recent releases. A little more help in their email wouldn't have taken much extra time and a PDF of the schematic wouldn't have hurt either.

Back to the actual Z100... To be able to fix "the problem", you must understand the problem - and how the device works. The symptoms were a rise in SWR back to the transmitter after it had already tuned. The critical words are after and already tuned. That means that the basic tuner operation is correct. The SWR sensing circuit , the microprocessor and the relay switching was working. The fault was in the RF path - something was getting "lossy", or hot, or both, once a high level of RF (100 watts) was applied. The additional symptom was : " it did it even while it was in Bypass mode." - which has all inductors in the switched L network short-circuited and all of the capacitor values open-circuited, all via the relevant relay contacts.... maybe there was a crook relay contact in that path ???

The RF portion of Z11 schematic will be similar to the Z100 simply because once a manufacturer has a really good functional design, they tend to stick to it. Sure, a few variations here and there but basically the same each time. (The "if you are on a good thing, stick to it" syndrome.) These extracts from the Z11 schematic show how most of the LDG series of tuners are configured :



This is the SWR sensing circuit. It is a fairly typical arrangement and unless the 3-23pF trimmer is faulty/lossy, there isn't much here to cause a high input VSWR.

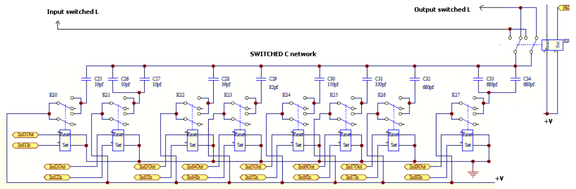


This is the switched inductor network. Each inductor is of toroidal construction. Each latching relay's contacts will be either open-circuit (and thus leave that inductance in line) or be short-circuit. Remember that inductors in series add their values together. By using 8 inductors that can be selected in any combination, there are 256 possible values of inductance available.

If any one of the relay contacts is "soft", that can mean that it does not connect properly (ie short-circuit effectively) and thus may leave an extra inductance in the circuit effectively permamently. Alternatively, the relatively high RF current through the contacts may cause heating and the contact resistance to actually rise. Either way, it can amount to a series inductance or resistance, or both, that will cause an impedance change and RF power loss.

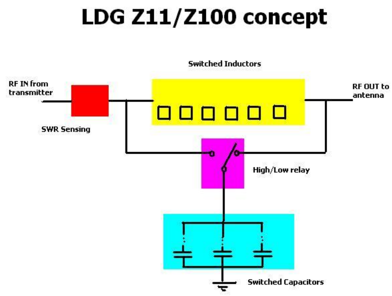
The contacts on just one relay being faulty could cause the fault I have discovered.

In case you haven't noticed, the connection tags on this schematic and that of the switched capacitor network have the "tags" swapped. This one should read, for example, Ind1Out instead of Cap1Out, and vice-versa on the capacitor bank..



This is the switched capacitor network. Unlike the inductor arm, these relay contacts are arranged to either open-circuit or short-circuit the path to the individual values of physical silver mica capacitor. Remember, capacitors in parallel add their values together. By using 8 capacitors that can be selected in any combination, there are 256 possible values of capacitance available. Actual values are 10pF, 20pF, 40pF, 82pF, 150 pF, 33pf, 680pF, 1360pF giving a maximum capacitance of 2340pF and a minimum approaching zero (0pF) with all relay contacts open circuit.

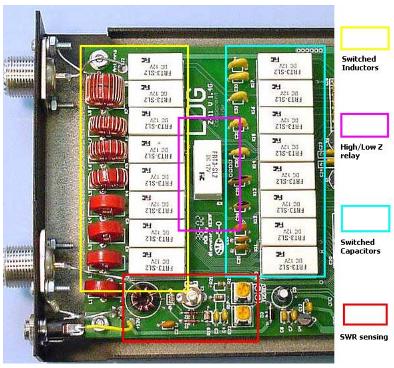
If one of the relay contacts in the actual capacitor switching network is faulty, it will be either open-circuit or high resistance. Note that both sets of relay contacts in each physical relay are paralleled so reducing the likelihood of this area causing the slow rise. The fact that it happens at 7 MHz as well as 50 MHz means that the selected values of C to obtain an impedance match are going to be widely different.



The interesting part of the schematic at left, and made more obvious by this conceptual block diagram, is the relay contacts at the upper right hand segment. This relay switches the capacitor "bank" (or switched C network) across either the input or output connection thus creating either an "L-network" impedance transformation network either up or down in ratio, i.e from 50 ohms to a higher impedance (eg 50 to 1000 ohms) or from 50 ohms down below it (i.e 3 to 50 ohms) .

The 256 values of inductor plus 256 values of capacitance provides an actual 65 thousand possible component/Z-matching settings, then add that it can be up or down matched, doubling that to 131 thousand settings possibilities.

Please note that the actual load impedance may not be purely resistive, almost always it will have an inductive or capacitive component at the applied radio frequency.



The RF section of the Z100 PCB layout follows the same trend as the Z11 image shown here. The microprocessor part of the unit has been updated to reflect the later technologies but it still does the same thing : measure the forward and reflected voltages and either sets, or re-sets, individual latching-style relays.

The LDG tuners use a microprocessor to sense the input SWR through the input detector (circuit at top left), apply a series of test L & C settings very quickly (by setting various inductor and capacitor values through respective relays) to try to initially decrease the input SWR. The microprocessor then goes into a fine-tune mode to minimise the SWR.

The reason that latching-style relays are use is primarily to reduce current consumption - these stay in the last-energised state - hence the two windings shown on the schematics : one to "set" and the other to re-set".

A more-detailed explanation is provided in the

Z100 manual (PDF) (/~vk4adc/web/images/UserFiles/File/z100/z-100manual.pdf) (about 440KB)

How it works is fairly straightforward and, explained for the most part, above. I should also mention that the PCB is marked as a V2.3 and has a V2.3 version firmware installed. Other later revisions marketed as the Z100, Z100Plus, newer models etc... hopefully will not have the effects noted on this web page.

Each inductor is in series with the next between the input terminal (from the transmitter) to the output terminal (antenna connection). The typical values are 0.11uH (for 0.1uH), 0.22uH (for 0.2uH) , 0.39uH (for 0.4uH), 0.56uH (for 0.6uH) , 1.25uH, 2.5uH, 5uH and 10uH. Each one has a shorting set of relay contacts. If all are set "open", the maximum inductance is the sum of all values : about 20uH. If all relay contacts are set "closed", the series inductance is basically that of the PCB layout inherent track inductance plus relay contact inductance - hopefully quite low - but always a constant value.

As I tipped above, my suspicion is that it will be one of the relay contact sets in the switched inductor arm of the L-network. The question is : "how do you find out which one ??".

The easiest approach is to "bridge across" each set of contacts in turn while the tuner is in Bypass mode. It is no good just trying to measure contact resistance because the inherent low resistance of the relevant toroidal coil will probably hide any variations in actual contact resistance. This bridge-ing might be done with a soldered wire or maybe a suitable insulated tool.... Just remember that 100 watts of RF at 50 MHz can easily cause significant RF burns to fingers and hands.... SAFETY FIRST !!

Well, I was wrong again... I have just gone around with a short-ish screwdriver across each inductor while in Bypass mode, 50 MHz in, and there was no real difference. The interesting bit was that, at one stage, the palm of my hand touched the edge of the PCB up in the controller section and I had a sensation of an RF burn.. Just a little bit but enough to make me wonder why.

It was time to get out the temperature probe - with RF power being lost in the ATU, it had to be going somewhere. The relays and inductors were all around the same temperature, just above shack ambient. The underside of the PCB was warm up near the back panel though. The top side of the PCB there contained only one component : a RFC consisting of a wire through a long ferrite bead. I monitored it's temperature directly while applying RF and watched the temp quickly climb to over 100 degrees celsius... Now I knew where some of the RF was going - but not why.

This RF choke was connected between two "earth planes", one for the RF section - the inductors, capacitors & relays etc.. & the other for the "control" section - the microprocessor that selects the relays. Bridging the RF choke with the screwdriver caused the transmitter output to return to around the 70 watt ((indicated on the 706 PO display) mark and the input SWR to drop from around 2.2:1 down to 1.7:1, so while somewhat better, still not the whole answer. I then soldered a wire strap (using solder braid. or braid-wick as it is also known) directly across the RF choke so I could experiment with changes elsewhere on the PCB.

It didn't take long to try another short-circuit with the screwdriver blade across the end of the PCB track to the "other" earth plane at the very end of the relay-switched capacitor arrangement. The transmitter power went up to 100 watts indicated, the input SWR dropped a little further - down to around 1.5/1.6:1. I was seeing about 70 watts of RF out from the tuner regardless of whether in Bypass or Tuned mode now. The RF power to the dummy load was staying pretty steady too, from transmitter keydown for many minutes - not like the original power drop within a few seconds. I no longer suspected relay contacts, my thinking quickly changed to "is this a PCB fault ?".

The question then arises : why is there such a RF potential between these two earth planes ? The need to separate the planes is a fair and reasonable RF practice but why this RF effect at this magnitude ? Is there a connection there on this particular PCB layout (V2.3) that shouldn't be there - or is there a track missing ??? It's a bit hard to know without the "official" schematic.....

Most of you probably know that even a short length of wire represents a fair inductance at 50 MHz so the earth lug wires from the back panel yelled at me - " we shouldn't be this long !!!". That lead length may also be the reason why the SWR wouldn't drop below the 1.5:1 / 1.6:1 region even when into dummy load. Soldering iron in action (again), I removed the tinned copper wire leads, rotated the solder lugs under the SO239 connectors so that they pointed directly downwards and fashioned them so they could be soldered directly to the PCB itself - onto the RF plane section. The wires from the centre pins were shortened too, to the minimum that would fit.

Did the above changes alter the input SWR at 50 MHz ? No, not much... plus the ATU still seems to be losing about 20 watts in 100 watts, which is really only about 1dB loss. Given the number of relays plus associated components in line, that might even be called acceptable.

I continued a few more tests to see if I could find any RF heating, and just using my finger as a temperature sensor, found that a few (but not all) of the soldered joints for the toroidal inductors were warm (to hot). Even after being resoldered, they still warmed up - even though the toroids themselves didn't seem to be as warm as the joints themselves. At this stage, the SWR seems to be as low as it can be given the PCB layout - and lack of other technical data - so I guess I will have to leave it there, modified as it is now. Yes, it is better than it was - but not as good as I would have expected. Why the ferrite-style choke was getting hot is still a mystery.....

I should point out that a "normal" user may never run 100 watts of carrier at 50 MHz into their Z100 and hence notice and "measure" the effects the way I did. I noticed it even when running SSB and then only because the RF output indication on the IC-706 transmitter dropped to around the 50 watt mark, an effect particularly noticeable during operations like field days and/or contests where the transmit duty cyle is fairly high (during busy periods).

Should LDG have sold the Z100's as suitable for 50 MHz (as well as the 1.8 to 28 MHz basic coverage) ??? If all of the others work the same as mine, NO.

I would be interested to hear from other LDG auto-tuner owners, Z100 or other model, as to whether they have also found the same effects in their units. If you have one, do the tests....

Transceiver --> SWR meter --> LDG tuner --> good 50 ohm dummy load

Check the SWR from the tuner back to the radio - the 50 ohm load should supply a 1:1 SWR on the load side of the ATU. Change the frequency from band to band up to 50 MHz and note the actual SWR reflected back to the radio by the ATU (as necessary : recalibrating the SWR meter as the frequency is changed).

If it is high (> 1.5:1), lift off the cover so that you can send me the LDG model code plus PCB production code (usually printed along one edge of the top side of the PCB along with a date code eg 0748 - ie 48th week of 2007..). Include the SWR values too so I can tabulate them for other readers/users to cross reference.

Email me and let me know your findings.

So much for the comment from LDG about the "relay going bad".....

POSTSCRIPT : I emailed a link to this page to LDG and received an email back on 27/3. It contained just one line :

Thanks for the info.

Still such great customer service !!!

Interesting to note that there was no rejection of the issue - or confirmation either ! (I suppose the " neither confirm nor deny" rule applies at LDG.

Addendum : I found a couple of interesting notes on Yahoo Groups : http://groups.yahoo.com/group/LDG-auto-tuners/message/3196 (http://groups.yahoo.com/group/LDG-auto-tuners/message/3196) where the last paragraph was relevant to the topic on this web page :

"I tried the unit on 6M but was not pleased- SWR remained high. On 10M it worked like a champ! I have not tried it on other bands yet.

Thanks & 73, -KR4WM"

Another was at : http://groups.yahoo.com/group/LDG-auto-tuners/message/231 (http://groups.yahoo.com/group/LDG-auto-tuners/message/231) and it contains the comment :-

"In the May 2004 issue of QST there is a write up and it states, "An early production unit exhibited some inconsistent tuning results on 6 meters. The manufacturer has developed a method of improved internal decoupling that solved this problem and the results (QST's) reflect the change. LDG states that this will be included in the future production units and that anyone having problems with 6 meter tuning on early units should contact them directly.

Marty KG6QKJ"

This post describes the same experience I had : http://groups.yahoo.com/group/LDG-auto-tuners/message/1976 (http://groups.yahoo.com/group/LDG-auto-tuners/message/1976) : "Hi All

Has anyone experienced decreasing power when using the Z100 on 50 Mhz ?
I have a IC7000 VIA Z100 into a dummy load using 10 watts, after about 15-20 seconds the output reduces to 2 watts and the choke L12 gets extremely hot. Other bands appear ok. LDG have replaced the original PCB and the new one exhibits the same condition. Even if you have not seen this condition using your set up, could I ask you to try this test and let me know the result.

Regards and thanks

Ian C Frith

G4GIR"

As a response : http://groups.yahoo.com/group/LDG-auto-tuners/message/1983 (http://groups.yahoo.com/group/LDG-auto-tuners/message/1983) : "Well, what you describe sounds like the same problem, Just remove the cover and after a few seconds transmitting drop the RF and feel the small choke (L12) below the antennae input socket . If that burns your finger then thats where your cq's are being dissipated. Hope other people can try this."

See also the followings posts :

http://groups.yahoo.com/group/LDG-auto-tuners/message/939 (http://groups.yahoo.com/group/LDG-auto-tuners/message/939)

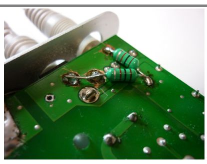
followed by http://groups.yahoo.com/group/LDG-auto-tuners/message/951 (http://groups.yahoo.com/group/LDG-auto-tuners/message/951)

It seems a number of others with Z100's have had the same type of issues - which LDG did not really resolve - even in later production models !!!!

March 31 2011 : I have ordered the V2.8 firmware update for the Z100 and expect it will arrive in the next few weeks - not that it will fix the loss & layout problems noted above.

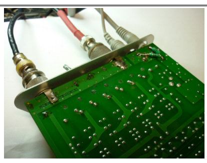
April 3 2011 : After some experimentation, I now have an acceptable (to me) SWR on all bands including 50 MHz.

I have disconnected the original ferrite-core choke that connected the RF and control segment ground planes, isolated the incoming DC and Tune 'ground' sockets via 1mH RFCs and then strapped the capacitive switching PCB land of the RF section to the control section in four places. The result is a "active mode" SWR of 1.15:1 and a "Bypass mode" SWR of 1.3:1 on 50MHz. Finally, the tuner is doing what it should have in the first place.

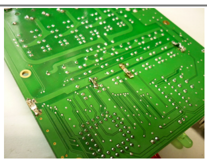


This shows the isolation of the two "ground" points - the DC power input plus the Control input - via a pair of 1mH (1000uH) RF chokes. The sockets were both removed then the 4 fingers of PCB material cut away both top and bottom of the PCB until there was no continuity to the earth plane. Once that was complete, the two sockets were resoldered back onto the top of the PCB and the RFC's added underneath.

Maybe this modification is not entirely necessary BUT what it does do is stop those flyleads from providing another "RF path/earth" to the Z100.



The tags from the two coax sockets were taken below the edge of the PCB, a section of the protective green coating removed and then the tags given a sharp 90 degree bend and then soldered directly to the underside of the PCB. What this photo does not show is the "grounding braid" across the gap in the track layout up in the top right hand corner. It was soldered between the solder tag and the original ferrite choke solder point near the two RFC's.



This shows where the solder braid was added to the capacitive arm to enhance the total ground plane of the unit and thus decrease the SWR at 50 MHz.

FINAL NOTE : The SWR on all bands into the 50 ohm RF load is now in the order of 1.1:1 on all HF bands 1.8 to 28 MHz, and about 1.15:1 on 50 MHz. Success at last.

Postscript : April 23rd 2011 : Email from Dave VK3AIF...

"G'day Doug,

I have an LDG Z200pro that exhibits similar tendencies to you Z100 pre modification. I have so far not bothered to look at the internals or investigate further and just decided not to use it above 28 MHz. It sounds to me like the inductor that is heating up is reaching its Curie point? Ferrites do that when saturated and some do not recover but it is interesting to note that someone else had the same problem at only 10 Watts?? Perhaps removing a few turns if there are plenty on might also have helped? I will keep your article in mind if I ever decide to improve mine.
73"

My reply contained : "There is only a single wire that passes through a long ferrite bead in the Z100 so it is a bit hard to reduce the number of turns....." along with other comments on topics not relevant to this web page.