Daughterboard Low Pass Filter Relay Solution To Reduce uBitx v3/v4 Harmonics

by GordonGibby KX4Z

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INTRODUCTION
Multiple volunteers have measured CW harmonics from the wildlly popular short-kit ubitx (hfsignals.com) that appear to be stronger than the -43dB (relative to fundamental) spurious response specified in FCC (USA) Regulations.

Measurements suggested that the primary problem is "bleed-through" within the relays, where the input and output signals from low pass filters are physically very close to each other (on opposite sets of contacts in a very small relay). Some measurements suggested that at some frequencies, the bleed through by itself might be as much as -20 dB -- significantly compromising what are otherwise excellent low pass filter designs in this innovative and low cost short-kit transceiver.

As one of multiple volunteer efforts to improve this situation, I designed a way to move the INPUT switching of the low pass filters to an external daughterboard. This document explains how a hobbyist might construct this solution. No guaranteed performance can be assured at all by this volunteer effort but measruements of signals from my own ubitx suggested dramatic reductions in all harmonics except those right around 24 MHz, and even then, the harmonics were reduced to likely acceptable levels. Other harmonics were reduced by large margins, exceeding 10, 20 dB in several cases by my estimation. The SSB harmonics from the ubitx (v3 v4) were not as strong as the CW harmonics and it would be expected that this modification would also basically eliminate any difficulties in the USA for those as well.

Other volunteers have found additional near-band spurious responses due to the plethora of mixer products which occur ONLY with SSB transmissions on the 17meter and higher bands --- this daughterboard is not intended to tread those difficulties and DOES NOT address them. Those spurious responses typically can be found at (45 MHz - intended transmission frequency) and are not a problem for use of the transceiver in CW mode on any band (because of the direct generation of the CW signal), and are not a problem for use of the transceiver on SSB below the 17m band.

The above information is gleaned from posts by many volunteers on the BITX20 groups.io forum and have not been independently verified by me but appear to be from reputable experimenters.

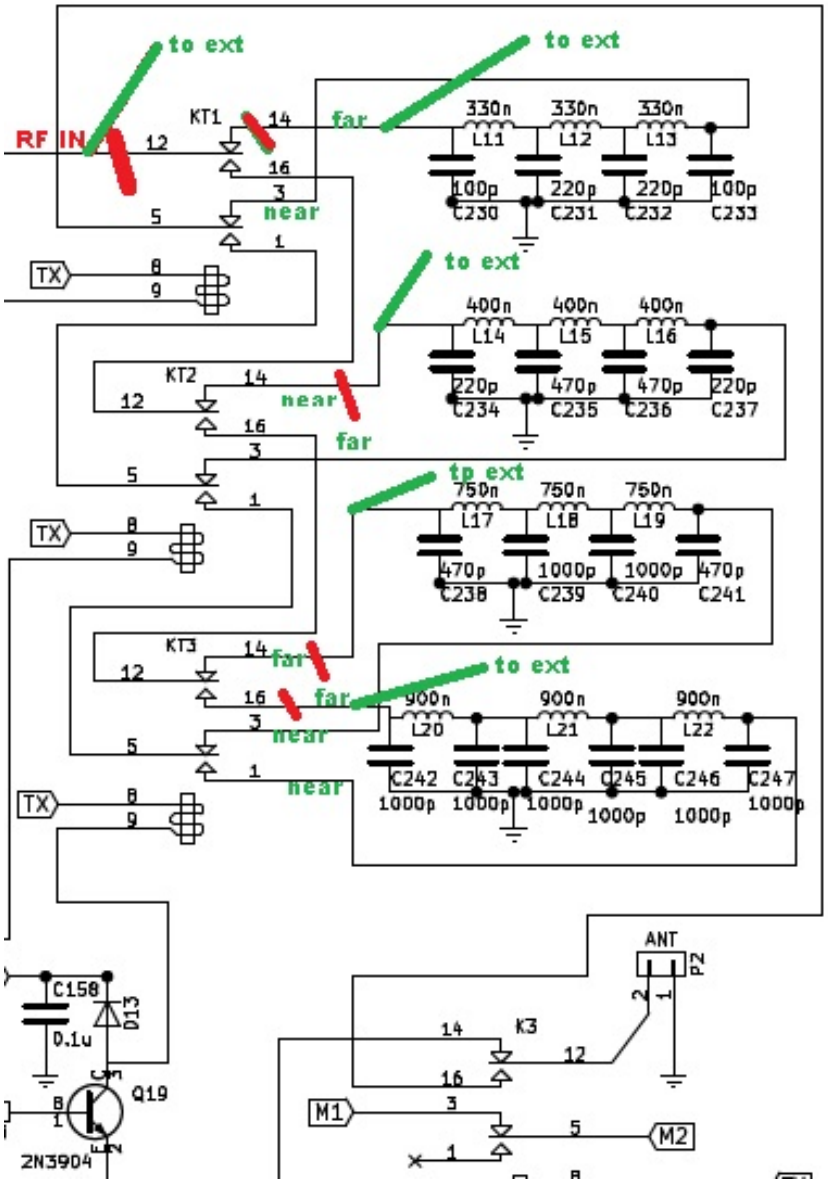
SUMMARY: With this daughterboard modification, the uBitx should be usable in the USA for CW & SSB on at least the 80/40/30/20 meter bands (I was unable to test on higher bands due to my lack of adequate test equipment.

DESIGN

The design of this modification has been documented in detail, see:

GitHub	https://github.com/ggibby1/uBitxExternalRelays/blob/master/OutboardRelaysDesignDocumentTry3.pdf
WWW	http://qsl.net/nf4rc/2018/OutboardRelaysDesignDocumentTry3.pdf

Briefly, the following breaks (red cuts) and connections (green lines) are made into the relay switching for the Low Pass Filters:



Then relay control voltages are tapped into as follows:

Signal	Connection Point
TX -- switched +12 that is live whenever in TRANSMIT mode	TOP: Junction between D11 and C154 is an easy point to solder to Alternatively, pin 8 of KT1 on bottom.
Control to KT1	TOP Junction of D11 and Q17 easy to solder to either.

	Alternatively, pin 9 of KT1 on bottom.
Control to KT2	TOP Junction of D12 and Q18, easy to solder to either Alternatively, pin 9 of KT2 on bottom.
Control to KT3	TOP Junction of D13 and Q19, easy to solder to either Alternatively, pin 9 of KT3 on bottom.

Caution in understanding the pin numberiing of the KT relays is advised as they aren't necessarily the same pin numbering convention as other popular relays.

CONSTRUCTION

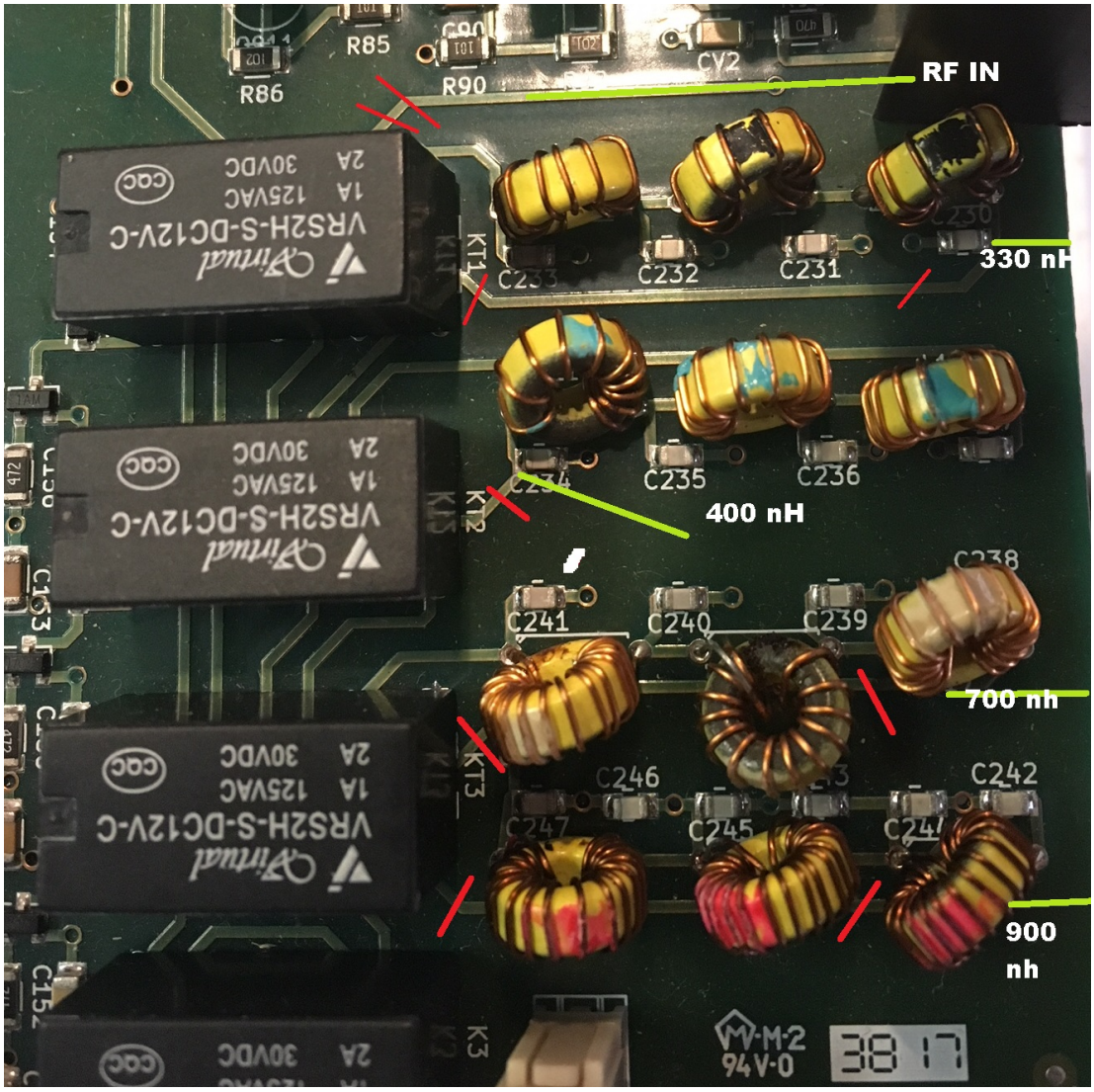
List of materials:

Printed circuit board	Gerber files can be submitted to pcb fabriactors (e.g., pcbway.com) and are freely available here: https://github.com/ggibby1/uBitxExternalRelays/blob/master/GLGExternal.zip
Relays	NOTE THAT THESE RELAYS ARE POLARIZED. For the printed circuit board to work properly, the relays must be installed on the component (silk-printed) side. Digikey 255-1079-ND https://www.digikey.com/products/en?keywords=255-1079-ND $3.89 each. It is likely that a less-expensive substitute would work well. The relays utiized in the uBitx itself are available at a cheaper price but the polarization of the relay coil may be reversed requiring changes to the wiring of the relay coils for them to operate.
Inductors	Digikey 587-2192-1-ND https://www.digikey.com/products/en?keywords=587-2192-1-ND $0.20 ea.

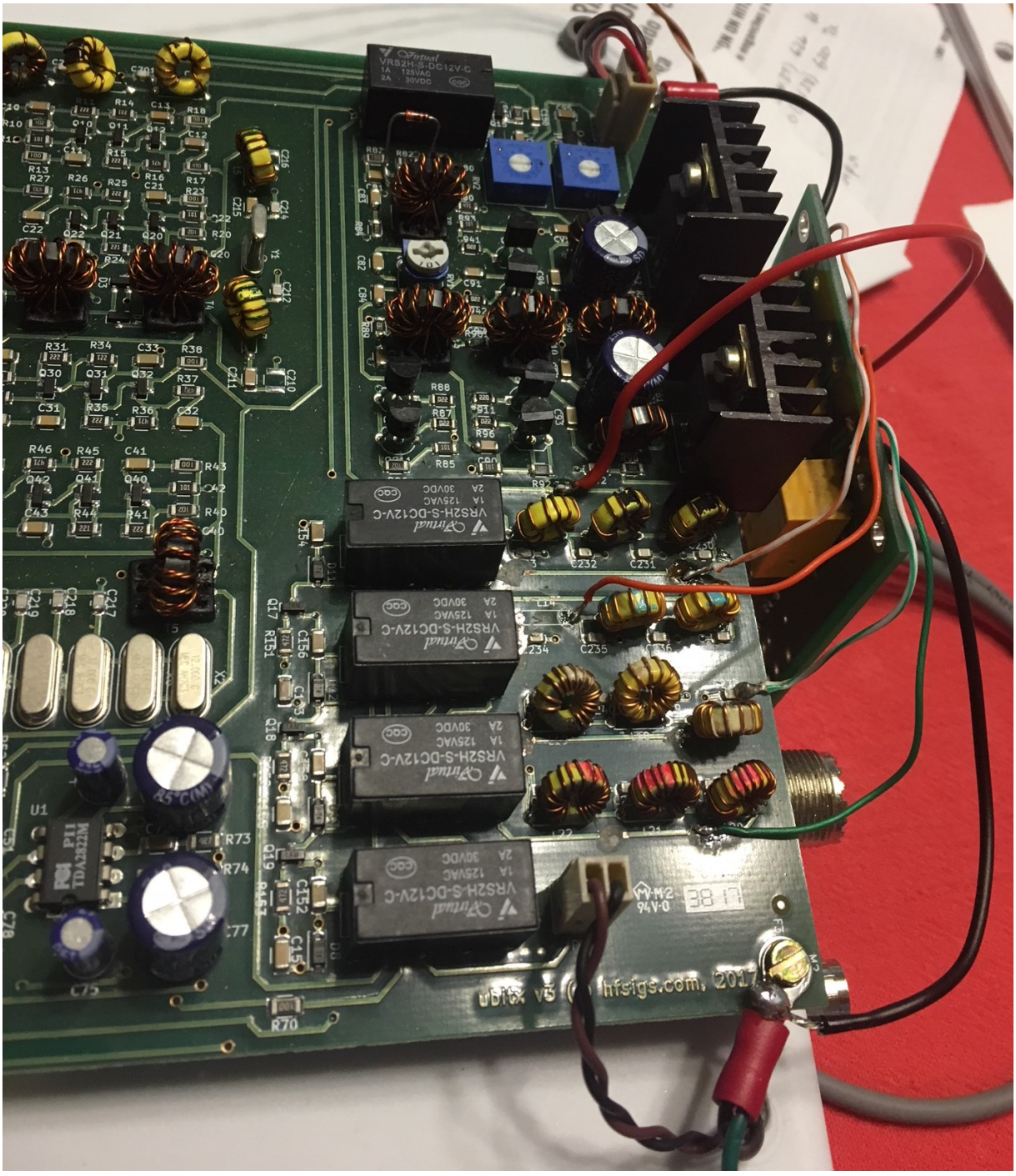
	This is an SMT product but a moderately large one. If you're unable to deal with this part, simply jumper the pads and eliminate this part. The results haven't been tested but are likely to be acceptable.
Bypass Capacitors	Digikey BC1160CT-ND https://www.digikey.com/product-detail/en/vishay-bc-components/K104Z15Y5VF5TL2/BC1160CT-ND/286782 $0.22 each. This is a through hold part
Wiring	Suggest #24 stranded wiring. Wire from ethernet cable works well. If possible, use shielded wire (multiconductor is fine) to carry the relay control voltages from the uBitx to the daughterboard. Use shortest possible direct wiring for the RF wiring. Mount the daughterboard physically right next to the uBitx to shorting wiring and orient so the contact side of the relays is abutting the ubitx for shortest RF wiring. Consider using shielded or twisted pair wiring for the "input" RF lead. (not tested).
Diodes	Use any silicon diode, 1N4001, 1N4004, 1N4007 or similar would work fine.

PHYSICAL CUTS AND CONNECTIONS TO THE uBITX Board:

I used a Dremel tool but this turned out to be much more difficult than I expected and I damaged one inductor. Other experimenters have said that an Exacto knife makes it far eaiserto cut sections out of these traces and even lift up unwanted wires remaining. Scrape off a bit of the solder resist on the "RF IN" long trace to solder to. For most of the other RF connections, you can either solder to the trace (after removing some solder resist) or to one of the exposed capcitor/inductor pads that makes the proper connection. If you are using a dremel, hold it in TWO HANDS and come directly vertical and make light pressure to maintain better control. An exacto would likely be a better choice.



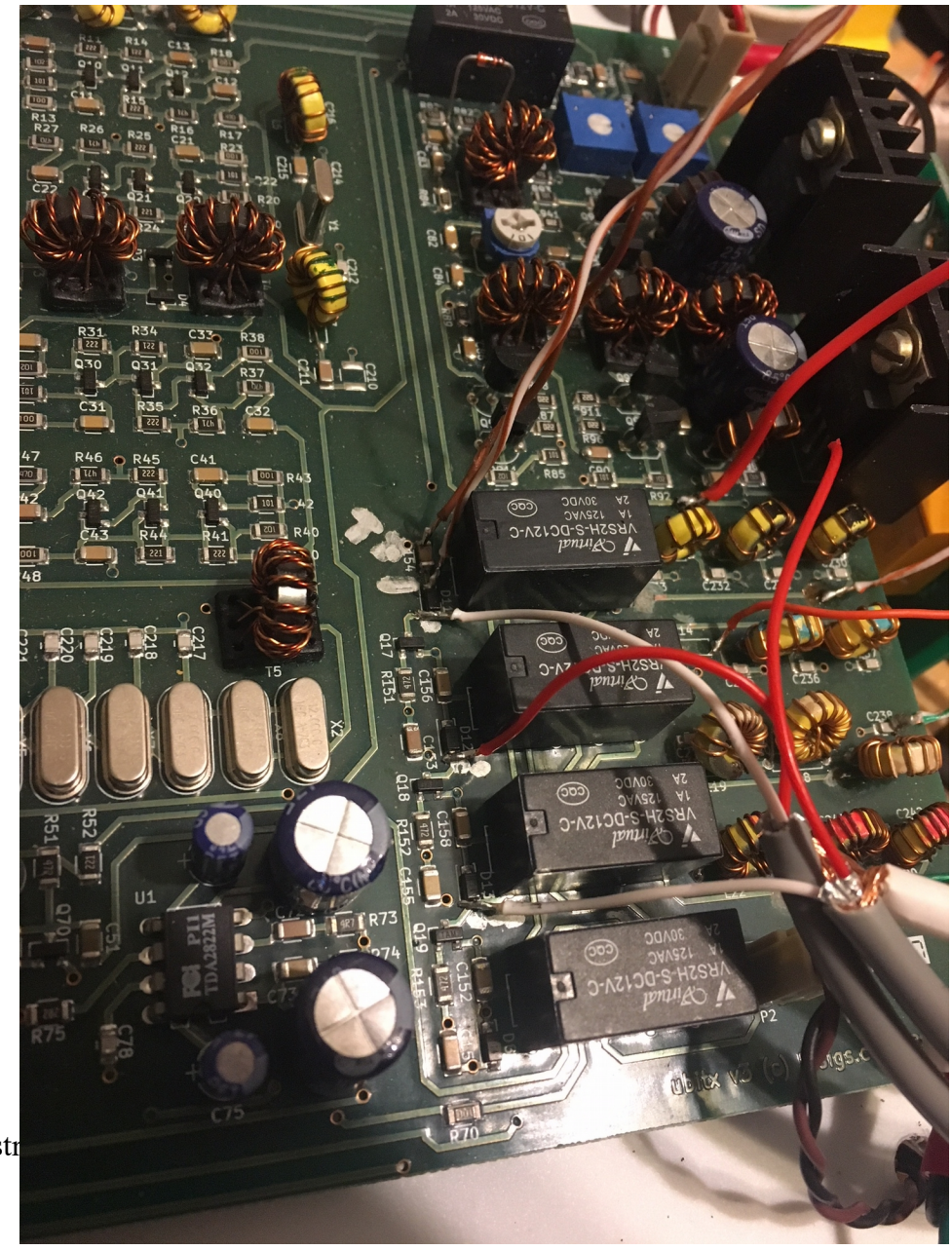
RF WIRING COMPLETED:



Be certain to ground the Daughter board in at least two locations on the uBitx board. You can see the black wires here going to the corner ground connections using ring terminals.

RELAY CONTROL WIRING:

TX (switched +12)	Brown-White wire soldered to connection of C154 and D11
Ground	Brown wire soldered to the grounded side of C154
KT1 control wire	top white wire soldered to the transistor-side of D11
KT2 control wire	red wire soldered tothe transistor side of D12
KT3 control wire	bottom white wire soldered to the transistor side of D12



Constr

TROUBLESHOOTING

Verify that you have rf output power on the desired bands.

If you don't, try to verify that the relays are receiving proper control voltages

All three relays should get coil voltages (measure across the coil) on 80 meters
Two relays should get coil voltages on 40 and 30 meters
One relay should get coil voltage on 20 meters

In order to trace RF transmitter signals, a voltmeter on a 200 volt AC scale can be used. If there is Transmitter CW signal at a point, it will read a significant voltage on many AC voltmeters.

PERFORMANCE

There are no guarantees with a homebrew circuit such as this, however the following table of BEFORE/AFTER signal charts shows significant reduction in harmonics. The S-meter on the ICOM718 used as the measruement device is not calibrated, however, between S7 and S9 it appeared to be 12 dB/S unit. (S-units are "nominally" 6 dB but the measurements between S7 and S9 were pretty solid that in that range at least, this reciever is 12dB per S unit). It is not known what the S units below S7 are worth.

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Presented witll be the BEFORE/AFTER  S unit measurements where before is the relatively
STOCK uBitx and the AFTER is is with my external daughterboard, with basically unshielded
wiring.  All measurements are for CW (because this is where the unit had the most problems)
Power is estimated from a Micronta cheap SWR/power bridge built for CB'ers many many years
ago

FREQ  PWR     FUNDAMENTAL 2ndHArm  3rdHarm  4thHarm 5thHarm  6thHarm  7thHarm
3.505 5 W/5+W S9+30/S9+30 S7.5/ S7 S8.5/ S6 S0 /S0  S8/S1    S0 / S0  S8.5/S8
(so on 80 meters, the 3rd and 5th harmonics were greatly attenuated, and the 7th lost maybe
6 db)

7.005 2.5/3.5W S9+30/S9+30 S0/ S0   S8.5/S7  S5.5*/S0  *=wavering
(so on 40 meters, harmonics went down by huge amounts

9.995 1.5/1.5W S9+30/S9+30 S0/S0    S9/S5 (or less)
(so on 30 meters, the 3rd harmonic was basically demolished)
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