How to build a $20 Banggood HF-PA kit

by
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(VE7DXW)

…and succeed without going MAD!!!

Good points of the design and kit ?

- Nice, compact 45W HF-AMP (as claimed)
- Drive power requirements of 100mW for 45W out
- Uses MOS-FET (IRF-530) transistors as finals (clean and cheap)
- Well designed circuit board – for most part
- Easy to install 805 size SMD components and thru hole construction.
- Only $20.- US

Shortcomings of the design and kit ?

- Missing and broken components
- No Instructions for this build and board!!! Not even in Chinese!!! Used V1.3 which is and approximation of the supplied kit!
- The kit looks easy and with proper instructions you could build it in a day (not so…)
- Thermal runaway correction system missing! This kit never ran for more than 5min, before blowing the MOS-FETs (how to fix, see below).
- It has potential, but there is a steep leaning curve! Thanks to Earl Rubin - 4Z4TJ for starting a document in English for this kit!

What's on the PCB, but not in the Schematic

- Improvement of input circuit by adding a 3dB attenuator. (R12=20Ω, R22,R23=300Ω)
- Damping resistors that are needed to linearize the preamp and to prevent parasitics. (R20 = 220Ω and R21=47Ω – not quite sure on that one yet)
- T1has now two separate windings (8 primary and 4 turns secondary), use smaller gauge wire than supplied
- A bias protection system using diodes, not working as desired! (Do not install.) Use new design – see below
- A bigger resistor (R18) to protect Q2 (2SC1971) - but still not enough power dissipation?
- T2 windings are 4 primary and 2 secondary

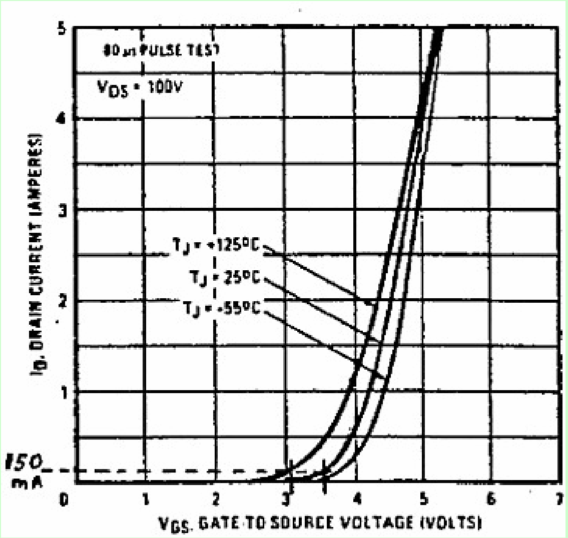
How to construct SMD Board with a standard soldering Iron

Here is a YouTube video on how I soldered SMD with a standard fine soldering iron. I used magnifying goggles for easier placement of the components.
https://www.youtube.com/watch?v=PU7wLcuqc-I

Instructions for Ver. 1 PCB from 4Z4TJ – Thank you!
http://www.caarc.ca/wp-caarc/wp-content/uploads/2016/03/Banggood-IRF-530-PA-Instructions-V1.3-.pdf

What is Thermal Runaway?

Without thermal runaway correction, the power transistors will destroy themselves. As they warm up and more current starts to flow, they become progressively hotter and finally overheat. This occurs even without input signal. This is the law of physics and the design needs to address this.



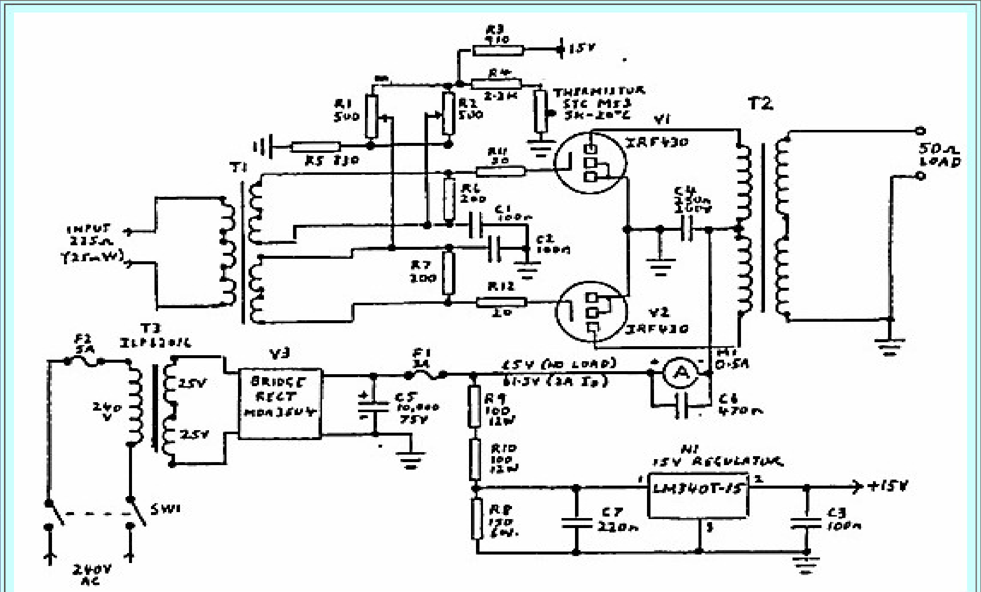
[Demo of MOSFET thermal runaway]

Figure 2 Over a temperature range of 25 degrees C to 125 degrees C, a change in gate to source bias volts of 3.5 to 3.1 volts is needed.

According to the graph, at room temperature the bias required to create a DC drain current of 150mA is 3.5V. To maintain this current throughout the temperature range of the transistor, a temperature sensitive resistor (NTC) circuit has to be designed that reduces the bias as the temperature of transistor increases. At junction temperature of 125°C the bias has to drop to 3.1V to maintain a DC drain current of 150mA per transistor.

Other designs using IRF MOS-FETs

A MOS-FET design proposed in 1989 by VK5BR. In this design there is a thermal runaway protection circuit using R1 to R5, including a NTC as a temperature sensor. The rest of the design is quite different, especially the fact that the supply voltage is 60V. By using 60V it is possible to create an output of 50W by drawing only 2A!



NOTES:
1. V1 & V2 mounted on 8 inch mullard 55D heat sink & insulated with beryllium washers.
2. STC M53 thermistor glued to heat sink.
3. T1 - 18 turns, 7 filar wound 35 SWG on 9 mm toroidal core u = 128.
4. T2 - 18 turns, quadfilar wound 22 SWG on 29 mm toroidal ferrite core u = 800.
5. Set R1, R2, for static Id of 150 mA in each transistor.

Figure 3 Linear Amplifier Circuit Diagram.

by **Lloyd Butler (VK5BR)**

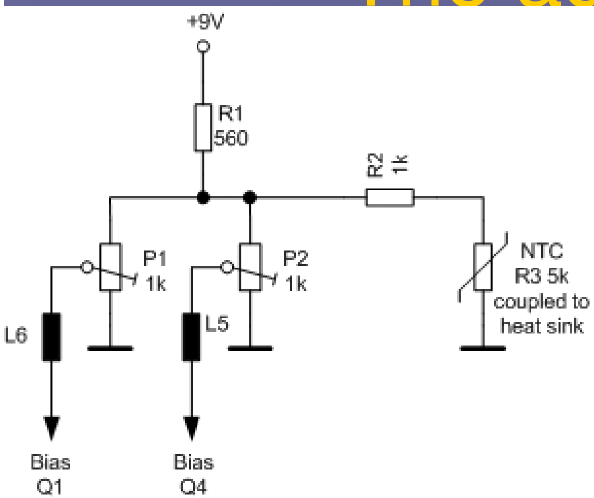
In his paper, that was published in Amateur Radio (November 1989) he claims that the input only required 25mW to fully drive the amp to 50W.

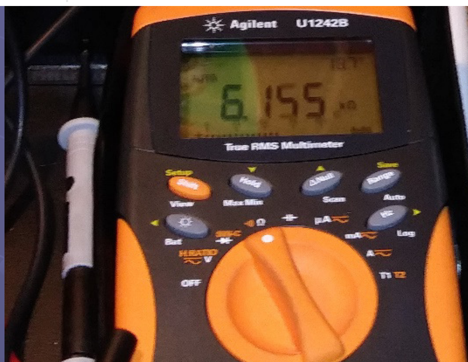
In this paper he also states that this amplifier requires Π filters to meet spectral-purity regulations.

One drawback of the MOS-FETs is that the power output drops off rapidly as one uses higher bands.

This design is only usable for up to 10MHz with reasonable results.

The added Bias Protection Circuit





The schematic on the left is the same as the one used in the design on previous page. The difference is that the supply voltage of the BangGood kit is 9V and that the NTC is 5k at 20°C but is not the part used there.

In order to come up with a design we need to characterize the 100°C point of the NTC which was supplied by RPE (#02-N502-1).

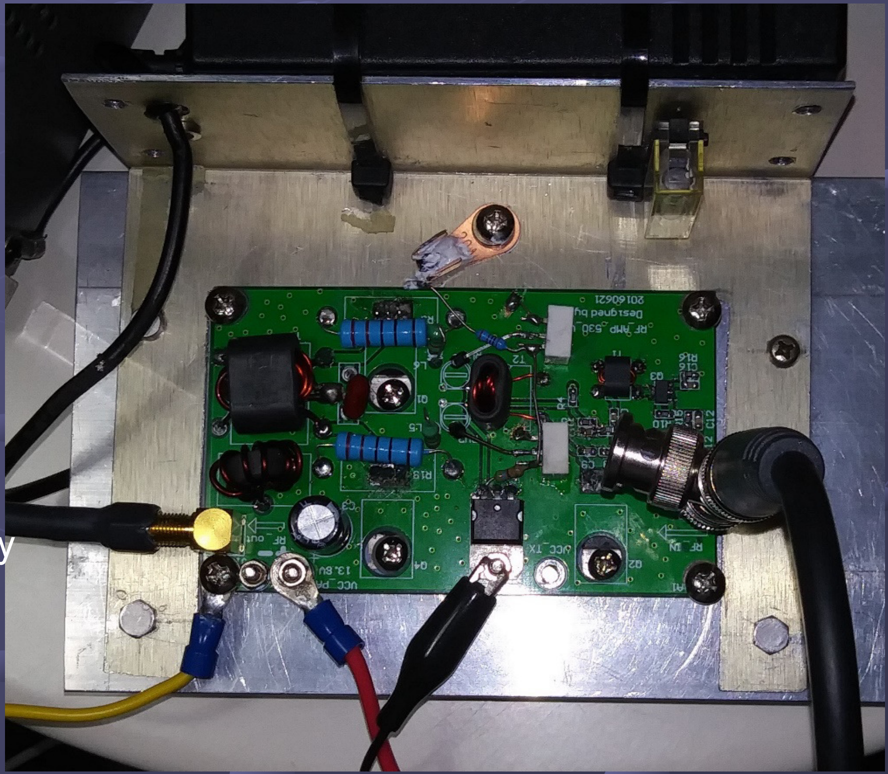
To do this, I used our kettle and after it boiled the meter read 500Ω. Now we can calculate, using Ohms law, the resistive values required to drop the voltage from 9V to 4.5V (@ 20°C) to 4V at the R1 – P1,P2 junction, when the FET is at 125°C. We estimate that the thermal resistance drops 25°C from the junction to the heat-sink.

If everything is calculated properly, the power output and Bias current of the AMP is consistent over heat-sink temperature range 15°C to 80°C.

The improved and working TRCS
(Thermal Runaway Control System)

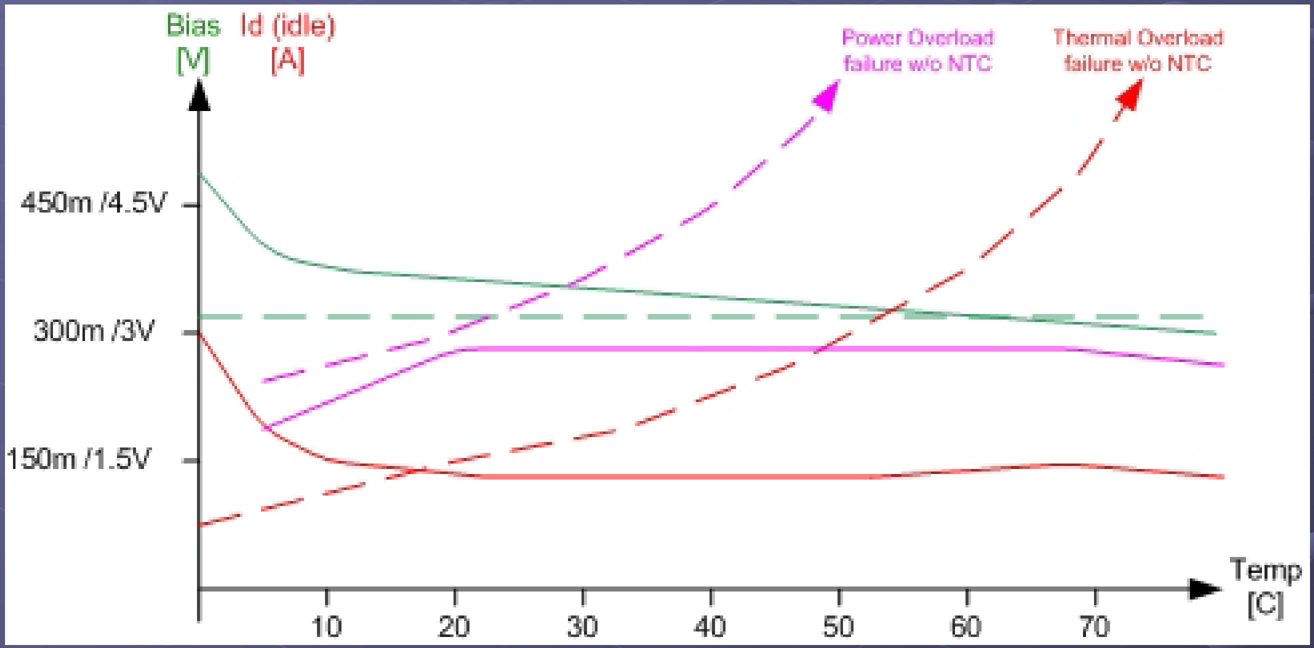
- The new TRCS system implemented on the PCB. Now that we now that it works we can better integrate it into the existing PCB.
- If re-using locations RV1 and 2, do not re-use the supplied parts (wrong value!)

- Cutting the power trace between U1 and RV2
- Cutting the power trace between RV2 and R4.
- Add a wire from the U1 (9V) to R4.
- Add the 560Ω resistor between U1 (9V) and RV2.
- Insert RV1 and RV2 with 1kΩ values.
- Add a 1kΩ resistor from supply side of RV1 and 2 to the 5k NTC mounted on the solder side.
- The ground side of the NTC is soldered parallel to the ground shield at about 5mm above the PCB on the solder side.
- When the board is mounted on the heat-sink the NTC with added heat paste will link the two thermally together as required.
- Use a rubber grommet between the NTC and the PCB to provide adequate force to keep the NTC touching the heat-sink.



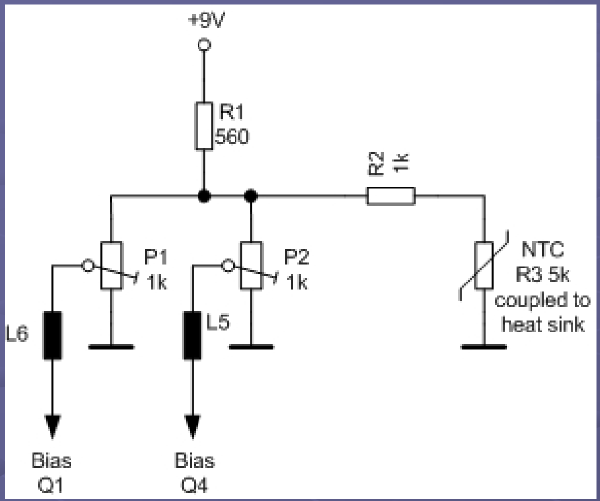
Measuring the Thermal stability of the Design

Amplifiers have a tendency to self-destruct via thermal runaway (dashed line), if the bias voltage is fixed. The circuit design has therefore to include a compensation system. This most likely contains a temperature sensitive resistor such as a NTC or PTC. Compensating also stabilizes the output power over the temperature range of the amplifier.



Above are the measured bias voltage (grn) and idle current (red). To keep the idle current constant (desirable), the bias correction circuit has to drop as the heat-sink temperature increases. Nominal power output is also maintained (pink). The value of R2, which is in series with the NTC, affects how strongly or weakly the compensation reacts to temperature change. A flat power output is desirable and R2 value must be selected accordingly.

How to set up the Idle current



Before attempting to power on the amplifier make sure the pots are set so that they are grounding the gates of the FETs (if they are not, the current flowing can damage them).

The output has to be connected to a 50W dummy load and the input is terminated with a 50Ω load.

Use a 10Amp meter and measure the total current flowing. The preamp will draw about 200mA, if there is not at least 190mA flowing check the preamp circuitry. Now slowly and carefully adjust the first pot until the total draw increases by 150mA to 350mA. Move to the second pot and again add 150mA so that the total consumption is 500mA +/-20mA.

Testing the TRCS

Connect a wattmeter to the output. Remove the dummy load from the input and feed a small signal to the input (about 1mW). Slowly increase the power until the output is 10W. Note the current draw and monitor it, in case it increases (if it increases turn the power off immediately and re-check your TRCS circuit). As the temperature of the heat-sink increases, the power consumption must be stable and flat for this input power setting. Also monitor the temperature of the heat-sink and do not go beyond 60°C. When 60°C are reached turn off the input and monitor the DC input current of the amp. It can initially be over 1A, but as the heat-sink slowly cools down is has to return to 500mA. Now the TRCS is working properly.

As the heat-sink warms up the power output will slightly decrease. That is normal and expected.

Part #2

- There are still some issues with the preamp and we need to solve them. So there will be a second presentation after all issues have been resolved.
- We will also talk about the Π filters that are required to clean up the signal for regulatory compliance..
- See you next time…..

All the best and 73;

Alex – VE7DXW

References

Instruction to assemble the Banggood-IFR-530PA (version 1.3)

http://www.caarc.ca/wp-caarc/wp-content/uploads/2016/03/Banggood-IRF-530-PA-Instructions-V1.3-.pdf\

AN RF POWER LINEAR USING IRF MOSFETS

http://users.tpg.com.au/users/ldbutler/MosfetLinear.htm

Data Sheet IRF-530 (100V AC rated)

http://pdf.datasheetcatalog.com/datasheet/fairchild/IRF530.pdf

Data Sheet IRF-730 (400V AC rated)

http://pdf.datasheetcatalog.com/datasheet/fairchild/IRF730.pdf

Thank you to 4Z4TJ for the documentation even if it is incomplete for the new version of the release. It was very helpful and it made me want to tackle this amp.

Questions?

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Thank you for your interest and participation in this presentation