

# G6LBQ - HF LINEAR AMPLIFIER

Last edited 10<sup>th</sup> April 2013

## Introduction

The G6LBQ HF Linear Amplifier is a reproducible 20Watt PA module using rugged Mitsubishi RF Mosfet's. There are many advantage of using genuine RF devices over cheaper general purpose power Mosfet's like the IRF510 devices commonly used in a lot of home-brew projects:

- 12 Volt drain voltage unlike IRF510's which typically require 24 Volts to operate well.
- Device source is connected directly to the metal mounting tab providing easier mounting options and more efficient thermal transfer.
- Flatter gain response across the HF frequency spectrum.
- Much better handling of poor mismatches.

The Linear Amplifier module has been designed to interface perfectly with the G6LBQ multiband transceiver but can also be used with the Bitx3 or any other transceiver project.

The RF drive level required for the module is around 10mw for an output power of 10 Watts. The maximum output that the module can deliver is 16 to 20 watts depending on bias and drive level. The amplifier has a front end 50 Ohms PI matching network which can be reconfigured to allow higher drive power levels if required providing greater flexibility for use with other projects.

There are many examples of proven designs using the Mitsubishi RF Mosfet's on the internet and also in various publications, the information I collected was used to aid in the design and construction of the G6LBQ amplifier module.

Currently the PCB artwork for the amplifier is not freely available however should you wish to make your own PCB for the module I have made the circuit diagram available in the G6LBQ Yahoo Group which can be found at <http://uk.groups.yahoo.com/group/g6lbq/> look under the files section and then navigate to the G6LBQ Bitx folder.

As with all my other Multi-band BitX modules a ready made PCB is available from DX KITS the sole worldwide distributor. The PCB is a professionally manufactured Glass Epoxy FR4 board, pre drilled, tinned, solder masked and screen printed to aid assembly. To purchase a PCB please visit <http://www.dxkits.com>

COMPONENT LIST		
Quantity	Description	Function
21	100nf Ceramic Disc or Multilayer 50-100 Volt – 5mm Lead Pitch	Coupling & Decoupling
2	10nf Ceramic Disc or Multilayer 50-100 Volt – 5mm Lead Pitch	Coupling & Decoupling
2	1uf Electrolytic 25-63 Volt – 2.54mm Lead Pitch	Decoupling
1	100uf Electrolytic 25-35 Volt – 5mm Lead Pitch	Supply LF Decoupling
1	150pF Multilayer Ceramic or Silver Mica 100 Volt – Lead Pitch Form To Suit	Frequency Tuning.
2	430 Ohm 0.25W Resistors	Input Attenuator/Matching.
2	10R 0.25W Resistors	Input Attenuator/Matching & 5Volt Regulator supply feed resistor.
1	10K 0.25W Resistor	BC640 emitter base resistor.
1	1K 0.25W Resistors	BC640 base resistor.
1	2K2 0.25W Resistor	2N3904 base resistor.
1	2K7 0.25W Resistor	78L05 load resistor.
1	470R 0.25W Resistor	Driver transistor bias feed resistor.
2	100R 0.25W Resistors	Output transistors bias feed resistor.
3	10K Horizontal Pre-sets	Driver/Output transistor bias setting.
1	560R 0.25W Resistor	Driver transistor feedback network.
2	680R 0.25W Resistors	Output transistor feedback network.
1	6R8 0.5W Resistor	Driver transistor supply resistor.
2	2R2 0.25W Resistors	Output transistor Gate resistors.
1	BC640 PNP Silicon Transistor	PSU series transistor feeding the 78L05 biasing regulator.
1	2N3904 NPN Silicon Transistor	Transmit bias switching transistor.
2	1N4001 General Purpose Diodes	Bias temp compensation.
1	1N4148 High Speed Switching Diode	Transient suppression for relays.
1	78L05 5Volt Positive Regulator	Bias voltage regulation.
1	RD06HHF1 or RD16HHF1 RF Power Mosfet	Driver stage Mosfet transistor.
2	RD16HHF1 RF Power Mosfet's	Output stage Mosfet transistors.
2	Omron G5V-2 Two Pole Relays	Input/Output switching.
3	BN43-202 Ferrite Balun core	RF Transformers.
2	Ferroxcube VK200 Choke Inductors or FT50-43 torroids with 10 turns of 0.7mm copper enamel wire. You can also use large ferrite beads with 0.7mm wire passed through.	Supply decoupling chokes.

HARDWARE LIST		
Quantity	Description	Function
5	SMA PCB Sockets “See Page ”	RF Input/Output option 1
5	2 Pin Molex 0.1 pitch headers “See Page “	RF Input/Output option 2
1	2 Pin Molex 0.1 pitch headers	Transmit switch line connection
1	2 Pole PCB Screw Terminal Block	PSU connection
1	Heat-sink	Heat dissipater for RF Mosfet's
1	0.5mm Copper enamel covered wire	For winding transformers
1	0.7mm Copper enamel covered wire	Only needed if winding L1 & L2 as opposed to using pre made inductors.

## BUILDING THE G6LBQ HF LINEAR AMPLIFIER

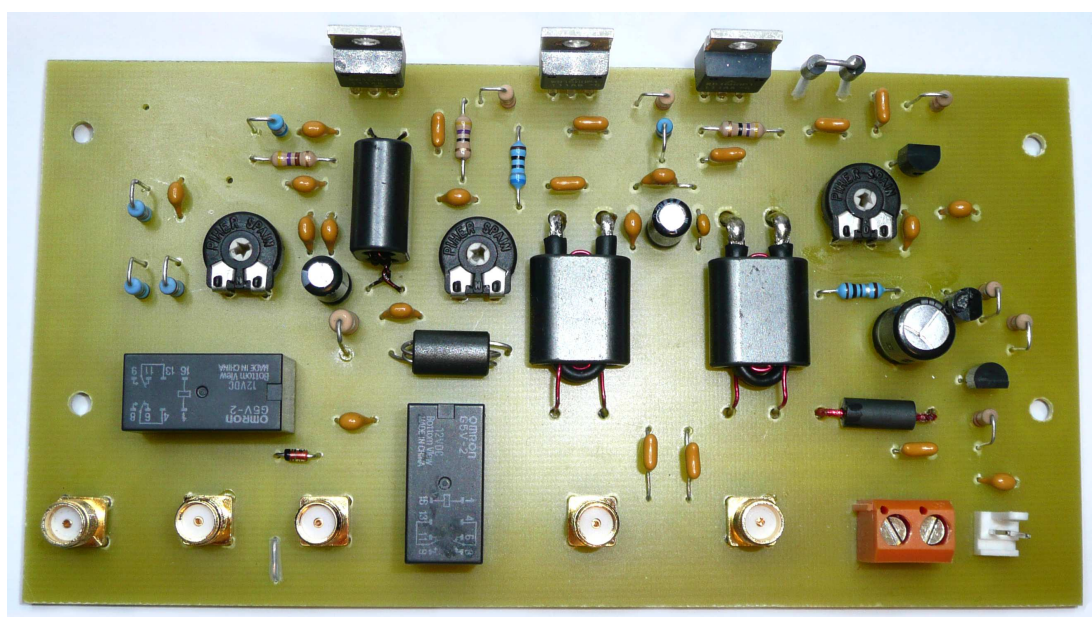
Construction of the G6LBQ HF Linear Amplifier should not prove difficult and is one of the easiest modules to construct in the multi-band transceiver.

Before commencing construction carry out an inventory of all parts and optional hardware.

Please visit the BitX Yahoo Group at <http://uk.groups.yahoo.com/group/g6lbq/> and make sure you have the latest documentation before commencing building. There is a folder in the files section of the group titled G6LBQ Bitx and all files relating to the amplifier can be found there.

There is no specific order of construction but I suggest all the resistors and capacitors be soldered to the PCB first. The last components to be installed should be the three RF Mosfet's as these could be damaged if the device legs are allowed to be bent with unnecessary disturbance during construction.

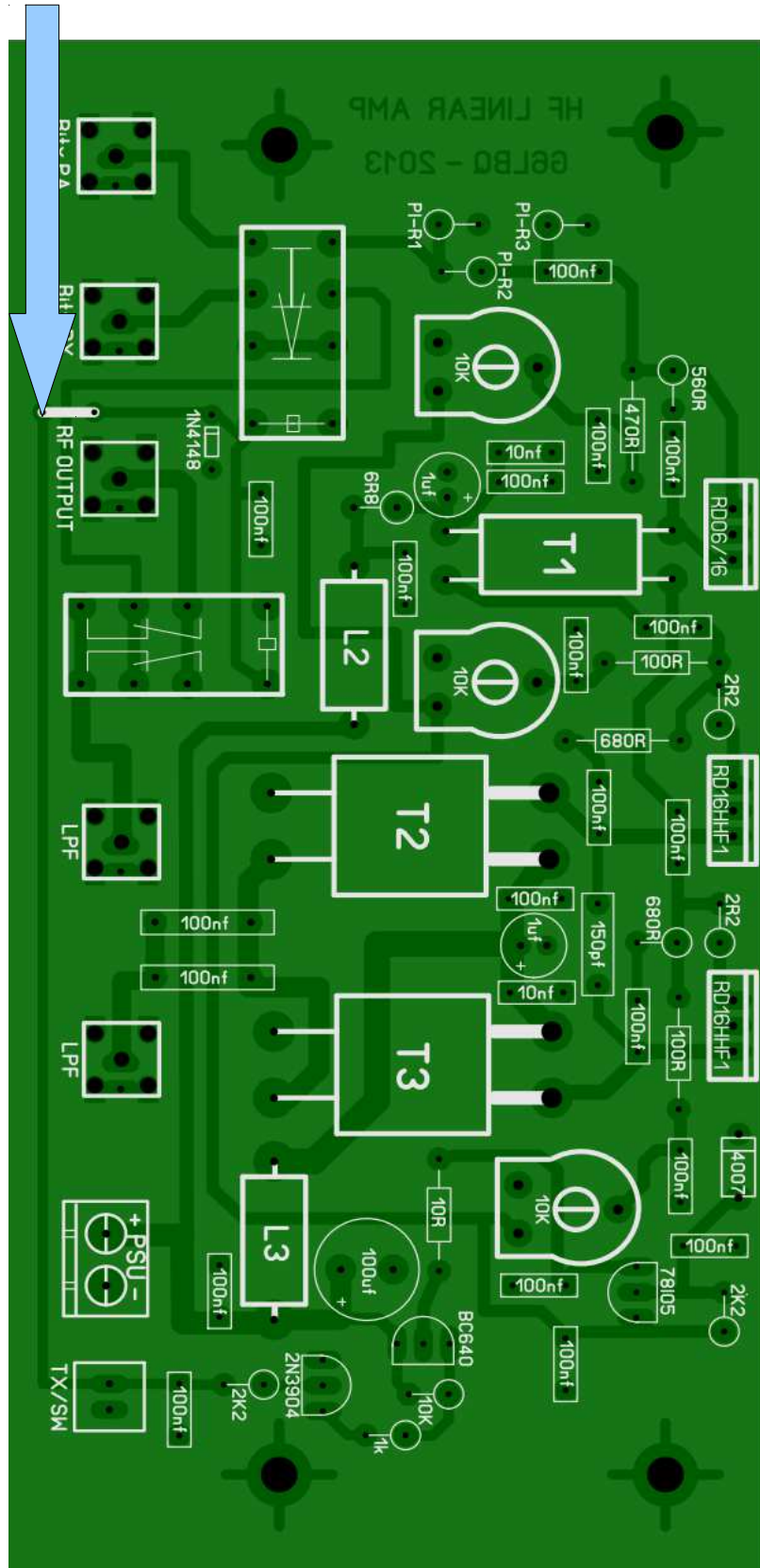
The finished PCB looks like this:



## PCB LAYOUT IMAGE

This image illustrates all the component locations to aid construction

**NOTE A wire link must be fitted at this location**



# WINDING THE TRANSFORMERS

The HF Linear Amplifier is equipped with three transformers which are wound on BN43-202 ferrite balun cores using 0.5mm Copper Enamelled Wire and short pieces of RG174 coax.

## T1 Driver Transformer

T1 is constructed by winding two lengths of 0.5mm enamel copper wire twisted together so there are 2 to 3 twists per centimetre, the length of the twisted pair should be approx 21 centimetres in length.



Twisted pair winding prior to being wound on the BN43-202 Core

The twisted pair of wires must now pass through the BN43-202 balun cores so that it fills one hole in the core twice and the other three times ( $2\frac{1}{2}$  Turns) this is illustrated below:



In the image above you can see that the top hole in the balun core has been filled with the twisted pair twice whilst the bottom hole in the core has been filled three times. The little pieces of white tubing inside the cores is only in place to help highlight the windings and are not required!

The transformer can be inserted into the PCB either way round as it is symmetrical.



## T2 & T3 Output Transformers

T2 & 3 are identical and are constructed with individual primary and secondary windings. The primary winding is created from a short length of RG174 coax and the secondary with a length of 0.5 enamel copper wire.

Begin by winding the secondary side of the transformers with 4 turns of copper enamel wire so that the windings are nice and tight against the centre of the BN43-202 core as illustrated below:



To make the primary winding take approximately 10cms of RG174 coax and remove 2cm of the outer plastic sheathing from one end, separate the exposed outer braid to reveal the centre coax core, the centre core can make threading the coax through the binocular holes tight so it is discarded by simply pulling it free from the rest of the cable. With the centre core of the coax removed chop off the 2cm of exposed braid as this will make it easier to thread the coax through the binocular holes. Thread the coax through the core and prepare as illustrated below:



With the three transformers wound it is important to clean off the enamel coating from the copper wires ends prior to PCB installation. Use a sharp blade to do this then pre tin all of the cleaned wire ends, DO NOT TIN THE RG174 COAX prior to installing into the PCB as this will make it difficult to form the wire ends to the PCB holes.

# MOSFET BIAS TEMPERATURE COMPENSATION

The following image illustrates the two 1N4001 Diodes used for the bias compensation, these Diodes must be mounted on the same heat-sink as the RF Mosfets and secured in place.



With a suitable aluminium enclosure it may be possible to get enough heat dissipation by bolting the RF Mosfet's and Diodes directly to the case. Care must be taken when bolting the Diodes down, they must be lightly secured in place but make contact with the aluminium dissipater, do not apply too much pressure against the Diodes or damage may occur!. A suitable washer must be included with the fixing screw to cover the Diode bodies and aid contact with the heat dissipater.



Attach the RF Mosfet's and Diodes to the heat-sink with a thin layer of heat-sink compound and then carefully check around the Diodes to make sure no part of the fixing screw or component legs are making contact with the aluminium dissipater.

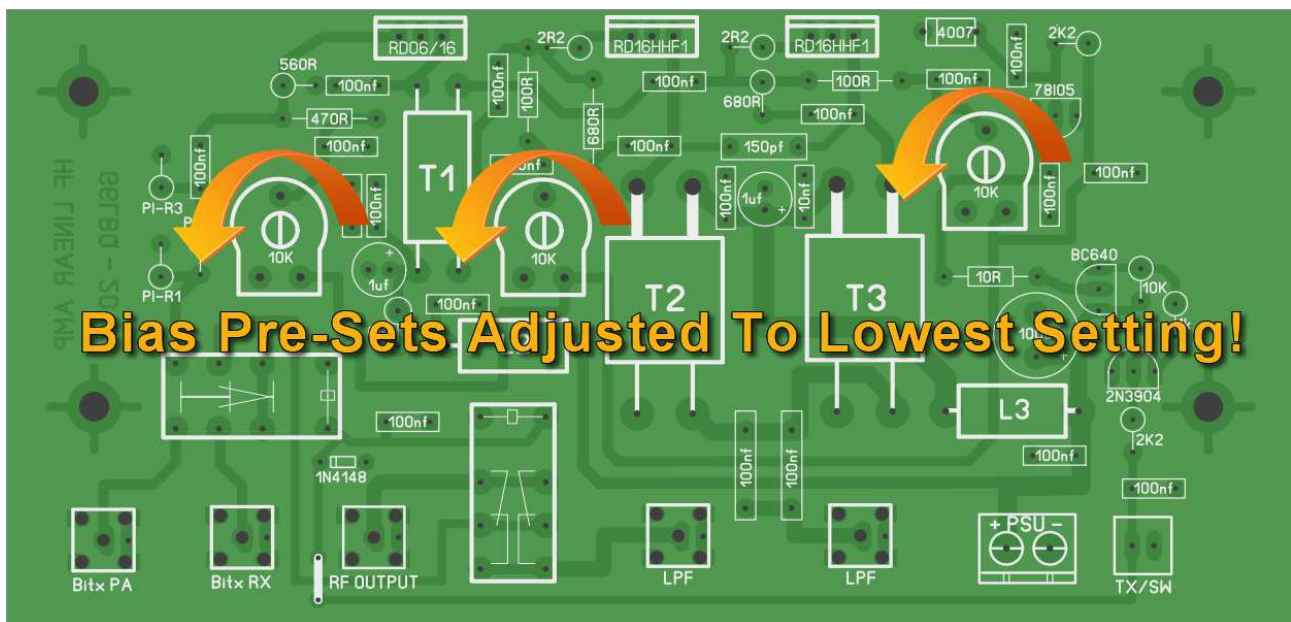
## INITIAL TESTING STAGE

**IMPORTANT Do not apply power to the finished module without a suitable heat-sink attached to the RF Mosfet's & bias compensation Diodes!**

## Preparing for initial testing and bias adjustment

Before applying any power to the finished module check the PCB for correct component locations, solder splashes and shorts.

The three 10K pre-set resistors that control the biasing must be initially set so the Mosfet's transistors are unbiased, observe the image below and set all three pre-sets anticlockwise:



With the three 10K pre-sets adjusted as above and a suitable heat-sink in place we are now ready to carry out some initial tests and bias alignment. No RF input signal, low pass filters or output load are required during the initial test and bias alignment stages.

### First Test - Standby Idle Current

With a 12 to 13.8 volt power supply connected to the amplifier the measured idle current should be approximately 35mA.



## Second Test – Transmit Mode Current

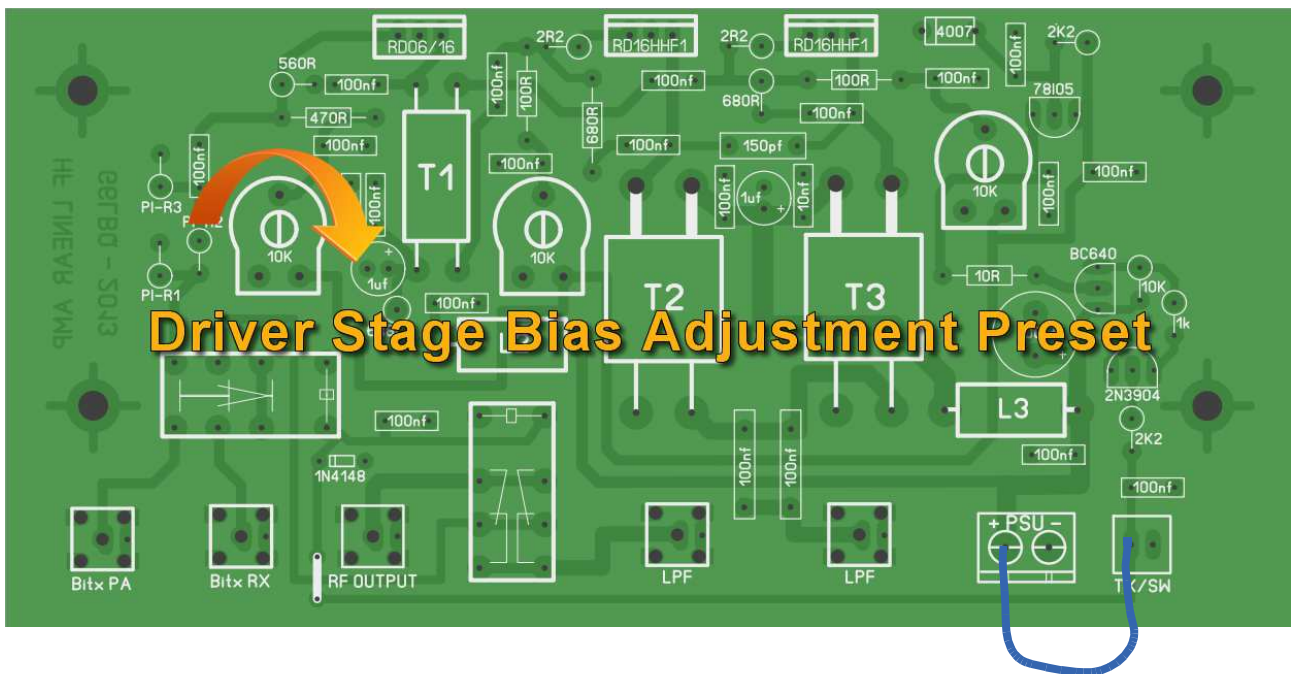
The measured current for this test should be approximately 120mA +/- 10%.

## DRIVER STAGE BIAS ADJUSTMENT

**IMPORTANT Do not apply power to the finished module without a suitable heatsink attached to the RF Mosfets & bias compensation Diodes!**

## Setting the driver stage bias

The driver stage is biased to 125mA and the illustration below indicates which of the three pre-sets controls the driver stage bias:



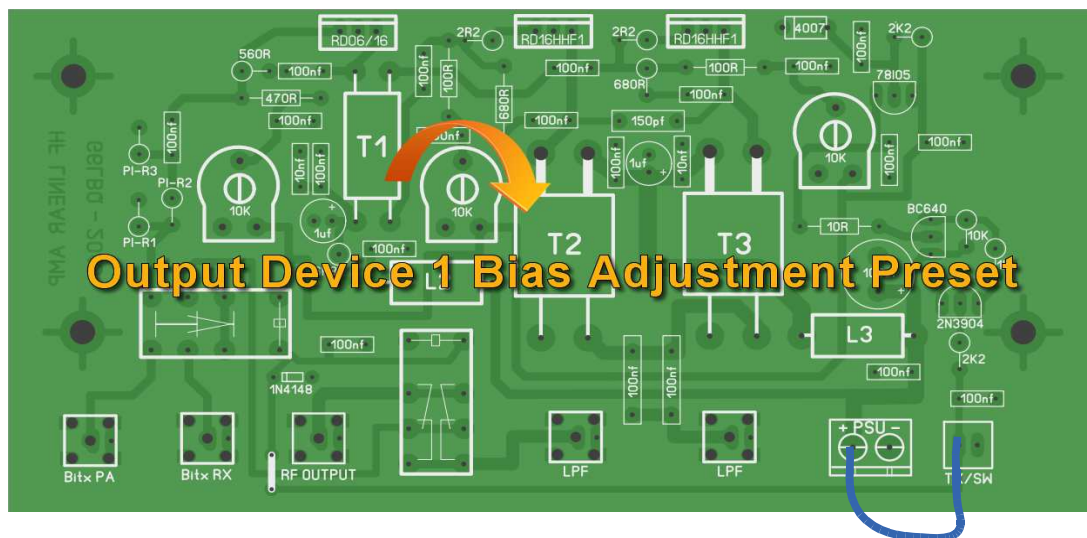
Whilst monitoring the current consumption of the amplifier **slowly** adjust the driver stage pre-set in the direction shown for a reading of 245mA, the driver stage is now biased.

# OUTPUT STAGE BIAS ADJUSTMENT

**IMPORTANT** Do not apply power to the finished module without a suitable heat-sink attached to the RF Mosfets & bias compensation Diodes!

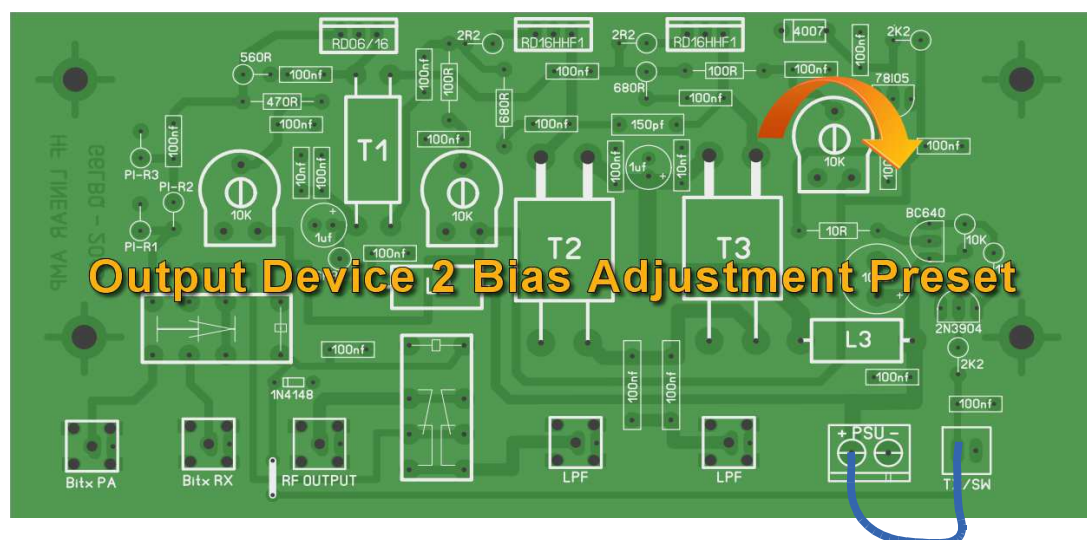
## Output stage bias adjustments

The final output stage consists of a pair of Mosfet devices each biased to 250ma. Using the illustration below the first output device is biased accordingly:



Whilst monitoring the current consumption of the amplifier **slowly** adjust the first output device pre-set in the direction shown for a reading of 495mA, the first output device is now biased.

Using the illustration below the second output device is biased accordingly:



Whilst monitoring the current consumption of the amplifier **slowly** adjust the second output device pre-set in the direction shown for a reading of 745mA, this completes the bias setting procedure.

# A UNIVERSAL APPROACH

## Connectivity

The HF Linear amplifier was designed with a universal approach and is adaptable to many home-brew projects requiring a reliable, solid and reproduce-able module.

- The PCB has provision for various RF input/output connectivity, you can fit high quality SMA connectors, Molex connectors or just solder straight to the PCB.
- There are separate input connectors for receive and transmit making the module ideal for use with separate transmitters and receivers
- The module has a transmit switch line that removes the bias during receive mode thus conserving energy, ideal for battery portable operation!
- On-board input matching PI network/attenuator – this allows the module to be configured for a wide range of power input levels and allows control of the final output power.

## Heat-sinks

The output devices and bias compensation diodes are all mounted along the back edge of the PCB which offers great flexibility when sourcing a heat-sink, some aluminium project cases may also serve as a good enough heatsink on there own!.

## Transmit Switching

The amplifier was primarily designed to compliment my G6LBQ Multiband BitX transceiver so has positive going transmit switching, there is a 2 pin header on the PCB marked TX/SW.





# FINAL NOTES & AMMENDMANTS

This manual should provide sufficient information to construct the amplifier but if you have any questions during the build please post a message in the BitX Yahoo Group at <http://uk.groups.yahoo.com/group/g6lbq/>

It is recommended that the power supply feed to the amplifier be fused, a 2.5 Amp quick blow fuse should be adequate.

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