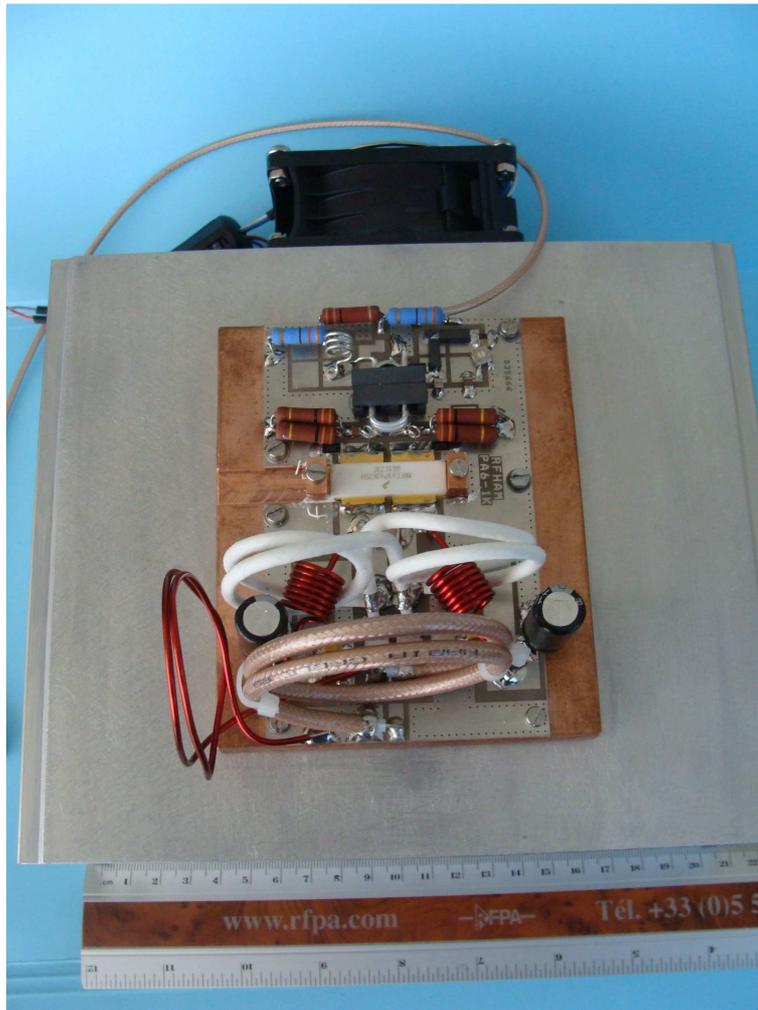


# Compact 50 MHz High Power Solid State Amplifier using MRFE6VP61K25H

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*This Article deals with RF amplifier design using high power RF solid state devices. If you have no experience working with these high power, please enlist the help of a qualified technician who has experience.*

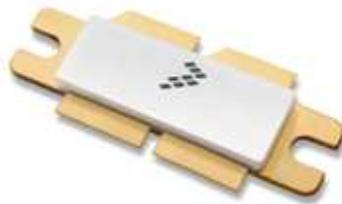
# 1. Introduction

Based in the article of F1JRD (AE7KX) Lionel, we have decided to build a 6 m module; all information's below are still valid.

*The MRFE6VP61K25H is a versatile device, well suited for a wide range of applications. It is capable of delivering 1.25KW under continuous wave test signal thanks to its high efficiency and low thermal resistance. It can also handle high VSWR condition, This description is focused on 50 MHz radio band for both analog and digital waveforms. (SSB or WSJT/FSK/CW)*

Main characteristics are :

Frequency band: 50 - 52 MHz  
Output Power @ P3dB > 1250W  
Operating supply voltage: 50V  
Gain typ > 26 dB  
Eff typ > 78%  
PCB Size: 12cm x 7.3cm



The MRFE6VP61K25H is part of the 50 V product line, which is designed specifically for high voltage application by Freescale for the RF Power market, fabricated using Freescale's proprietary Very High Voltage 6th generation with enhanced ruggedness (VHV6E) platform, this technology is fully qualified and ships in volume.

## 2. Advantages of 50V Drain Voltage

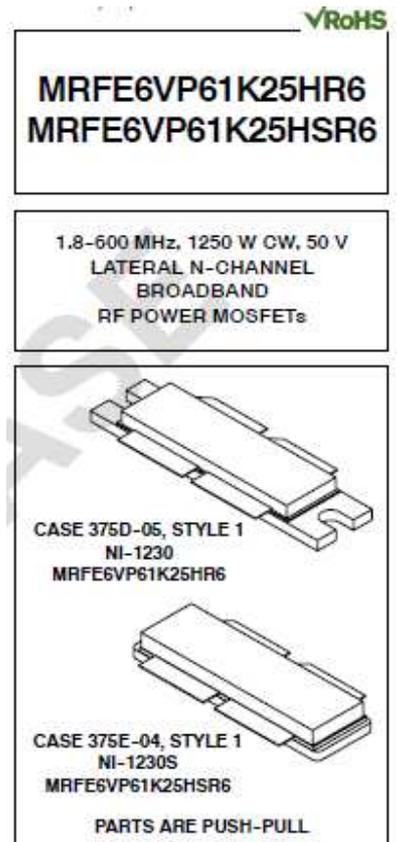
*Using a 50V device is a great advantage compared to lower voltage because the output impedance of the device for the same output power is much greater, so the output match circuitry is simpler and less lossy. Current will also be lower compared to lower voltage.*

*In addition, 50V LDMOS provides increased power density, which enables in excess of 1.25kW in the industry standard NI1230 package platform.*

*50V LDMOS technology has also better IMD performances compared to lower voltage specially the 12V devices on bipolar technology.*

*The reference fixture was designed with the market standard drain supply, allowing the amplifier to utilize a standard 50V power supply (most are adjustable 43 to 54 V).*

For all technology aspect refer to DUBUS magazine issues 4 / 2010 vol 39 "Compact 144 MHz High Power Solid State Amplifier using MRFE6VP61K25H" from AE7KX



### 3. Amplifier design and performance

The goal of this module is to be able to get 1 KW solid state, with good efficiency, small size and good handling to VSWR operation.

We based our design on the application note from Freescale MRFE6VP61K25HR6 FM broadcast (88 to 108 MHz).

For all thermal aspect please refer to (1).

The pcb is TC350 material witch have a very good RF and thermal performances.

The size of the amplifier is 120 x 72 mm.

The transistor has to dissipate more than 300 w in a small area, so a copper plate is necessary to transfer the heat to the aluminum heat sink.

Two techniques can be use to put the PCB on the copper heat spreader:

With screw like in the picture

With solder, this last technique needs some expertise and some solder paste (3).

#### Circuit description:

The transistor gain in low frequency is very high; we have to put some attenuation circuit to limit the gain.

The input circuit is realize with a 9:1 transformer like in the 2 m amplifier, because of the 6 m frequency a ferrite "E" and "I" have been added.

The frequency matching is tune by coil L1, L2, L3.

The 500 Ohms trimmer can be removing if an external bias circuit is use.

R5 , R6 , R7 , R8 are use to stabilize the input circuit; C4 and C5 are DC block .

1 K R9 and R10 are connected to ground to prevent a bias disconnection (if P1 is not use)

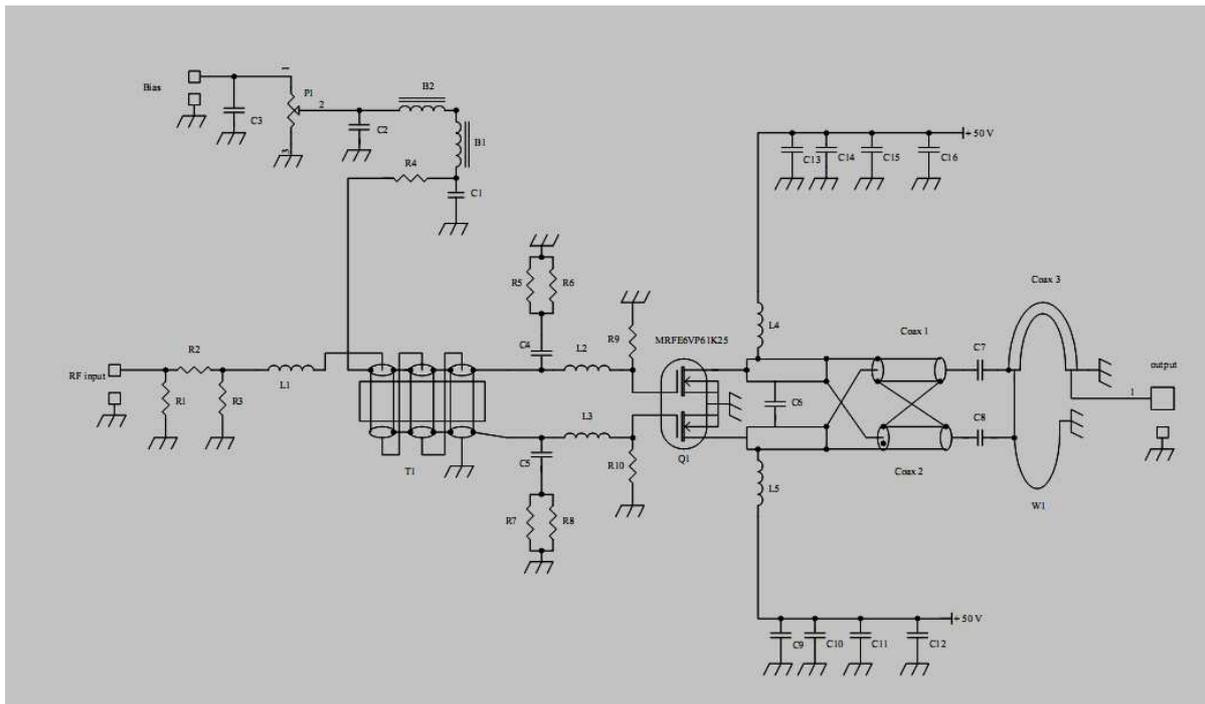
The output circuit is done also with a 9:1 transformer

A particular attention has to be done to manufacturing the 10 ohms coaxial cable Coax 1 and coax 2, see the manufacturing parts.

C6, C7, C8 are a high Q factor capacitor CLX series from TEMEX . C6 (75 pf) is a part of the matching, C7 and C8 are DC blocking.

This capacitor have a very low ESR and can handling more than 20 A RF current with 300 V for C7 and C8.

The output symmetrical balun is realized in 50 ohms Teflon coaxial RG142 and the same length of 16/10 wire, this balun improved the 2 nd harmonic.



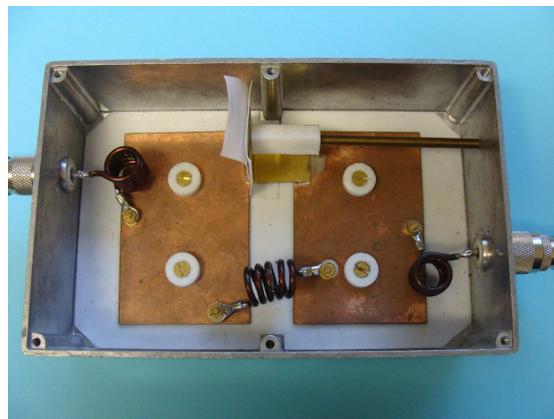
## 4. RF measurements

The RF measurement have been done in CW and without the 3 dB input attenuator.

50 V Drain supply, 2000 mA Idq (For linear operation):  
 This test is done with the amplifier pallet only ( without filter)

Freq (MHz)	Pin (W)	Pout (W)	Gain (dB)	IRL (dB)	Eff (%)	Vd (V)	Id (A)
50	0.1	100	30	-13	23.1	49.8	8.7
50	0.2	200	30	-13	33.5	49.8	12
50	0.3	300	30	-16	41	49.8	14.7
50	0.38	400	30.2	-17	47	49.8	17.1
50	0.51	500	29.9	-16	52.3	49.8	19.2
50	0.73	600	29.1	-16	56.3	49.8	21.4
50	0.88	700	29.0	-16	60.3	49.8	23.3
<b>50 P1 dB</b>	<b>1</b>	<b>800</b>	<b>29.0</b>	<b>-16</b>	<b>64.3</b>	<b>49.8</b>	<b>25</b>
50	1.4	900	28.1	-16	66.9	49.8	27
50	2	1000	27	-16	70	49.8	28.7
<b>50 P6dB</b>	<b>4.6</b>	<b>1100</b>	<b>23.8</b>	<b>-17</b>	<b>72.4</b>	<b>49.8</b>	<b>30.5</b>

The harmonic test show H2 @ - 40 dBc and H3 @ -10 dBc , this mean about 100 W of 150 MHz .  
 A filter is absolutely necessary to get the harmonics below 60 dBc.  
 We have test with a filter describe by F1TE some year ago (3),



The result with the (amplifier + 91 cm RG142 + filter) is in the new table below (without the input attenuator):

Freq (MHz)	Pin (W)	Pout (W)	Gain (dB)	IRL (dB)	Eff (%)	Vd (V)	Id (A)
50	0.2	200	30	-16	38.6	49.8	10.4
50	0.3	300	30	-16	41.7	49.8	14.6
50	0.4	400	30	-16	48.1	49.8	16.7
50	0.5	500	30	-17	53.4	49.8	18.8
50	0.6	600	30	-16	57.4	49.8	21
50	0.70	700	30	-16	61.7	49.8	22.8
50	0.88	800	29.6	-16	65.3	49.8	24.6
<b>50 P1 dB</b>	<b>1</b>	<b>900</b>	<b>29.5</b>	<b>-16</b>	<b>67.9</b>	<b>49.8</b>	<b>26.6</b>
50	1.4	1000	28.5	-16	71.7	49.8	28
50	1.8	1100	27.9	-16	74.1	49.8	29.8
<b>50 P4dB</b>	<b>2.8</b>	<b>1200</b>	<b>26.3</b>	<b>-17</b>	<b>76</b>	<b>49.8</b>	<b>31.7</b>

This last result shows a improvement in efficiency and output power. What that mean??  
 The 3<sup>rd</sup> harmonic is fully reflected to the transistor and the amplification class is not any more AB, we are closer to class F or FG this is the reason of the 80 % of efficiency.  
 But to get this result the length of the coaxial cable between the amplifier and the filter need to be adjusted.  
 And if the length is not correct, the result can be very bad and can destroy the transistor.  
 As a example if we had 30 cm more to the existing cable the efficiency is not more than 60 % and the power is limiting to 900 W.

***This mean for each type of filter design, the length of the cable have to be adjust for the better efficiency.***

***For the filter used I have to had 91 cm of RG142BU***

A new design have to be test to improved H3, it have to be design with a 4:1 output balun and some H2 and H3 trap.

## 5. IMD measurement

The IMD mesure was done in the same condition than the 2 m amplifier

Pout : 800 W PEP

Idq : 2 A

IMD3 : - 28 dBc / PEP

IMD5 : - 47 dBc / PEP

## 7. Ruggedness

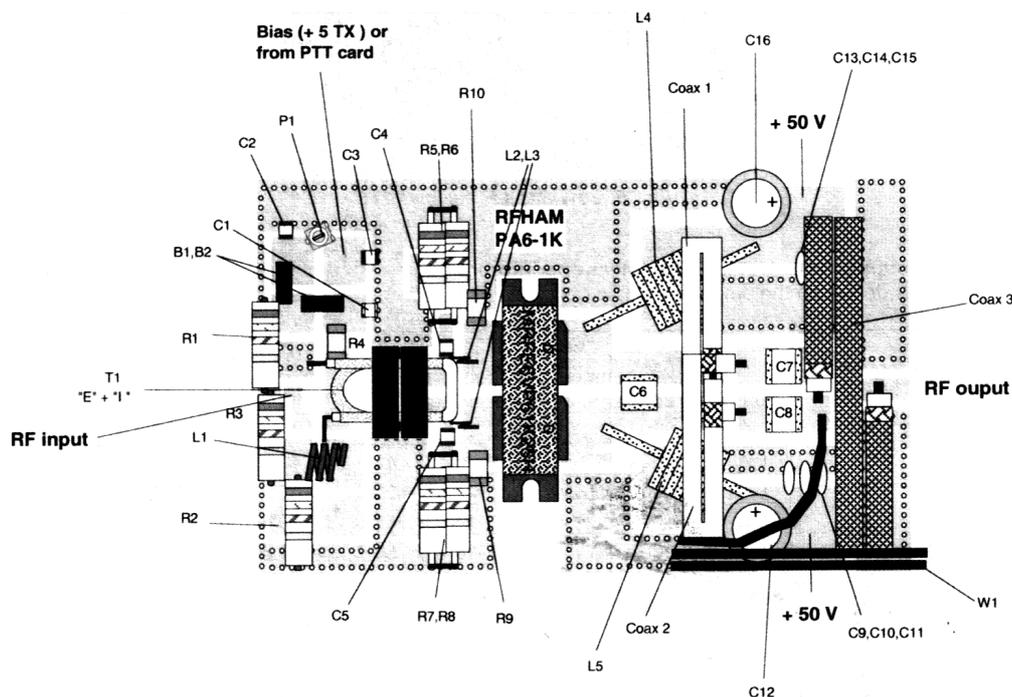
*MRFE6VP61K25H is a very rugged part capable of handling 65:1 VSWR in pulse mode, It was designed for high mismatch applications, such as laser and plasma exciters, that exhibit repetitive high VSWR values at startup and then come back to a more friendly impedance.  
 In CW, at these VSWR level and rated power, the limiting factor is the max DC power dissipation.*

*VSWR protection that shutdown the gate voltage within 10mS on a single shot will protect the transistor effectively.*

*The amplifier presented here, was tested all phase angle 10mS pulse 5% duty cycle without any faillure or degradation in RF performance.*

### Construction:

#### Layout and bill of material



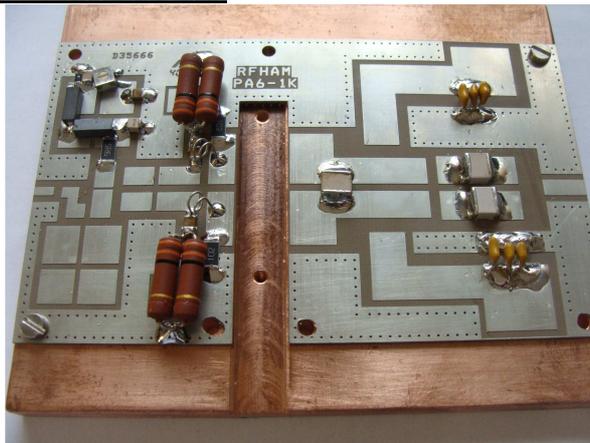
## Fixture layout and placement

Tab1. Bill Of materials

B1,B2	Bead Long Fair-Rite (95 ohm@100MHz)	2743021447	Fair-Rite
L1 (Air inductor)	3 Turn air inductor on 6 mm diameter,	Tinned copper wire of 10/10mm diameter	
L2,L3 (Air inductor)	1.5 Turn air inductor on 3 mm diameter,	Tinned copper wire of 6/10mm diameter	
L4,L5 (Air inductor)	7 Turn air inductor on 10 mm diameter,	Enamalled copper wire of 16/10mm diameter	
C1	1 nF ATC 100B Ceramic Capacitor	ATC100B102KT500XT	ATC
C2,C3,C4,C5	100 nF Ceramic Capacitor 30 V	SMD	
C 6	75 pF CLX Ceramic Capacitor	CLX	TEMEX
C7, C8	2.7 nF CLX Ceramic Capacitor	CLX	TEMEX
C9,C10,C13,C14	1 nF Ceramic Capacitor 100 V		LCC
C11, C15	100 nF Ceramic Capacitor 100 V		LCC
C12,C16	100 uF 160V		
R1 ,R3	330 ohm 3 W Power Resistor	PR03	Vishay
R2	18 ohm 3 W Power Resistor	PR03	Vishay
R4	5.6 ohm 1 W Chip Resistor	2512	Vishay
R5 ,R6,R7,R8	33 ohm 3 W Power Resistor	PR03	Vishay
R9,R10	1 Kohm 1 W Chip Resistor	2512	Vishay
P1	500 Ohms SMD pot		Bourns
T1	Balun TUI-9 Comm Concepts	TUI-9	Com Concepts or RF Power Systems
E , I	Ferrite for TUI-9 Comm Concepts	E, I	Com Concepts or RF Power Systems
Coax1,Coax2	Flex Cable (10.2 Ohm) 25cm	TC-12	Com Concepts or RF Power Systems
W1	35 cm 2 t 40 mm diameter	Enamalled copper wire of 16/10mm diameter	
Coax3	Coax cable, 50ohm, 35 cm	RF142 BU	
PCB	Arlon TC350, 2 OZ 30 mils	PA6-1K	RFham.com

**1) put the PCB on the copper plate**

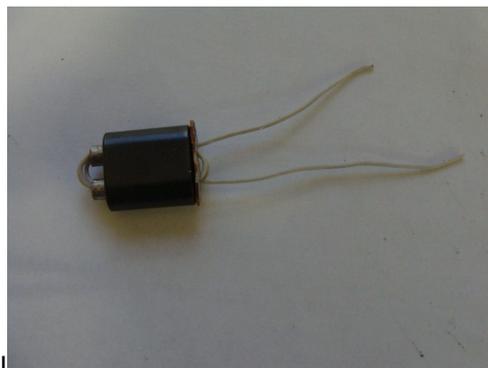
**2) mount SMD components and PR03 resistors**



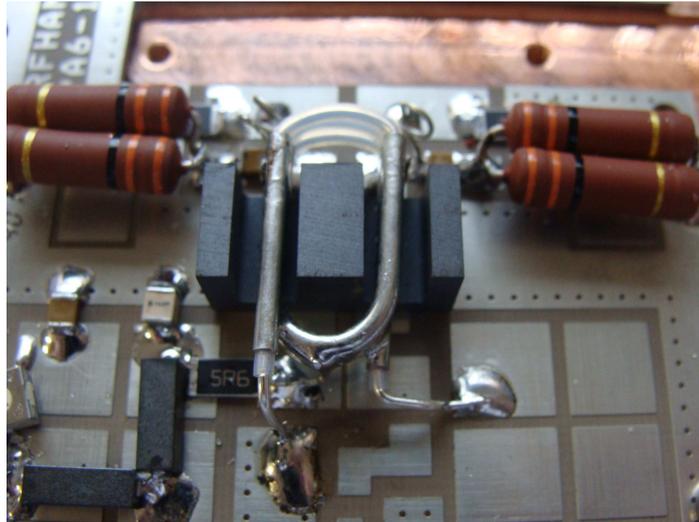
**3) Prepare the 9:1 input balun**



A alternative is to use a binocular 43 mix ferrite a description is available (3)



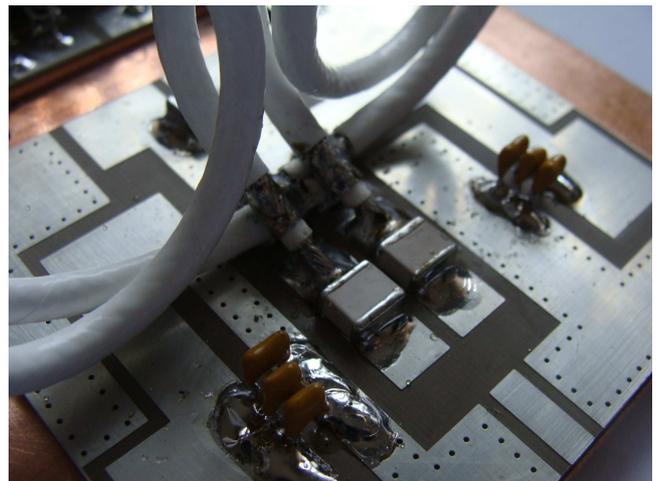
**4) put the balun in place**



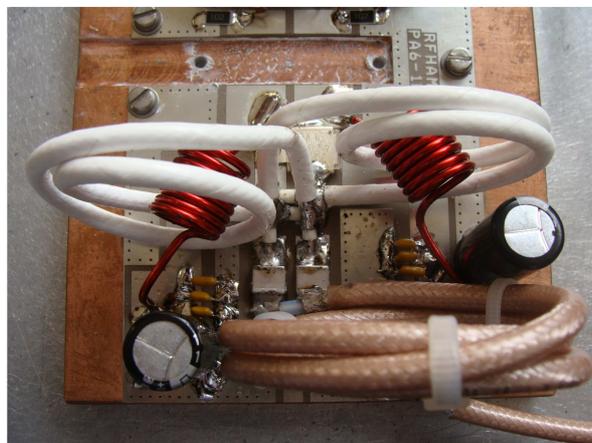
5) stick the two "I" with cyanolite glue and just one point of glue in the "E" and PCB

**6) prepare the 10 ohms coaxial cable**

Length: 25 cm



**7) next step the output balun**



**8) Before soldering the transistor it is much better to make some small test.**

a) Set the pot to zero.

b) With a DVM measure in the resistance between the gate pad and ground

R = 5.6 ohms

c) If you have a “network analyzer” or any type like mini VNA you can measure the output matching of the amplifier ( this method is also use for tube amplifier).

Put a 5.6 ohms and a 180 pF capacitor between the two drain pad  
The output match is about 20 dB ( see the curve below)

**9) Transistor placement :**

Two technique can be use :

a) the transistor can be solder, in fact this is the better technique to have a very low thermal resistance  
disadvantage if the transistor is destroy for any reason it will be very difficult to change

b) use silicon grease ( the white one for a lower thermal resistance)

before any thing, the transistor have to be prepare

the flange of the transistor is not very “flat”, the best way to do it, it is to use abrasive paper type “1200”

the abrasive paper have to be put in a very flat surface like glass

with the transistor make 8 with your hand until the flange is very flat



Put the transistor in place.

**10) Bias adjustment**

Connect the ouput to a 50 ohms load

Use two power supply:  
One for the bias 0 to 12 V

Set to 5 V ( the pot is set to ground)

Set the drain power supply to 50 V (the best is to use a 2 A max PSU)

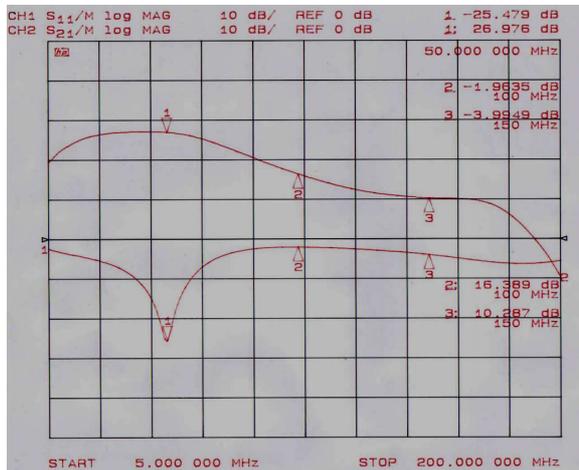
Adjust the Idq up to 2 A

## 11) Small signal test :

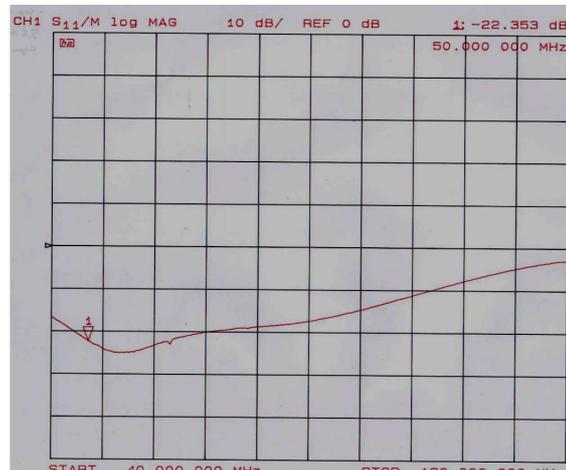
If you have a network analyzer or similar, test the amplifier in small signal otherwise in very low output power with the appropriate load.

Set the input VSWR by tuning L1,L2,L3  
The input return loss is better than 15 dB  
The small signal gain is around 28 dB

If you didn't get this value don't put the amplifier in full power, you may be have a wrong output wiring



Small signal gain



Output VSWR

## 12) High power test:

the best way to keep the transistor alive, the best way is to attenuate the input power of the amplifier.  
Most of the 50 MHz transceiver have a output power of 100 W, the power can be set to 10 W but "if you forget" you will put 100 W at the input of amplifier and destroy the transistor.  
In addition many amateur transceiver with power control turn down have bad ALC and transmit a big spike at the beginning of each transmission.

Several technique can be use, like F1TE have describe in is web site (3) or to use a 100 W 10 dB pad and a small 3 dB resistor pad install in the pcb.

Set the power the output power in the range of 300 W and check the drain current:  
it have to be in the range of 14 A.  
if it is not the case, **stop and verified the output balun.**  
If it is ok, you can increase the power up to 1KW.

Don't forget to use protections, several description are available now (3) (4)  
Kit of main components is available (5)

## Conclusion

The board was duplicated several times and each board show similar results, no need to re-tune the board to get the expected performances.

But be careful high power amplifier can always be dangerous.

Many thanks to F1JRD Lionel , F4CWN Florent , Thomas Jann , F5VHX Graham

The next description will be a 70 cm amplifier.

## References

MRFE6VP61K25 datasheet

- (1) A compact 144 MHz High Power Solid State Amplifier using the MRFE6VP6125KH
- (2) AN1034D Freescale (ex TRW application note)
- (3) [WWW.f1te.org](http://WWW.f1te.org) ; [WWW.f5cys.eklablog.com/](http://WWW.f5cys.eklablog.com/)
- (4) [WWW.vk4dd.com/](http://WWW.vk4dd.com/)
- (5) [WWW.rfham.com](http://WWW.rfham.com)