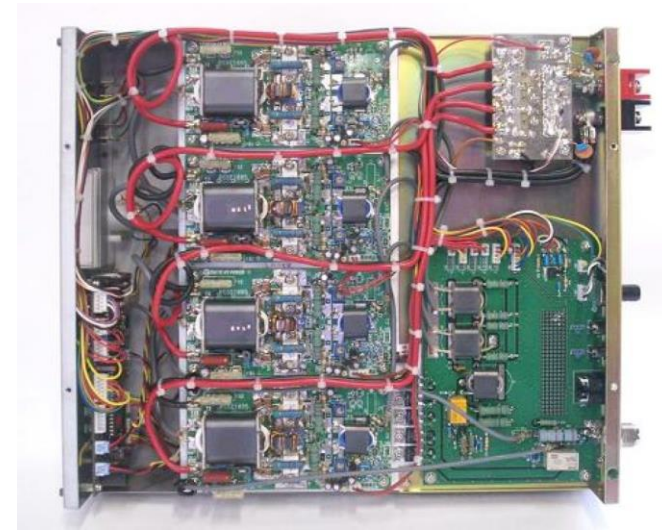


Transition to Solid State QRO (Part 1)

Tino Zottola, VE2GCE
September 21, 2020



Agenda

Part 1: September 21, 2020 presentation

- Introduction
- Tube Amplifier Landscape
- Tube Amplifier Architecture
- Bipolar Amplifier
- MOSFET Amplifier
- LDMOS Amplifier
- Commercial Amplifiers
- Conclusion #1

Part 2: October 19, 2020 presentation

- Building your own SS Amplifier
- Amplifier Protection
- Sequencing & Monitor Circuits
- Automatic Band Selection
- Conclusion #2

Introduction (1/2)

90% of RF linear amplifiers in use by hams today are still tube based.

Advantages:

- Simplicity: can be repaired easily
- Robustness: forgiving of mistuning or mismatching
- Inexpensive and plenty of used tube amplifiers available

2. Disadvantages:

- Each band must be individually selected and tuned
- Tubes have limited life time (e.g. 5-10 yrs) and replacement set costs 250-500 US dollars
- Lethal Power Supply: same voltages & current used by electric chairs (+2000 volts, +1 amps)
- Warmup time needed

Introduction (2/2)

How do solid state amplifiers compare with 100 yr old proven tube technology ?

1. **Advantages:**

- No components to replace, semiconductors can last forever
- No tuning needed, with some amps requiring band selection only.
- Lower voltages (i.e. relatively safer), typically 50 volts at 50 amps.
- No warm up time

2. **Disadvantages:**

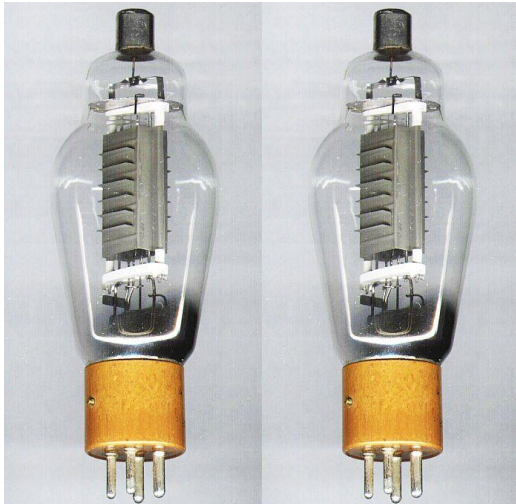
- Expensive: can cost several thousand dollars for commercial units
- Less forgiving of mistuning and mismatching, if protective circuits not present
- More complicated to repair

RF Tube Amplifier Landscape (1/3)

1. **90% of tube amplifiers in use today have one of following three tube complements:**
 - 2 to 4 x **811A**, 500 to 1000 watts output
811A have thin and fragile plates
➔ Recommendation: Replace with tubes more robust 572B (with thick graphite plates)
 - 2 or 4 x **572B**, 500 or 1000 watts output
 - 1 or 2 x **3-500Z**, 750 or 1500 watts output

New production of these tubes from China.

RF linear amplifiers using these tubes are very popular.



RF Tube Amplifier Landscape (2/3)

10% of tube amplifiers use more obscure tube types:

2. Amplifiers with following tube types should be avoided:

- Sweep tubes (6JE6, 6JSC, etc.)
Used to be cheap and plentiful, once used in tube TV horizontal output stages
- 8877, 3CX800A7 : Expensive
- 8875: No longer produced

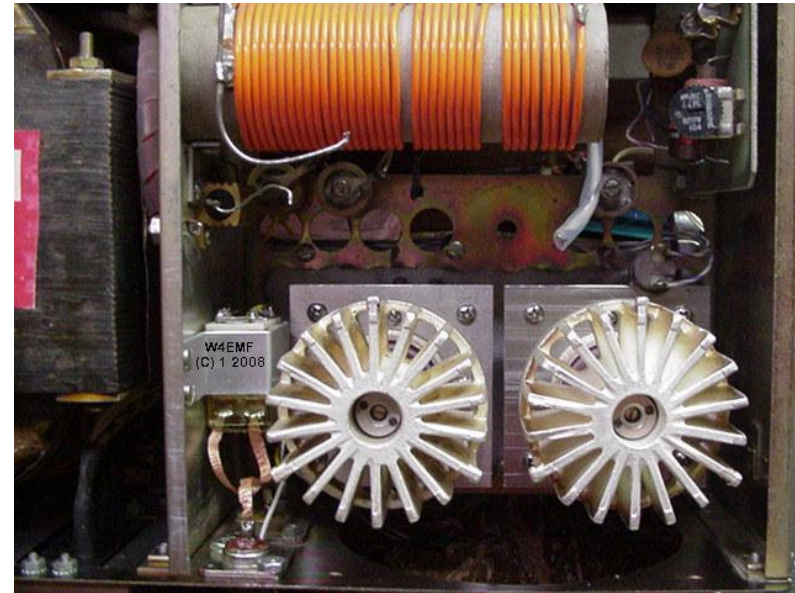


RF Tube Amplifier Landscape (3/3)

Amplifiers using obsolete tubes (e.g. 8875) can be brought back to life economically.

3. Conversion to Russian VHF military tubes:

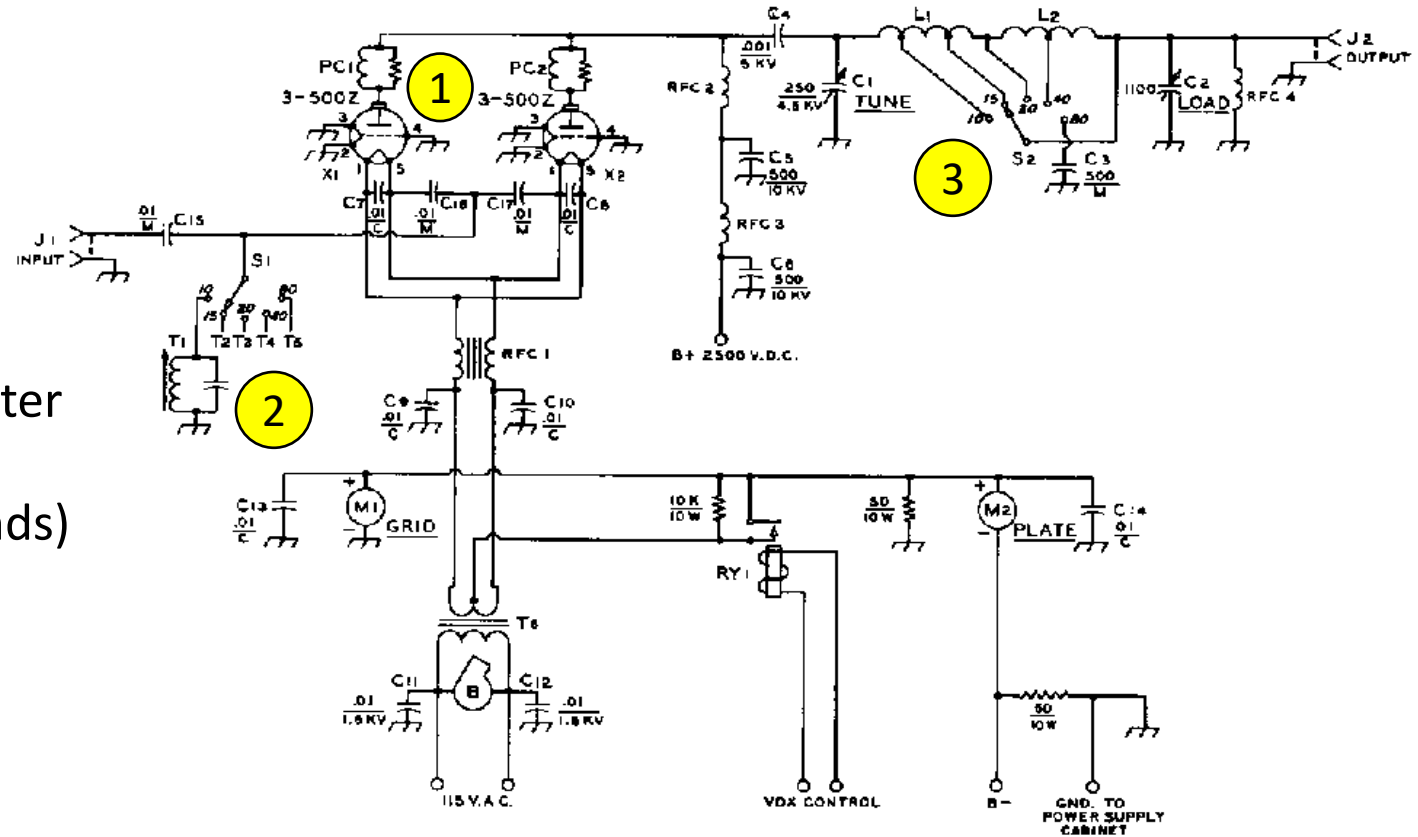
- Gi7B is the most popular tube used in conversions
- Cheap and readily available from Russia, Ukraine and Lithuania for \$25 USD each
- Involves major work for conversion (e.g. Dentron MLA2500)



3-500Z RF Amplifier Circuit

Typical features:

1. Grounded Grid:
 - Zero bias
 - No neutralization needed
2. Input circuit:
 - Low input impedance, easy match to exciter
 - Bandpass filter (older amps, pre-WARC)
 - Low pass filter (modern amps, WARC bands)
3. Pi output network:
 - Impedance matching of plate to antenna
 - Band select, tune and load controls
 - TVI filter



Solid State Amplifiers (1/3)

One of 1st KW solid state amplifier was designed (circa 1976)

➔ by Motorola RF guru Helge O. Granberg, K7ES (SK)

All his books, articles, ANs and EBs are highly recommended

Amp details in Motorola application note AN758.

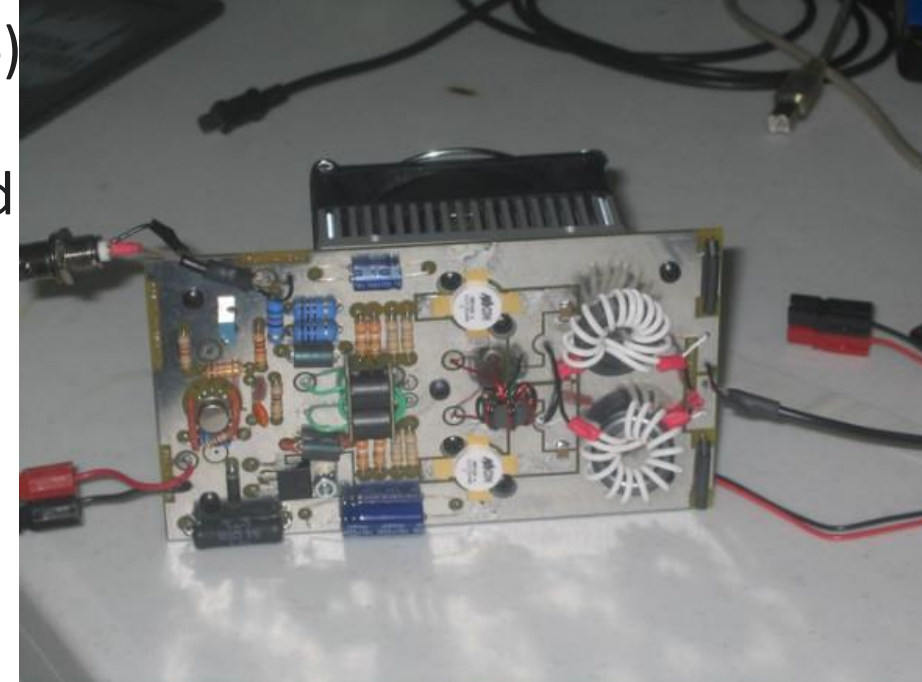
- Push-pull MRF428 bipolar transistors in module
- Module outputs 300 watts with 15 watts input
- 4 x modules in parallel for 1200 watts output

Advantages:

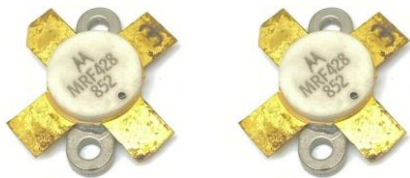
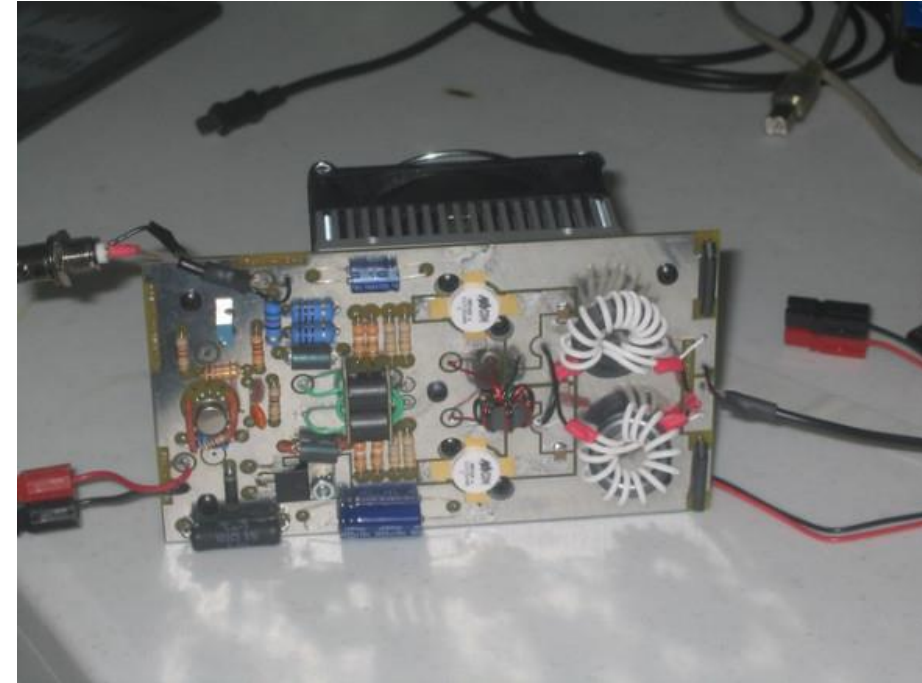
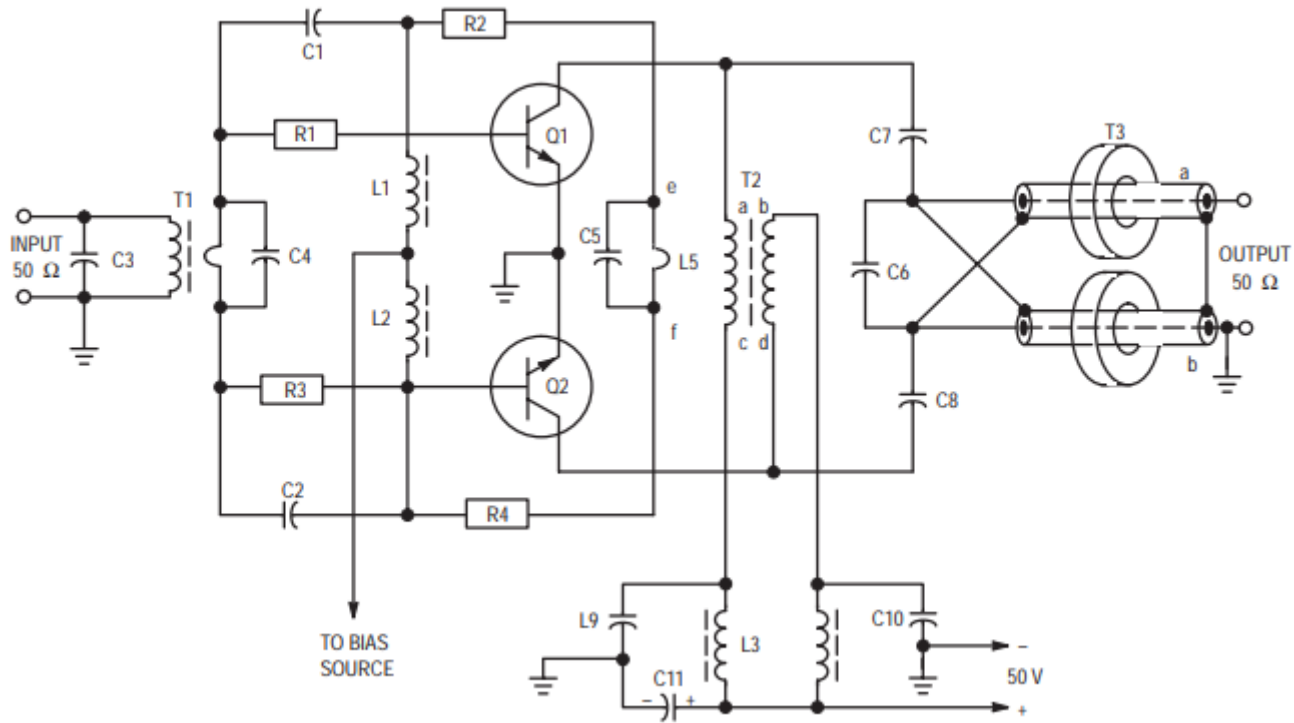
- 1.2 KW completely solid state amplifier
- Operates in broadband mode (1.8-30 MHz)

Disadvantages:

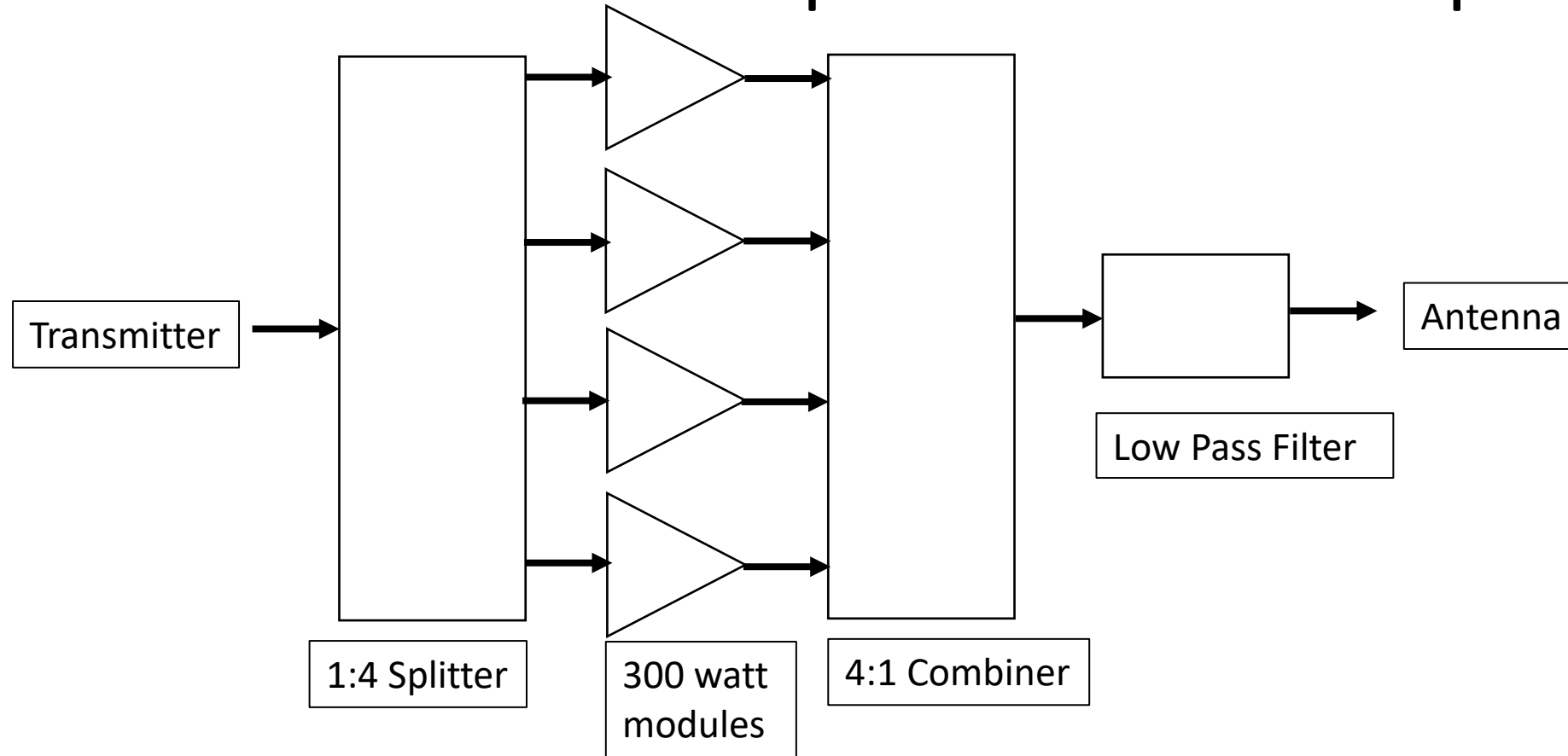
- Requires splitter and combiner to parallel modules together
- Broadband mode ➔ harmonic suppression is weak and amplifier requires LPF



MRF428 Bipolar Amplifier



Architecture – Bipolar KW Amplifier



Description:

- 4 x 300 watt modules in parallel to get 1200 watts
- Splitter used to divide and match transmitter output to module inputs
- Combiner used to aggregate module outputs and match to antenna
- LPF filter (switchable) suppresses unwanted harmonics

Power Divider & Combiner

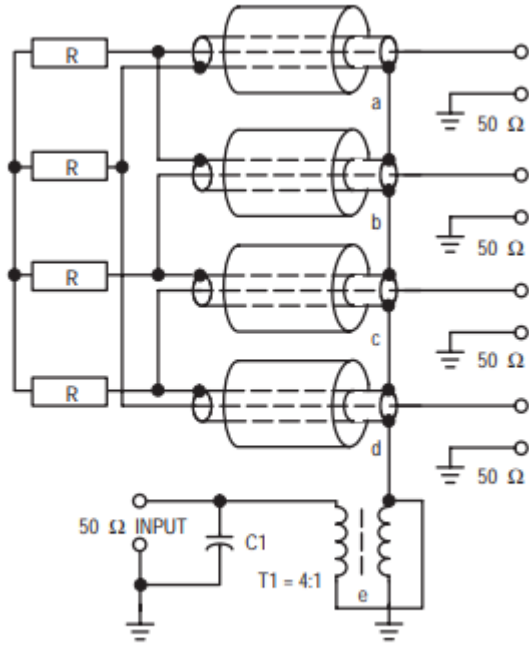


Figure 10. Four Port Power Divider

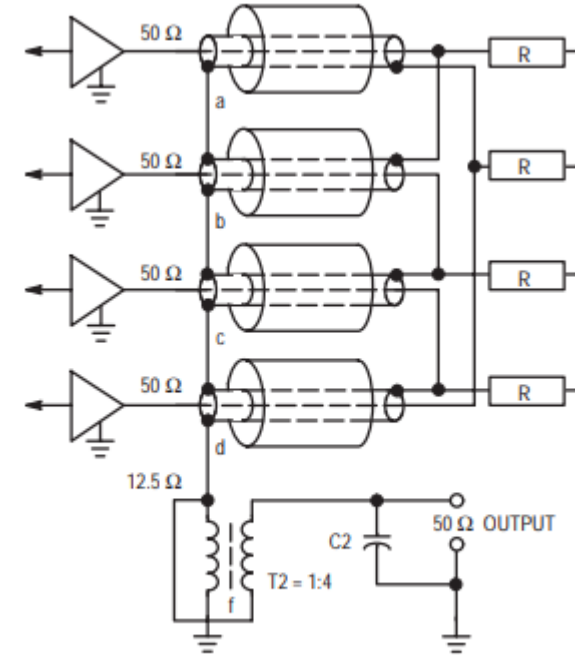
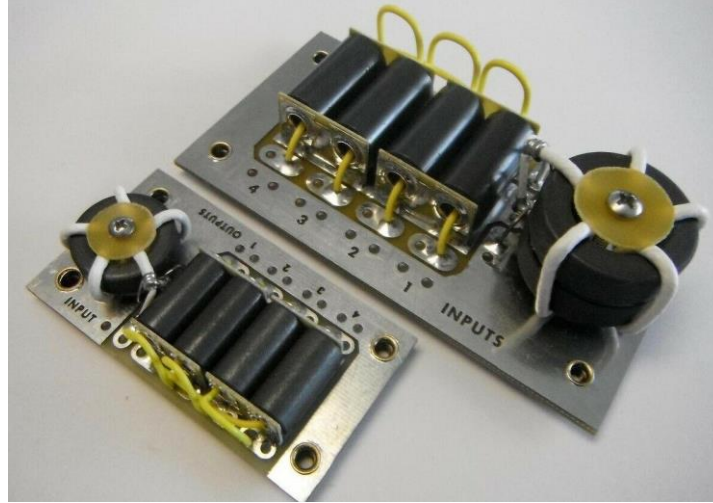


Figure 12. Four Port Output Combiner

Description:

- Input transformer: 50 ohms to 12.5 ohms
- Balancing resistors dissipate excess power, if one of more module inputs are open (or have high SWR)
- Output transformer, same as input transformer, but in reverse order at high power levels

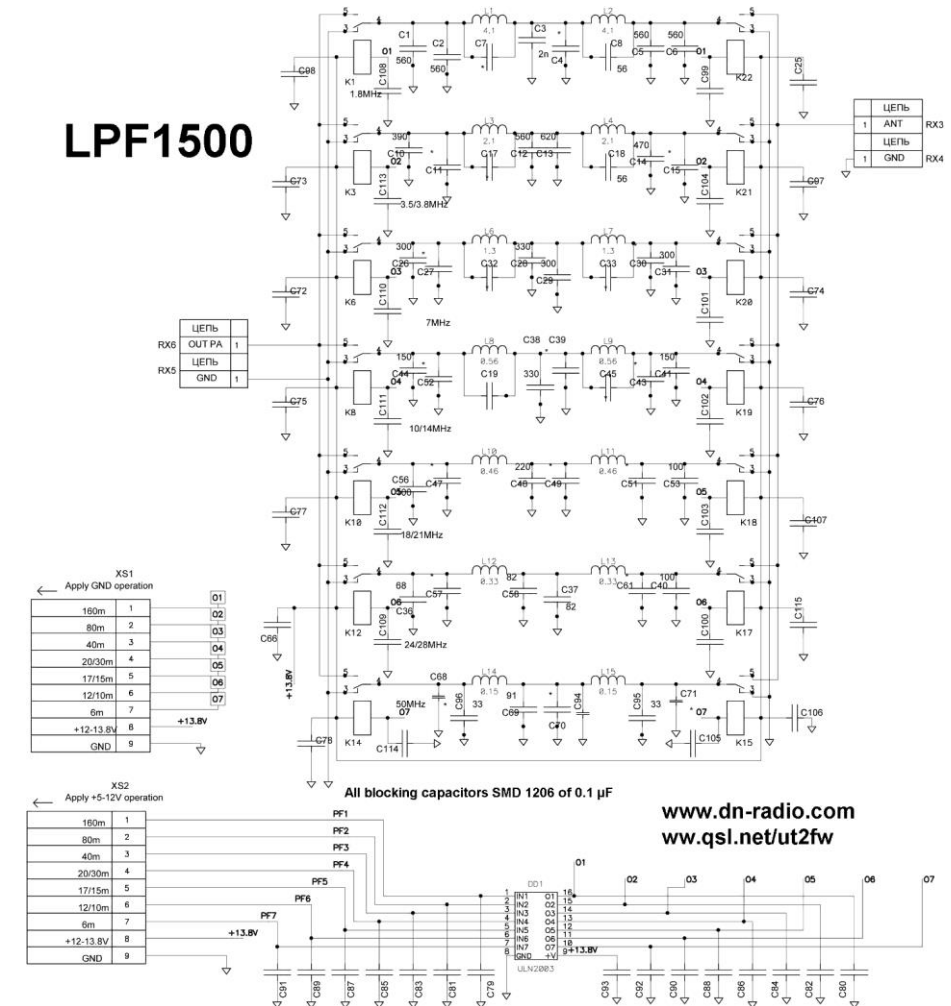
Low Pass Filter



Typical features:

- LPF is 5 pole Chebyshev filter per band (rated at 1.5 KW)
- Bands electronically selected (160 through 6 meters)
- Neighbouring WARC bands share same setting 20/30, 15/17 and 10/12 meters

LPF1500



Solid State Amplifiers (2/3)

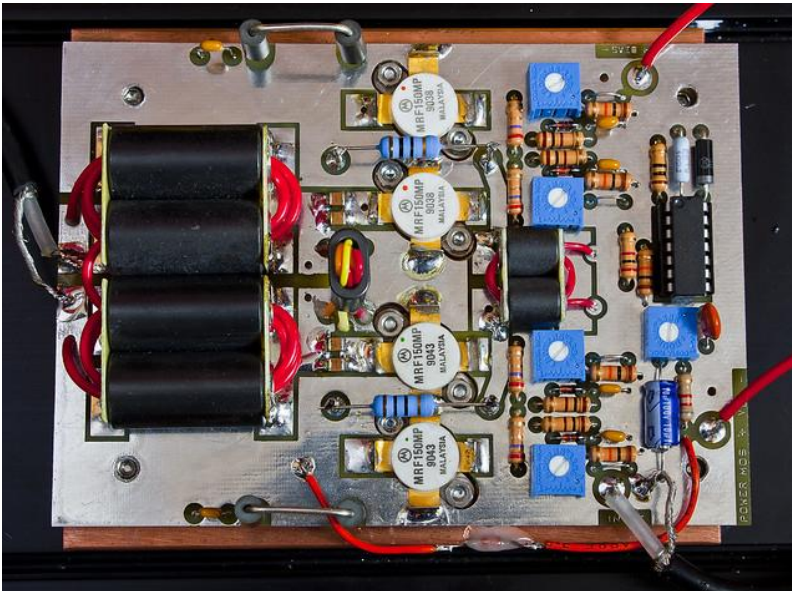
2nd Generation (circa 1982) of high power solid state amplifiers are MOSFET based.

Helge Granberg MOSFET amp designs are in the following Motorola bulletins:

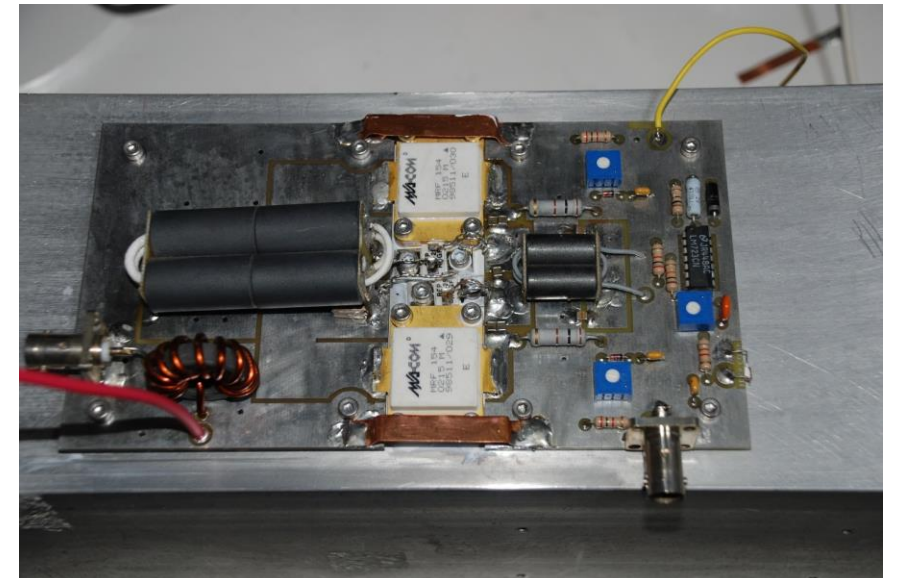
- EB104: 600 watt amplifier with 4 x MOSFET (MRF150)
- AR347: 1200 watt amplifier with 2 x MOSFET (MRF154)

Advantages:

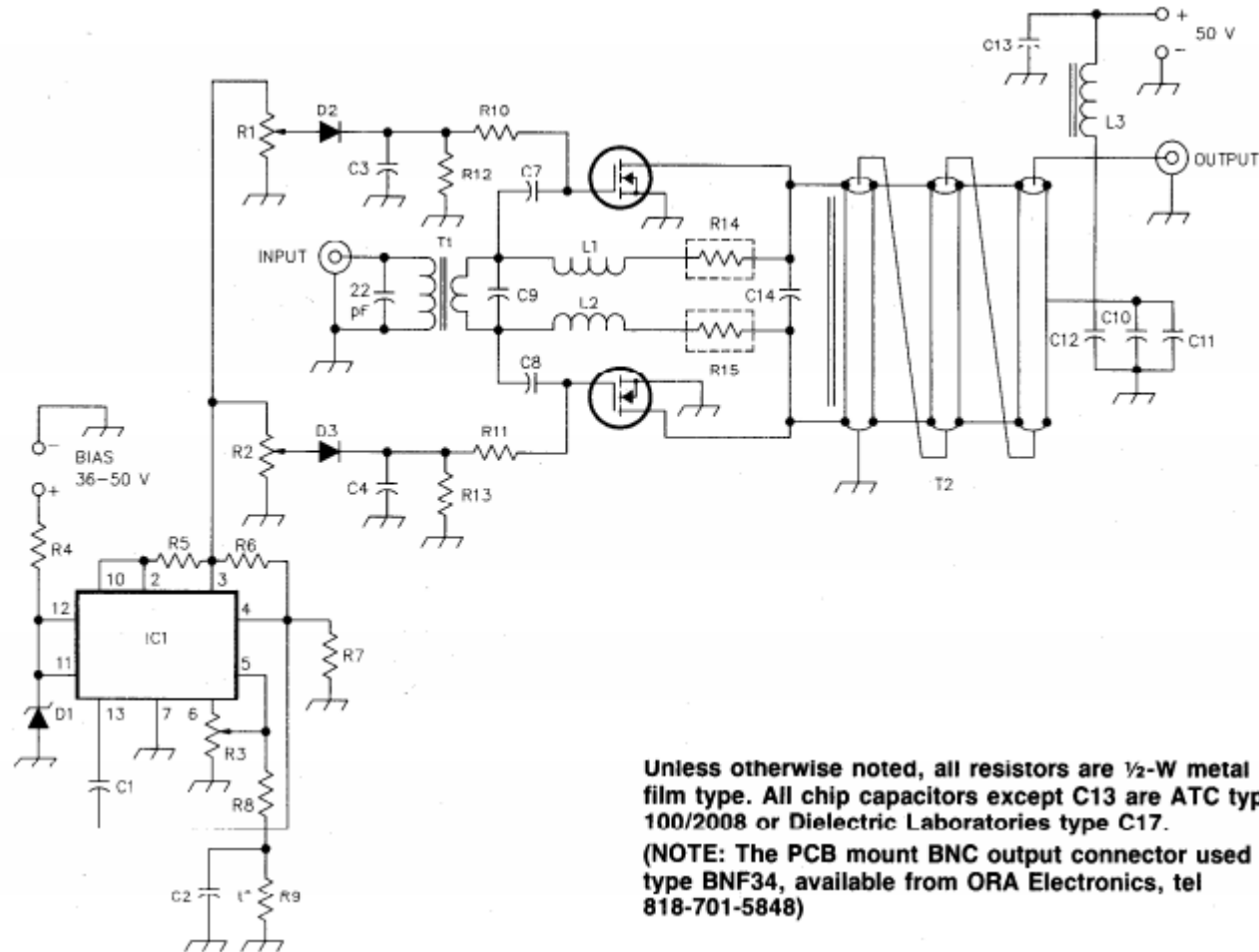
- More power with less devices
- Cheaper and more efficient (less toroidal losses) → No input splitter or output combiner needed
- Better gain than bipolar amplifier → Full output with only 6 watts drive
- Better frequency bandwidth → 1.8 to 54 MHz



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MRF154 MOSFET Amplifier

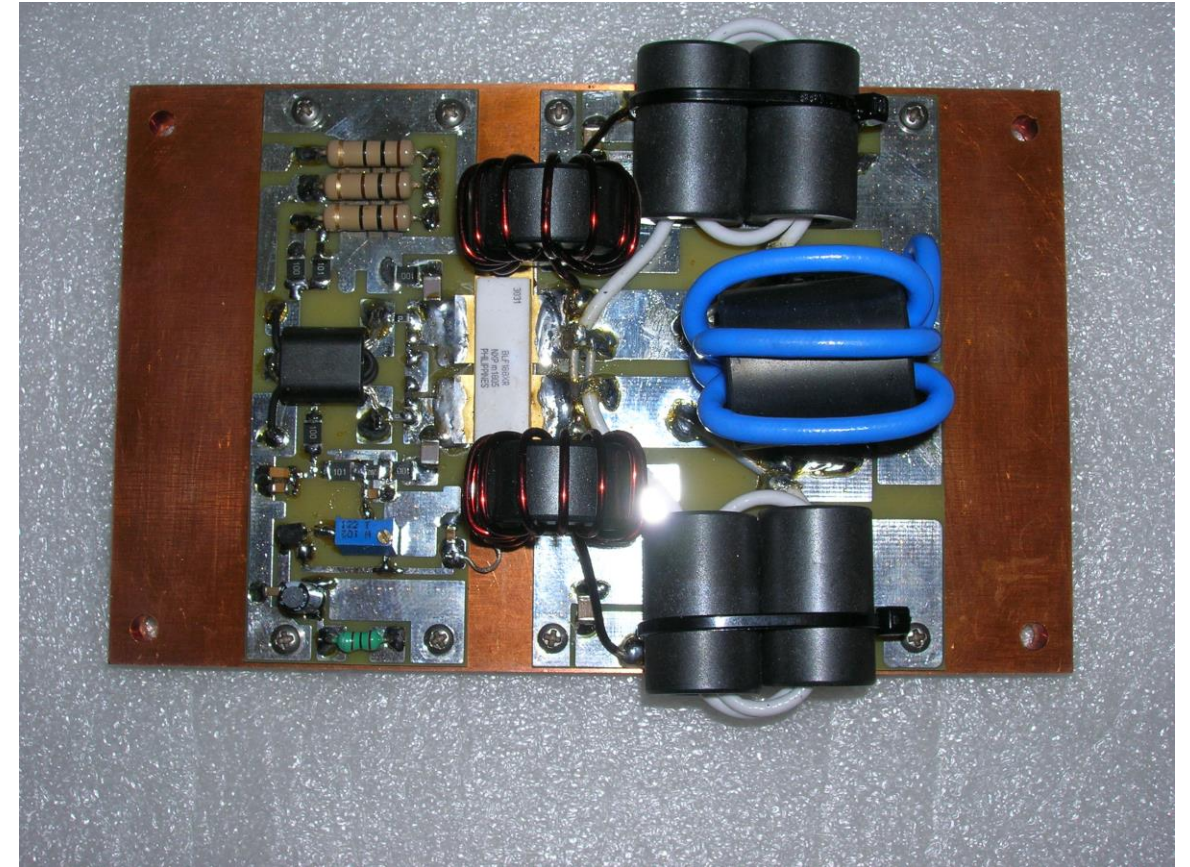
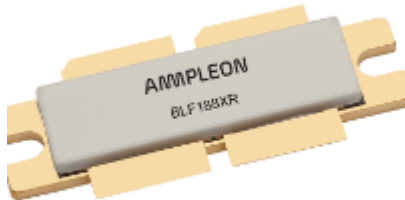


Solid State Amplifiers (3/3)

- 3rd generation of solid state amplifiers featured *LDMOS technology introduced in 2000
- LDMOS package consist of two perfectly matched MOSFET devices on a single slab.

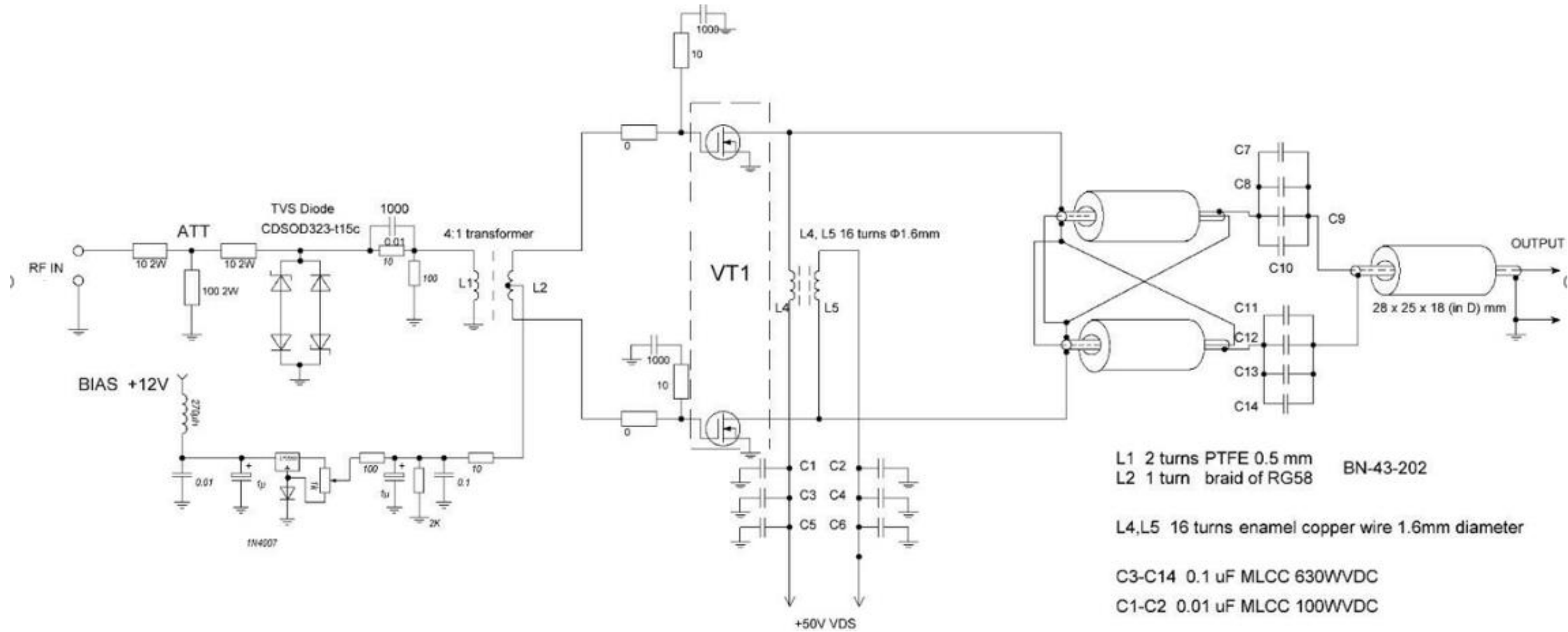
Advantages:

- Capable of up to 600 MHz
- 1200 watts output with 2 watts input
- Better linearity and efficiency
- Most economical approach: Watts / dollar



* Laterally Diffused Metal Oxide Semiconductor

LDMOS Amplifier



Commercial SS HF Amplifiers

1) Ameritron ALS 1300

- 8 x MRF150 MOSFET, 1200 watts
- 160 - 10 m
- \$3000 USD
- Made in USA



2) Palstar LA-1K

- 5600H LDMOS, 1000 watts, touch screen
- 160 - 6 m
- \$3500 USD
- Made in USA



3) Elecraft KPA1500

- 2 x BLF188, 1500 watts, built-in antenna tuner
- 160 - 6 m
- \$5995 USD
- Made in USA



Commercial SS HF Amplifiers

4) Acom A1200S

- 2 x BLF188 LDMOS, 1200 watts
- 160 - 6 m
- \$3500 USD
- Made in Bulgaria



5) Burst 2000A

- 2 x BLF188 LDMOS, 2200 watts, water cooled
- 160 - 6 m
- \$4000 USD
- Made in Russia



6) RF-Kit RF2K-S

- 2 x BLF189XR LDMOS, 2000 watts, with antenna tuner
- 160 - 6 m
- \$4500 USD
- Made in Germany



Part 1: Conclusion

Why are tube amplifiers still dominating the Amateur Radio landscape ?

1) Commercial solid state amps are very expensive, costing between \$3000 to \$6000 USD.

2) Quality used tube amplifiers from 1970-80's are available for anywhere between \$300-600 USD.

- Heathkit SB200 series
- Dentron QRO, Clipperton
- Amp Supply LK500 series

- Most post-1980 amplifiers support WARC bands (30, 17 and 12 meters)

- Modern tube amplifiers to be avoided unless they are “Cadillac” brands like Alpha.

3) Alternative to options 1 and 2

- Homebrew SS amp by integrating pre-built modules (‘Lego approach’) as opposed to ‘ground up’ build.
- Can be made for under \$1000 USD
- Reliability and functionality of commercial amplifiers can be had.

Resources

Bipolar and MOSFET amplifier build descriptions:

AN758 Motorola Bipolar 1200 watt amplifier:

https://www.rf-microwave.com/app/resources/uploads/transistors/Motorola_AN758.pdf

EB104 Motorola FET 600 watt amplifier

<https://www.ab4oj.com/dl/eb104.pdf>

AR347 Motorola MOSFET 1200 watt amplifier

http://www.communication-concepts.com/content/AR347/AR347_Application_Note.pdf

Useful information with many details on LDMOS amplifier construction (1.8 to 1200 MHz)

<https://w6pql.com/>

➔SS amplifier builders users group

Facebook: [RF SSPA Builders group](#)

LDMOS amplifiers controlled by Arduino

https://www.qsl.net/on7eq/projects/arduino_sspa.htm

https://www.qsl.net/yo4hfu/LDMOS_2M.html

Resources

Amplifier component and kit supplier:

<https://w6pql.com/>

<https://www.communication-concepts.com/>

<https://eb104.ru/>

<https://www.heatsinkusa.com/>

<https://www.rf-microwave.com/>

Gi7B tube conversions:

<https://www.gi7b.com>

Questions ?