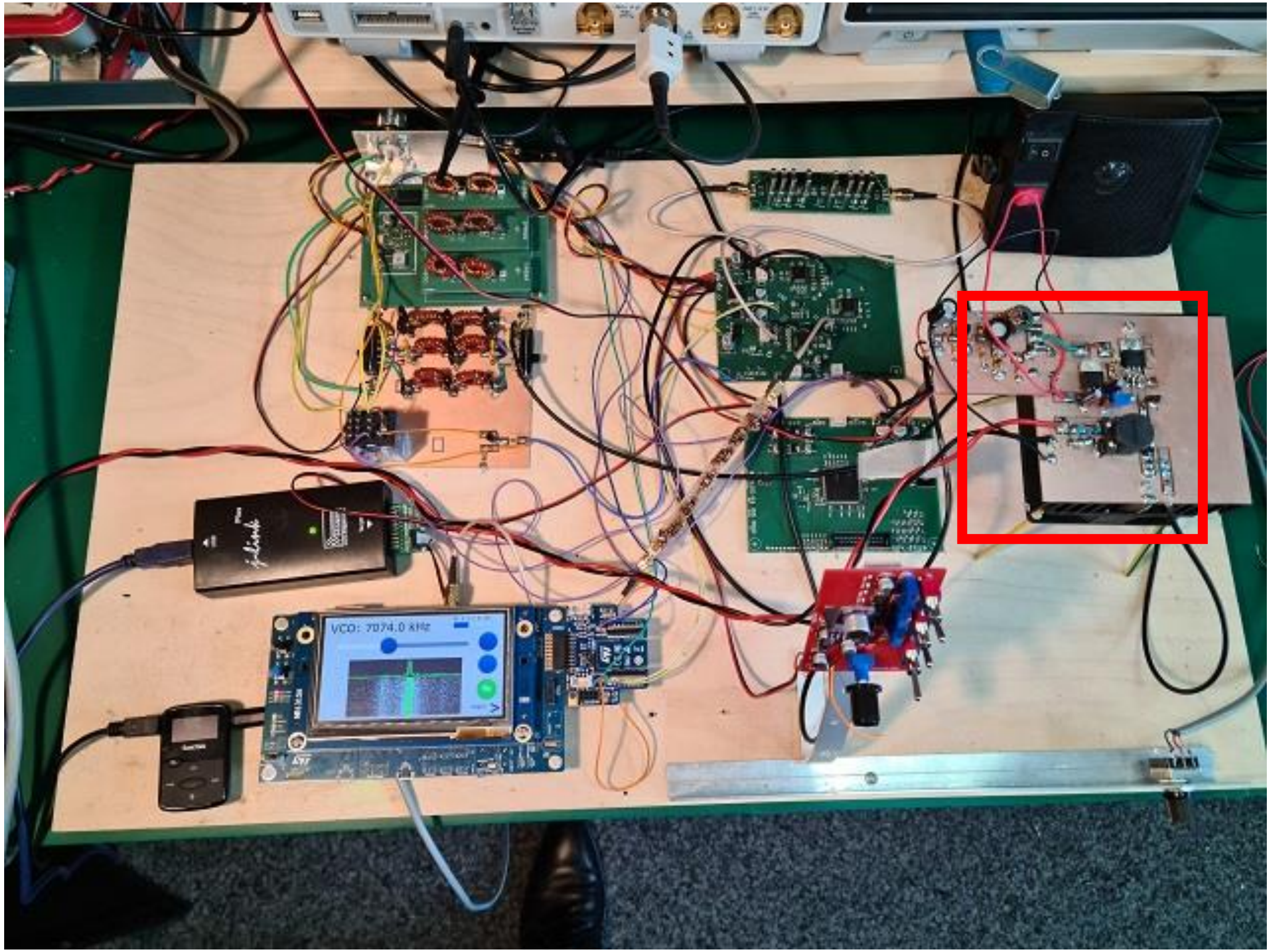
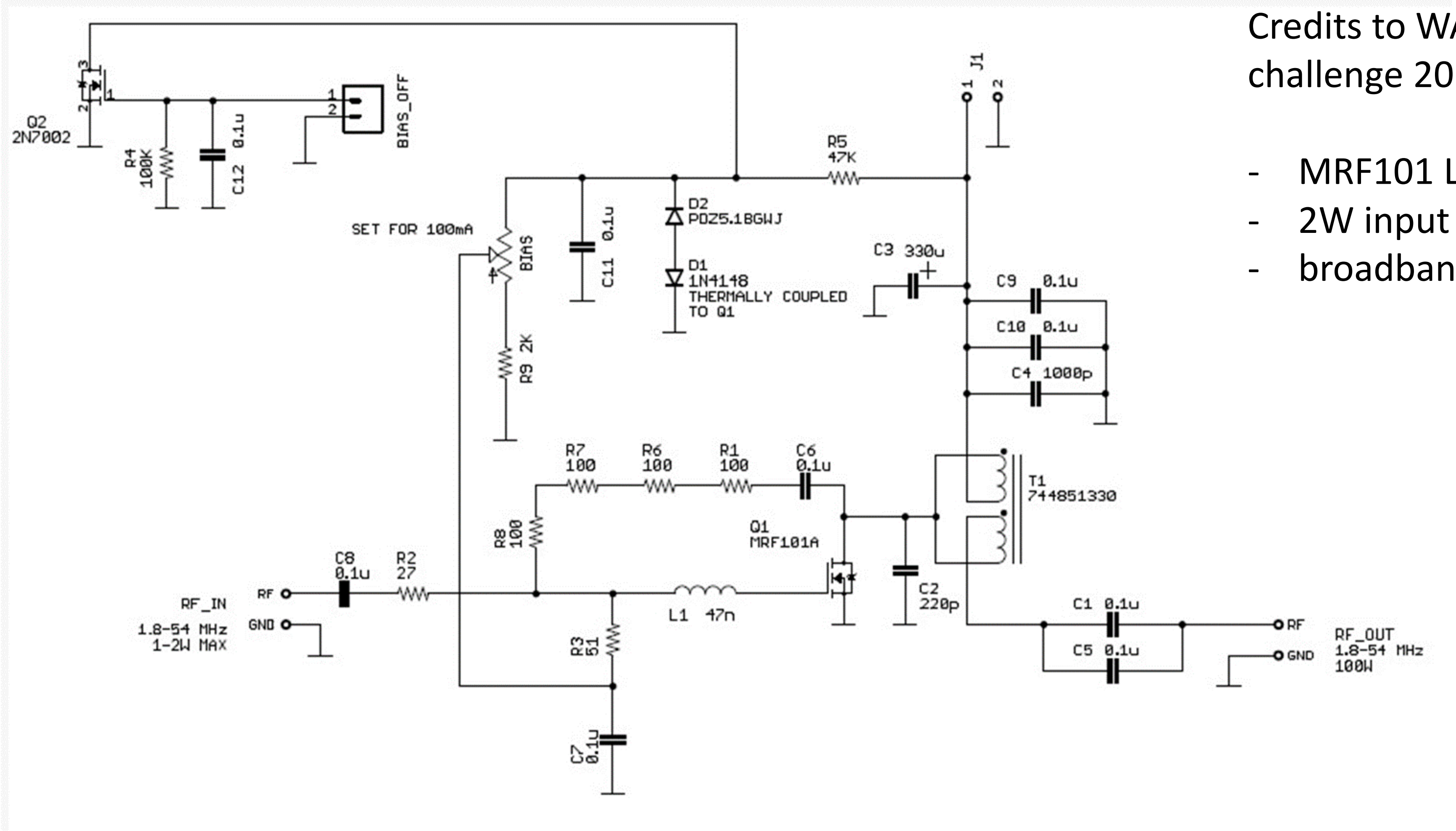
Design Power-Amplifier



Amplifier Design by Jim, WA2EUJ

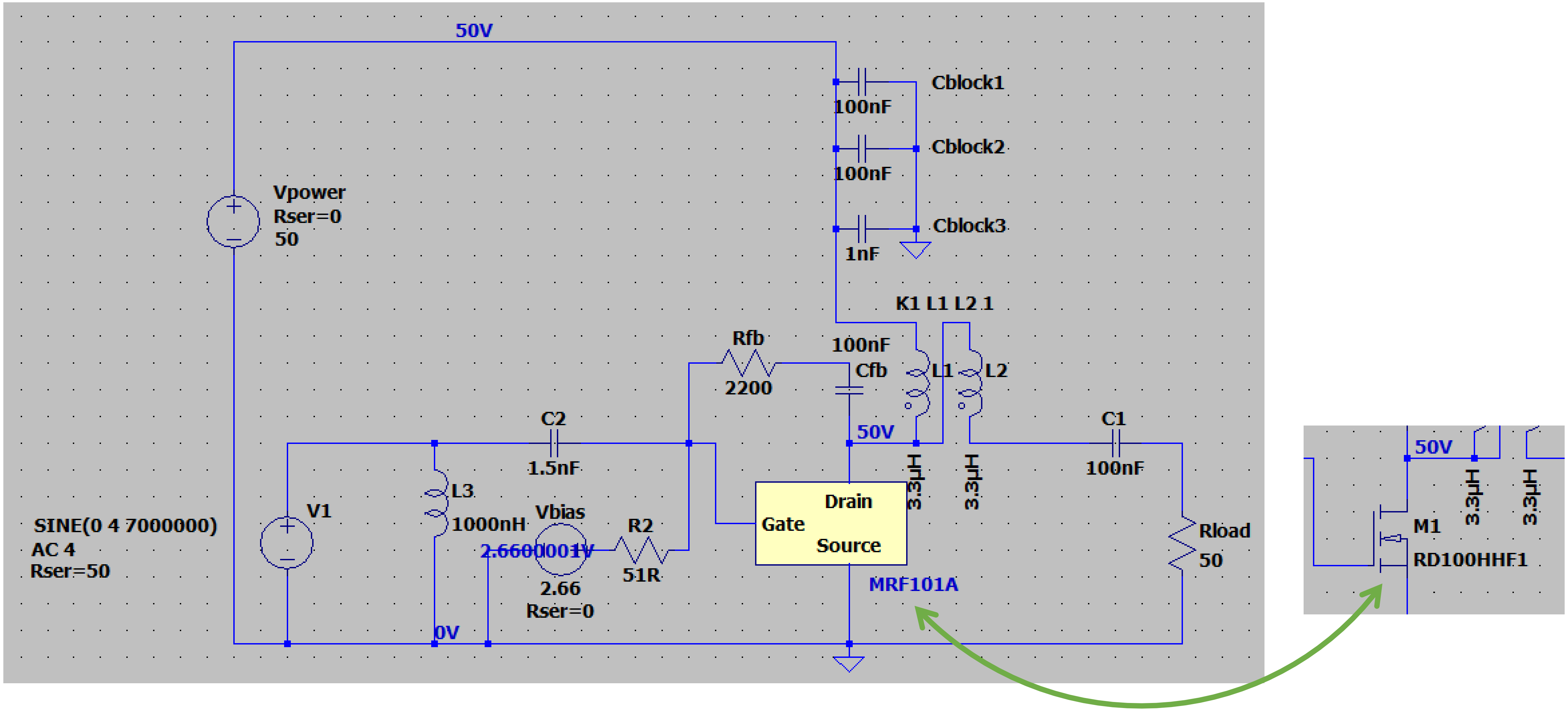


Credits to WA2EUJ who won the NXP design challenge 2019!

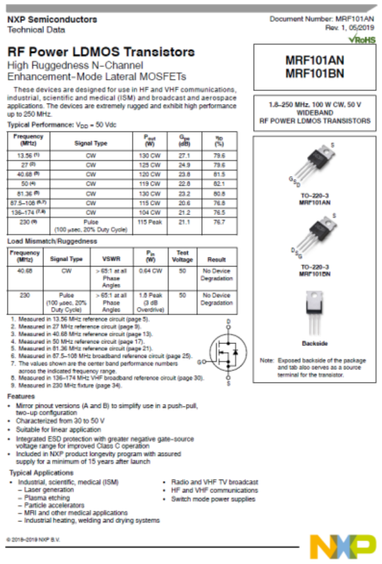
- MRF101 LDMOS (25$/p)
- 2W input / 100W output → 17dB
- broadband

https://sites.google.com/site/rfpowertools/rf-power-tools/nxp-mrf-101

Amplifier simulation LTSpice



The LTSpice simulation challange


NXP Semiconductors
Technical Data

Document Number: MRF101AN
Rev. 1, 05/2019

RF Power LDMOS Transistors
High Ruggedness N-Channel
Enhancement-Mode Lateral MOSFETs

These devices are designed for use in HF and VHF communications, industrial, scientific and medical (ISM) and broadcast and aerospace applications. The devices are extremely rugged and exhibit high performance up to 250 MHz.

Typical Performance: V_{DD} = 50 Vdc

Frequency (MHz)	Signal Type	P_{out} (W)	G_{ps} (dB)	η_D (%)
13.56 (1)	CW	130 CW	27.1	79.6
27 (2)	CW	125 CW	24.9	79.6
40.68 (3)	CW	120 CW	23.8	81.5
50 (4)	CW	119 CW	22.8	82.1
81.36 (5)	CW	130 CW	23.2	80.8
87.5–108 (6,7)	CW	115 CW	20.6	76.8
136–174 (7,8)	CW	104 CW	21.2	76.5
230 (9)	Pulse (100 μsec, 20% Duty Cycle)	115 Peak	21.1	76.7

Load Mismatch/Ruggedness

Frequency (MHz)	Signal Type	VSWR	P_{in} (W)	Test Voltage	Result
40.68	CW	> 65:1 at all Phase Angles	0.64 CW	50	No Device Degradation
230	Pulse (100 μsec, 20% Duty Cycle)	> 65:1 at all Phase Angles	1.8 Peak (3 dB Overdrive)	50	No Device Degradation

1. Measured in 13.56 MHz reference circuit (page 5).
2. Measured in 27 MHz reference circuit (page 9).
3. Measured in 40.68 MHz reference circuit (page 13).
4. Measured in 50 MHz reference circuit (page 17).
5. Measured in 81.36 MHz reference circuit (page 21).
6. Measured in 87.5–108 MHz broadband reference circuit (page 25).
7. The values shown are the center band performance numbers across the indicated frequency range.
8. Measured in 136–174 MHz VHF broadband reference circuit (page 30).
9. Measured in 230 MHz fixture (page 34).

Features
- Mirror pinout versions (A and B) to simplify use in a push-pull, two-up configuration
- Characterized from 30 to 50 V
- Suitable for linear application
- Integrated ESD protection with greater negative gate-source voltage range for improved Class C operation
- Included in NXP product longevity program with assured supply for a minimum of 15 years after launch

Typical Applications
- Industrial, scientific, medical (ISM)
  - Laser generation
  - Plasma etching
  - Particle accelerators
  - MRI and other medical applications
  - Industrial heating, welding and drying systems
- Radio and VHF TV broadcast
- HF and VHF communications
- Switch mode power supplies

MRF101AN
MRF101BN

1.8–250 MHz, 100 W CW, 50 V
WIDEBAND
RF POWER LDMOS TRANSISTORS

TO-220-3
MRF101AN

TO-220-3
MRF101BN

Backside

Note: Exposed backside of the package and tab also serves as a source terminal for the transistor.

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No LTSpice Model; not even for LDMOS (only VDMOS)
NXP provides only S-Parameters.

```
! Copyright - 2018 NXP B.V.
! 11/29/2018
! Rev 0
! MRF101AN/BN S-Parameters
! Vdd=50V, IDQ=1000mA
# hz S ma R 50
! Comment
! freq  magS11  angS11  magS21  angS21  magS12  angS12  magS22  angS22
!
        30000000   0.564235448   -99.7043106   53.2145653   102.23512   0.00547553021   28.7605559   0.416624089   -97.7164457
        35000000   0.572121868   -105.443103   46.8439683   98.2792741  0.00622285213   18.0655717   0.416214496   -102.203608
        40000000   0.585440496   -109.745584   41.8694627   95.6498936   0.0059789161   15.4206392    0.42123798   -105.432068
```

On groups.io “LTSpice” you find a tool to convert a S-Parameter file (touchstone) into a .subckt spice model/library:
https://groups.io/g/LTspice/files/z_yahoo/Tut/S-Parameter/S-Parameter%20to%20SPICE/s2spice.exe
(added manually S-Parameters for 3 MHz)

```
.SUBCKT MRF101A 1 2 3
* Copyright - 2018 NXP B.V.
* 11/29/2018
* Rev 0
* MRF101AN/BN S-Parameters
* Vdd=50V, IDQ=1000mA
* hz S ma R 50
* Comment
* freq  magS11  angS11  magS21  angS21  magS12  angS12  magS22  angS22
*
* Z1=50.000000 Z2=50.000000

R1N 1 10 -5.000000e+001
R1P 10 11 1.000000e+002
R2N 2 20 -5.000000e+001
R2P 20 21 1.000000e+002

*S11 FREQ MAG PHASE
E11 11 12 FREQ {V(10,3)}= MAG
+( 1.000000e+006, 5.642354e-001,-9.970431e+001)
+( 3.000000e+007, 5.642354e-001,-9.970431e+001)
+( 3.500000e+007, 5.721219e-001,-1.054431e+002)
```

.lib file
.ac worked well; .trans did not work at all…

LDMOS vs. GaN

LDMOS (**laterally-diffused metal-oxide semiconductor**) is a planar double-diffused MOSFET (metal–oxide–semiconductor field-effect transistor).

→ used in RF power amps in e.g. mobile networks (2G, 5G)
→ High power, linear, high efficiency
→ 1MHz up to 3.5GHz
→ drain – source breakdown >60V typically

GaN (gallium nitride) power amplifiers:

- 10% higher efficiency (smaller output capacitance, easier to build wideband applications), higher frequencies, higher break down voltage and easier to linearize…

Impedance matching

13.56 MHz COMPACT REFERENCE CIRCUIT (MRF101AN)

f (MHz)	Z_{source} (Ω)	Z_{load} (Ω)
13.56	25.3 + j10.2	11.3 – j6.4

Z_{source} = Test circuit impedance as measured from gate to ground.

Z_{load} = Test circuit impedance as measured from drain to ground.

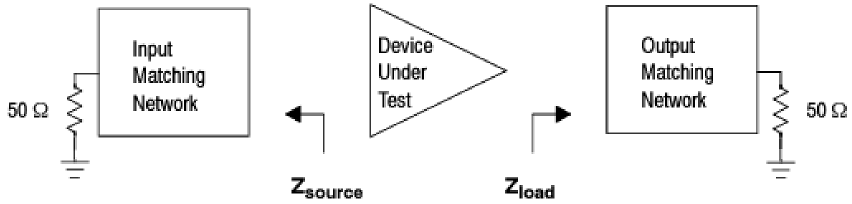
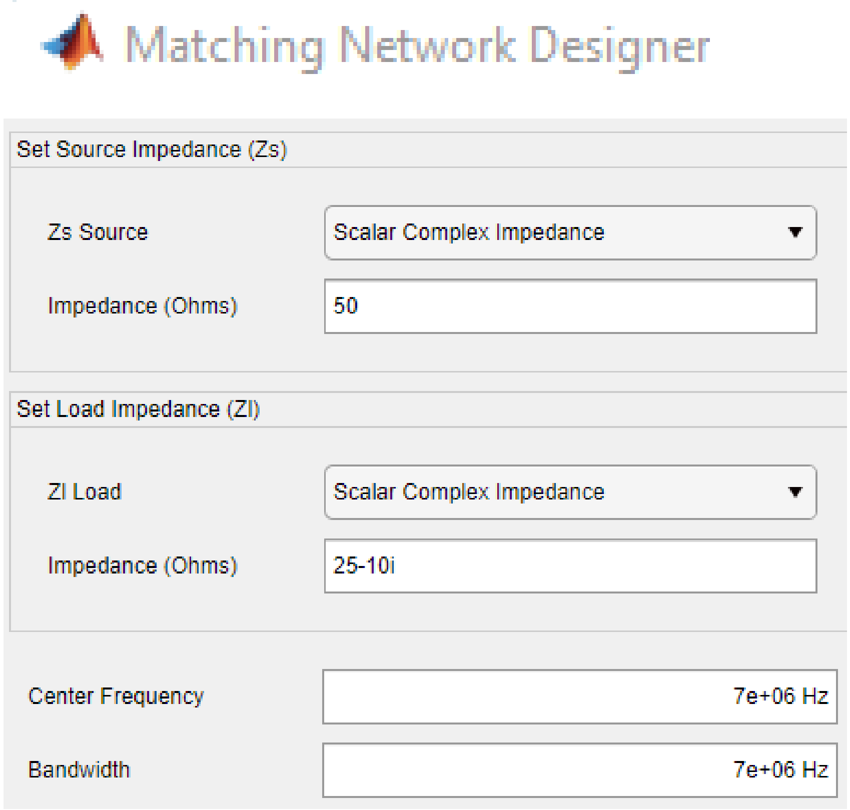
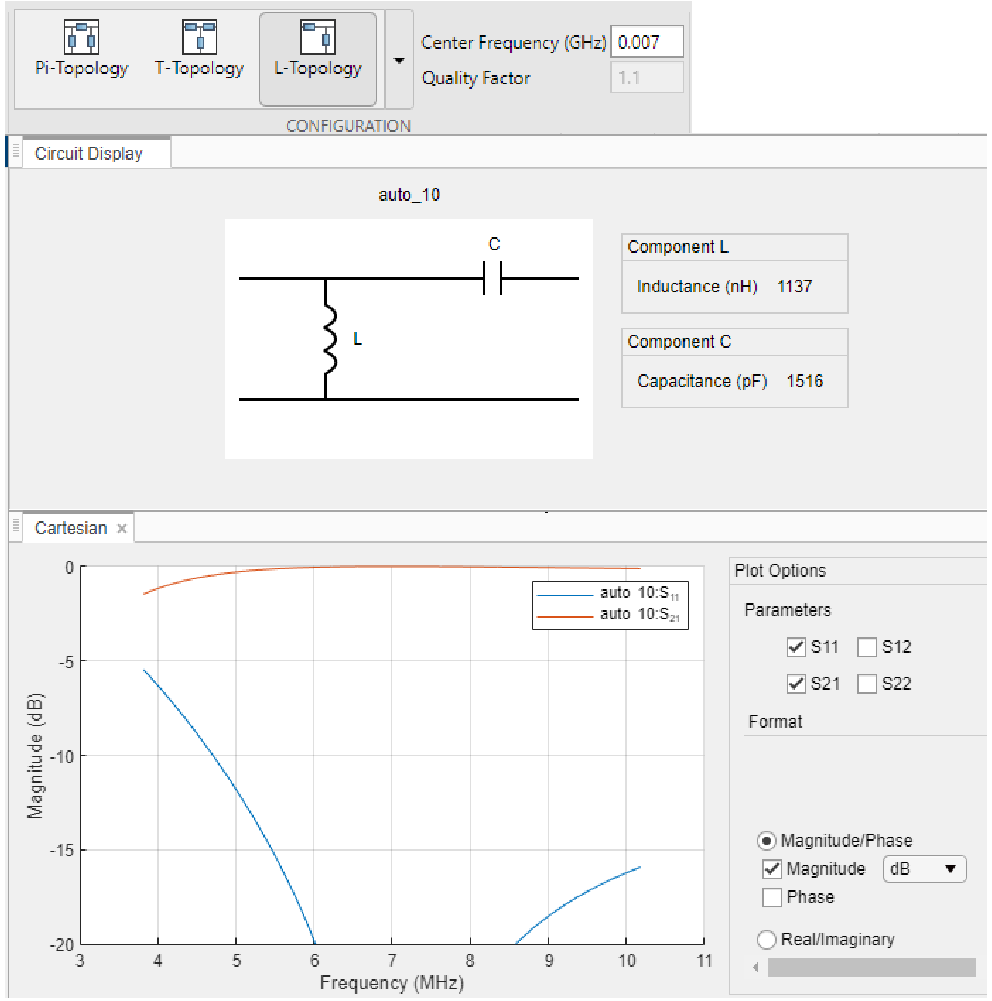


Figure 8. Series Equivalent Source and Load Impedance — 13.56 MHz

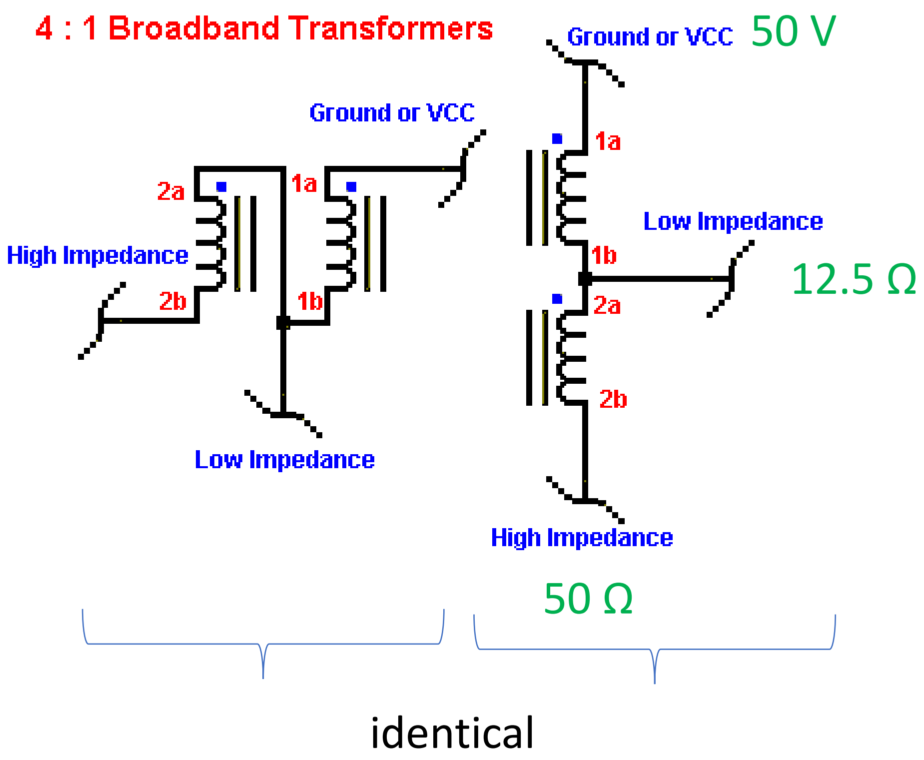
25 – j10



Input-Impedance matching



Output-Impedance matching

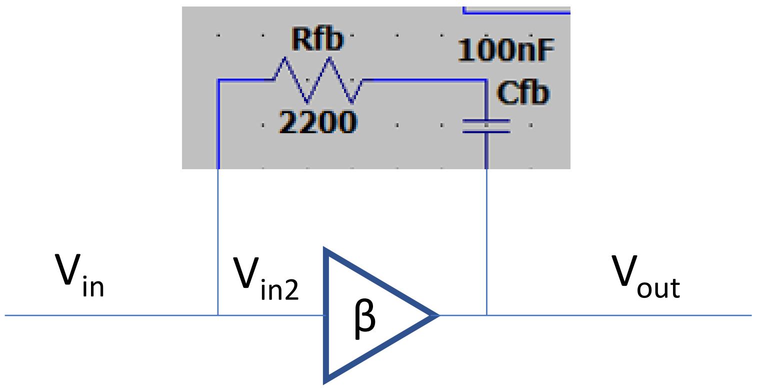


Z_{target}: 11 Ω - j6 Ω → | Z_{target} | = 12.5 Ω

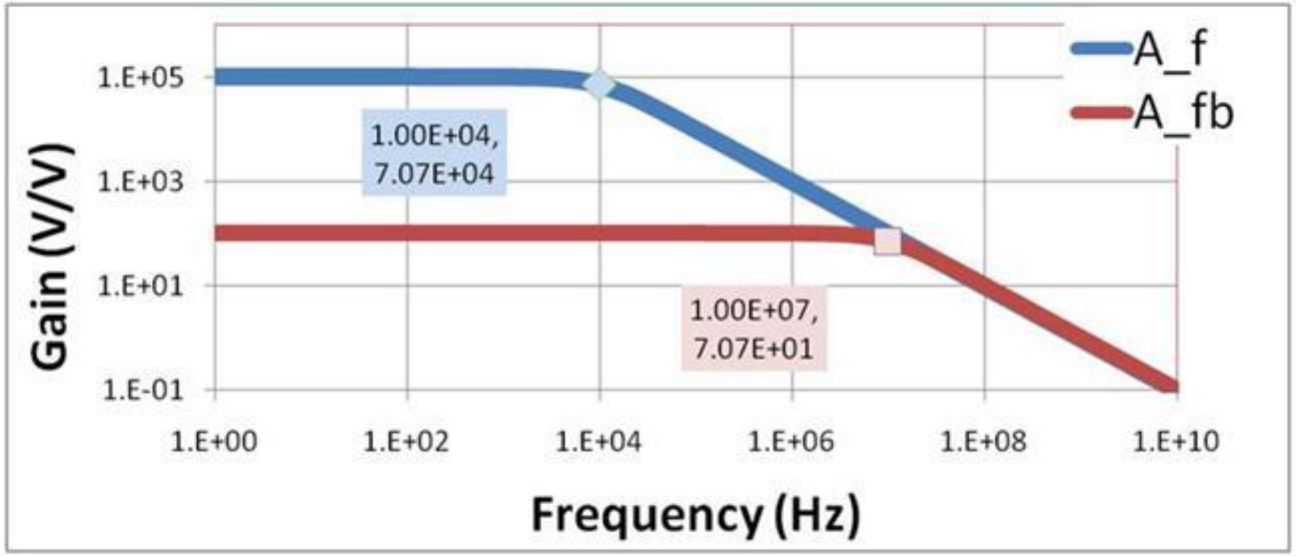
Transmission-Line-Transformer; symmetrical

https://cloud.kyme32.ro/ftp_backup/PAGINI%20HTML%20ELECTRONICA/Broadband%20Transformers.htm

Providing negative feedback



$V_{in2} = V_{in} - \beta * V_{out}$

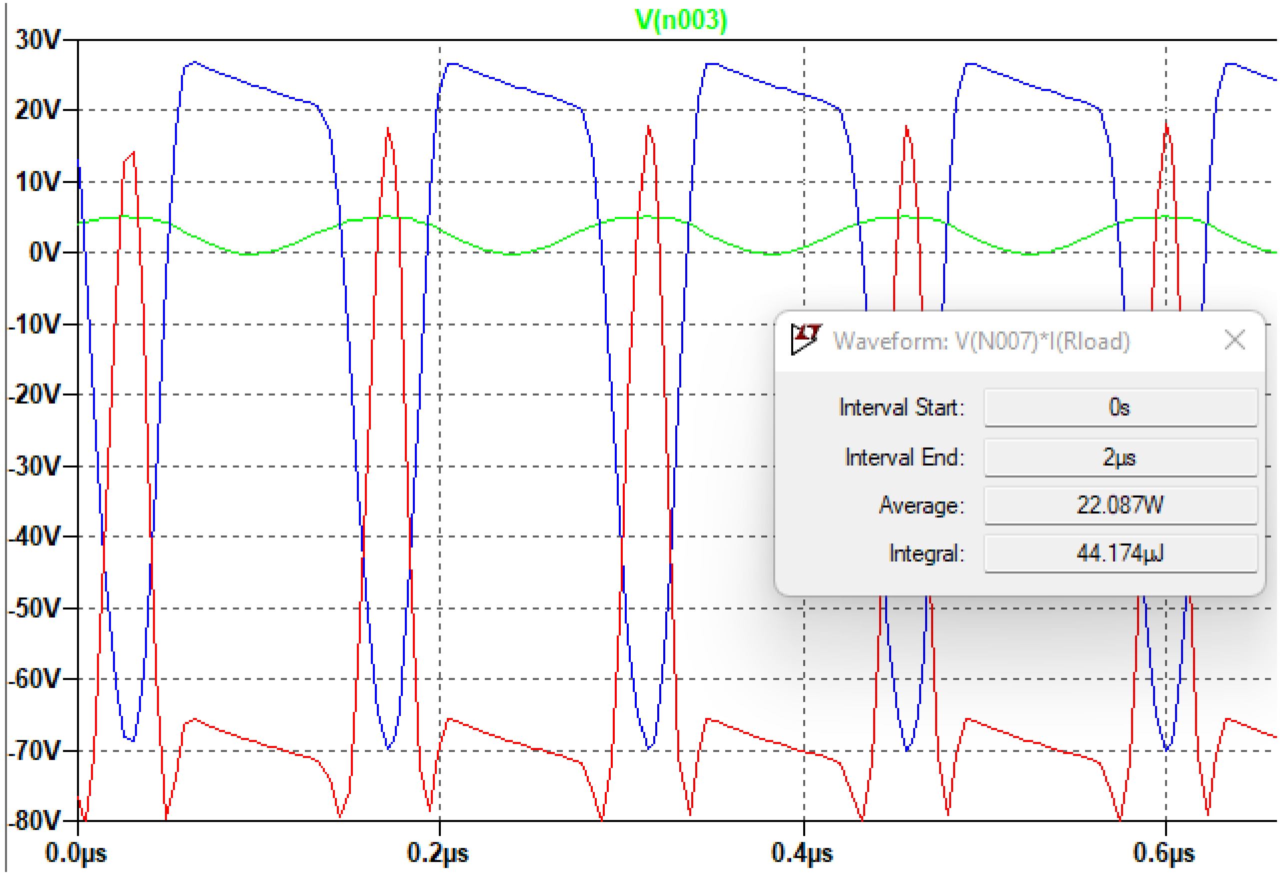


https://en.wikipedia.org/wiki/Negative-feedback_amplifier

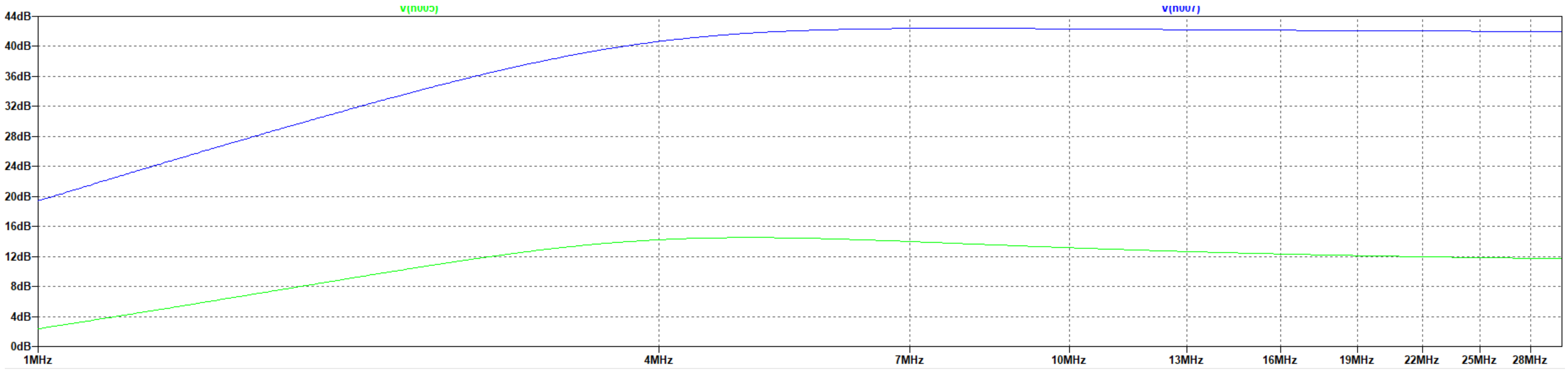
Simulation results LTSpice

Vin = 10Vpp, 7MHz

green = V_{GS}
blue = $_{Vload(50)}$
red = p(t) @ load(50)



Simulation results LTSpice



Vin = 10Vpp, 7MHz

gain of about 30dB

green = V_{in}
blue = $V_{load(50)}$

But: no S-Parameters down to 1 MHz!!