LDMOS Power Amplifiers
for 23 cm - 150 W to 1 kW

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LDMOS: „full legal power“?

- Popular LDMOS amplifier modules (pallets):
  - 144 MHz: 1 kW LDMOS MRFE6VP61K25
  - 432 MHz: 500 W MRFE6VP5600
  - 1296 MHz: 150 W 2 x MRF286
Pallets without a shielding box

- OK for a prototype – but not for a product
PAs based on such pallets

- Imperfectly shielded outer enclosures
Module concept

- Use of a cheap shielding box, to be integrated with a large heat spreader

- Low cost LDMOS surplus transistors (from cellular, not broadcast market)

- Expensive components only where really needed (but reliable design nevertheless)
Concept of the box

- Transistor is installed on a copper heat spreader
- Frame and cover from tin plated material (possibly joint with the heat spreader)
- PCB fixed with screws to the copper and soldered to the tin plate frame
Concept of the box

- Two separate PCBs for input and output circuits
- As few through-holes as possible
High-current feedthrough

- Feedthrough capacitors for 10-25 A
Which transistors for 1296 MHz?

- Cellular transistors for 900 MHz 60 W: MFR9060, MRF6S9060, MRF286 etc. (without internal pre-matching)
- Broadcast/ISM transistors for 1300/1400 MHz (internally pre-matched):
  - PTF141501E 150 W 28 V
  - BLF6G13L-250P 250 W 50 V
- Cellular transistors for 900 MHz 125…160 W: MRFE6S9125, MRFE6S9135, MRFE6S9160 (only pre-matched at the input)
RF Power Field Effect Transistors

N-Channel Enhancement-Mode Lateral MOSFETs

Designed for N-CDMA, GSM and GSM EDGE base station applications with frequencies from 865 to 960 MHz. Suitable for multicarrier amplifier applications.

- Typical Single-Carrier N-CDMA, Performance @ 880 MHz: \( V_{DD} = 28 \) Volts, \( I_{DS} = 1200 \) mA, \( P_{out} = 35 \) Watts Avg., IS-95 CDMA (Pilot, Sync, Paging, Traffic Codes 8 Through 13) Channel Bandwidth = 1.2288 MHz, PAR = 9.8 dB @ 0.01% Probability on CCDF.
  - Power Gain — 21 dB
  - Drain Efficiency — 31%
  - ACPR @ 750 kHz Offset — -46.8 dBc in 30 kHz Bandwidth

- Capable of Handling 10:1 VSWR, @ 32 Vdc, 880 MHz, 6 dB Overdrive, Designed for Enhanced Ruggedness.

**Features**

- Characterized with Series Equivalent Large-Signal Impedance Parameters
- Internally Matched for Ease of Use
- Qualified Up to a Maximum of 32 \( V_{DD} \) Operation
- Integrated ESD Protection
- RoHS Compliant
- In Tape and Reel, R3 Suffix = 250 Units per 56 mm, 13 inch Reel.

**MRFE6S9160HR3**
**MRFE6S9160HSR3**

880 MHz, 35 W AVG., 28 V
SINGLE N-CDMA
LATERAL N-CHANNEL
RF POWER MOSFETs

CASE 465-06, STYLE 1
NI-780
MRFE6S9160HR3

CASE 465A-06, STYLE 1
NI-780S
MRFE6S9160HSR3
MRFE6S9160HS - 10 EUR
PA 1296 MHz: the prototype

- Let’s try it!

With success: 150 W output power at 19...20 dB gain
PA 1296 MHz: push-pull?

- Experiment of a push-pull amplifier:

Poor result: asymmetric behaviour, low efficiency.
PA 1296 MHz: MRFE6S9160

• Design of an amplifier without through-holes close to the transistor:

  Result: similar to the first prototype, but critical contacts at the PCB edges
PA 1296 MHz: MRFE6S9160

- Soldering of the transistor to the heat spreader: first trials with tin-lead solder
Result: this process was working, but caused several failures too (transistors had reduced transconductance)

Then: use of a low temperature SMD solder paste - 138°C – Edsyn CR11 Sn42Bi58 (tin – bismuth)

Slowly heating and cooling the pallets
=> no more failures (from 20 transistors)!
PA 1 x MRFE6S9160 RO4003

- Design verification with 4 new prototypes – all achieve >150 W at 28 V
PA 1 x MRFE6S9160 RO4003

+28 V TX
max. 10 mA

2.7k

100m 5.1V 1k

1n 0805 NP0

1n 0805 NP0

1n 0805 NP0

1n 0805 NP0

2k2

100µF

63V

Duko

MURATA T203

28p ATC600S

RF in

47p 0805 NP0

2.2p 0805 NP0

1n 0805 NP0

1n 0805 NP0

6 x 3.3p ATC100B

2 x 47p ATC600S

RF out

max. 12 A
PA 1 x MRFE6S9160 RO4003
PA 1 x MRFE6S9160 RO4003
PA 1 x MRFE6S9160 FR4

- Another experiment on 1.5 mm FR4 substrate, as RO4003 is difficult to buy in small quantities

- The result is lower output power and reduced efficiency
PA 1 x MRFE6S9160 FR4

MRFE6S9160 1296 MHz

- **Output Power**
- **DC Input**
- **Efficiency (PAE) %**

Drive Power / W vs. Power / W vs. PAE / %
PA 2 x MRFE6S9160 RO4003

- Next stage: coupling of two amplifiers
PA 1296 MHz: 2 x MRFE6S9160

- Prototype of the twin amplifier
PA 1296 MHz: 2 x MRFE6S9160
PA 1296 MHz: 2 x MRFE6S9160

- Result: success, nearly 300 W at 28 V, efficiency and gain bit lower than for the single amplifier
- Adjustment procedure: first supply and adjust each transistor single (resulting in 6 dB less gain and 3 dB less power than in a single amplifier); e. g. 5 W to 70 W
- then only minor fine adjustment necessary for the joint operation (expect 5 W to 280 W then, according to the above example)
- Next step: try to make PCB smaller and module simpler to build
PA 1296 MHz: 2 x MRFE6S9160
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Use an isolator in the input during test and optimization
PA 1296 MHz: 2 x MRFE6S9160
PA 1296 MHz: 2 x MRFE6S9160

- **Result:**
  - Small high-power boxed amplifier module
  - 275 W at 26 V – 305 W at 28 V – 340 W at 30,6 V
  - 17 dB gain
  - >50% efficiency

- **Adjustment more difficult than with single transistor module**

- **For bigger PAs I prefer to combine twin modules externally**
F5J WF: 4 x MRFE6S9160

Based on the single transistor amp

Couplers and total design by Philippe F5J WF
F5J WF: 4 x MRFE6S9160

Efficient water cooling

$P_{\text{sat}} > 600$ W

Philippe plans to mount two modules behind his dish feed for EME
How to make 1 kW on 1296?
PA 1296 MHz: 8 x MRFE6S9160

4 modules

Input:
Wilkinson coupler
on FR4

Output:
isolators +
non-isolated coupler
(antenna combiner)
PSU 28 V >100 A

- PSU and DC filtering has to be investigated
Conclusion

- Concept of a 150 W 1296 MHz power amplifier module with a bill of material cost <30 GBP

- PA with 2 transistors in a box with printed couplers (min. 250 W for 60 GBP BOM)

- Higher power by combining multiple modules – 1 kW demonstrated