Solid State Kilowatt Amplifiers

A tutorial on how to annoy your neighbors with modern LDMOS transistors

Which bands will we explore here?

- 2m, 222MHz and 70cm
- 6m (winter 2013/14)
- HF through 6m (spring 2014)
Can You Build One of These?

Sure, why not?
Another version
BIG LDMOS devices are available at “reasonable” cost

- Freescale and NXP (Phillips)
  - MRFE6VP1K25H - 1.25kw (Freescale) HF to ~300MHz
  - MRFE6VP5600H – 600w (Freescale) HF to 450 MHz
  - BLF578XR -1.25KW (NXP) HF to ~300MHz
  - BLF184XR – 600w (NXP) HF to 450MHz (new device, unverified)
Measured Performance

• 6m, 2m and 222MHz
  – 1.25kw part produces 1kw at P1db, and up to 1.35kw at P3db
  – Efficiency is >70% at P1db
Measured Performance

70cm

- 1.25kw part produces ~350w with low efficiency
- 600w part produces 500w at P1db with 53% efficiency
- Two of the 600w parts produce 1kw at P1db with 53% efficiency
Where to Find Design Info

- Manufacturer reference designs
- Dubus magazine
- QST and QEX magazine
- Web sites
  - [www.w6pql.com](http://www.w6pql.com)
  - F1JRD
  - Many others
Critical Parts

1. LDMOS distributors
   - Newark Electronics [www.newark.com](http://www.newark.com) (Freescale)
   - Digikey [www.digikey.com](http://www.digikey.com)
   - Mouser [www.mouser.com](http://www.mouser.com)
   - Richardson RFPD [www.richardsonrfpd.com](http://www.richardsonrfpd.com) (Freescale)
Critical Parts

High power RF capacitors

– Metal Micas
  • Mouser
  • Digikey
  • Communication Concepts [www.communication-concepts.com](http://www.communication-concepts.com/)

– SMT micas (CDE MC series)
  • Mouser

– Coaxial matching capacitors
  • Self-made
More Critical Parts

Inductors and transformers

- Communication Concepts
- Mouser
- Self-wound RF chokes and transformers

Coax (special stuff, 10, 12, and 25 ohm)

- Communication Concepts
- RF Elettronica [www.rfmicrowave.it](http://www.rfmicrowave.it)
- eBay (50 Ohm RG401, RG402, RG316, RG142)
More Critical Parts

Terminations
  • Richardson RFPD
  • RFMW Limited (Florida RF labs terminations)
  • EBay

High power RF resistors and attenuators
  • Richardson RFPD (ATC attenuators)
  • Newark (Johanson attenuators)
  • Mouser (high power resistors for attenuators)
More Critical Parts

Relays and transfer switches
- RFPARTS (www.rfparts.com) - Tohtsu, Dow Key
- Surplus Sales of Nebraska - Tohtsu, Dow Key
- EBay
- WWW.W6PQL.COM (input relay board)

PC boards
- Communications Concepts
- RFHAM
- WWW.W6PQL.COM
More Critical Parts

Copper spreaders

• RFHAM
• WWW.W6PQL.COM

Aluminum heat sinks

• www.heatsinkusa.com
• WWW.W6PQL.COM (fully machined to accept spreaders)

Cabinets and panels

• www.frontpanelexpress.com
Design Cautions

1. All bands
   - Use good quality PC board substrate
   - Matching components (capacitors)
     - Best capacitor for matching is coaxial
   - Instability due to low frequency gain
     - Gate components

2. Bias stability (thermal drift)
   - LDMOS IDQ thermal drift
     - Use of thermistors for stabilization
OK, you have an RF Deck

Now what?
Block diagram
For a complete Desktop amplifier
Flange-Mount Attenuators

- Available in 3, 6, 10, 20 and 30 db packages (availability varies)
- Made by ATC and Johanson
- 100 watt package
- Requires transition boards
A more flexible option
## Attenuator setup

<table>
<thead>
<tr>
<th>Frequency (MHz)</th>
<th>3db</th>
<th>6db</th>
<th>10db</th>
<th>13db</th>
<th>16db</th>
</tr>
</thead>
<tbody>
<tr>
<td>432 MHz</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R1</td>
<td>300-15w</td>
<td>100-15w</td>
<td>100-30w</td>
<td>75-30w</td>
<td></td>
</tr>
<tr>
<td>R2</td>
<td>15-15w</td>
<td>50-15w</td>
<td>75-15w</td>
<td>100-15w</td>
<td></td>
</tr>
<tr>
<td>R3</td>
<td>300-15w</td>
<td>Not used</td>
<td>100-15w</td>
<td>75-15w</td>
<td></td>
</tr>
<tr>
<td>L1</td>
<td>27nh</td>
<td>3 turns #22 3mm dia, space-wound input inductor; position across R1 terminals near body</td>
<td>8.5nh inductor 3 turns #22, 3mm id, 8mm long; position across R1 terminals near body</td>
<td>8.5nh inductor 3 turns #22, 3mm id, 8mm long; position across R1 terminals near body</td>
<td></td>
</tr>
<tr>
<td>L2</td>
<td>27nh</td>
<td>33nh</td>
<td>27nh</td>
<td>27nh</td>
<td></td>
</tr>
<tr>
<td>222 MHz</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R1</td>
<td>100-15w</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R2</td>
<td>50-15w</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R3</td>
<td>Not used</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L1</td>
<td>120nh</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L2</td>
<td>220nh</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>144 MHz</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R1</td>
<td>300-15w</td>
<td>100-15w</td>
<td>100-30w</td>
<td>75-100w</td>
<td>75-100w</td>
</tr>
<tr>
<td>R2</td>
<td>15-15w</td>
<td>50-15w</td>
<td>75-15w</td>
<td>100-15w</td>
<td>150-30w</td>
</tr>
<tr>
<td>R3</td>
<td>300-15w</td>
<td>Not used</td>
<td>100-15w</td>
<td>75-15w</td>
<td>75-15w</td>
</tr>
<tr>
<td>L1</td>
<td>330nh</td>
<td>270nh</td>
<td>220nh</td>
<td>220nh</td>
<td>120nh</td>
</tr>
<tr>
<td>L2</td>
<td>330nh</td>
<td>560nh</td>
<td>330nh</td>
<td>330nh</td>
<td>270nh</td>
</tr>
<tr>
<td>50 MHz</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R1</td>
<td>300-15w</td>
<td>100-15w</td>
<td>100-30w</td>
<td>75-100w</td>
<td>75-100w</td>
</tr>
<tr>
<td>R2</td>
<td>15-15w</td>
<td>50-15w</td>
<td>75-15w</td>
<td>100-15w</td>
<td>150-30w</td>
</tr>
<tr>
<td>R3</td>
<td>300-15w</td>
<td>Not used</td>
<td>100-15w</td>
<td>75-15w</td>
<td>75-15w</td>
</tr>
<tr>
<td>L1</td>
<td>Not used</td>
<td>Not used</td>
<td>Not used</td>
<td>Not used</td>
<td>Not used</td>
</tr>
<tr>
<td>L2</td>
<td>Not used</td>
<td>Not used</td>
<td>Not used</td>
<td>Not used</td>
<td>Not used</td>
</tr>
</tbody>
</table>
PNWVHFS conference
October 2013
Low Pass Filter

low pass filter
Low Pass Filter
Filter Passband
2m setup
Low Pass Filter
with dual directional detector
Low Pass Filter

1 KW LPF and dual directional detector assembly - total insertion loss is < 1/10 db (7-2013 version)

<table>
<thead>
<tr>
<th>Attenuation</th>
<th>R1, R3 or R4, R6</th>
<th>R2 or R5</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 dB</td>
<td>not used</td>
<td>jumper (zero)</td>
</tr>
<tr>
<td>3 dB</td>
<td>300</td>
<td>17</td>
</tr>
<tr>
<td>6 dB</td>
<td>56</td>
<td>33</td>
</tr>
<tr>
<td>13 dB</td>
<td>82</td>
<td>100</td>
</tr>
<tr>
<td>16 dB</td>
<td>99</td>
<td>158</td>
</tr>
<tr>
<td>23 dB</td>
<td>57</td>
<td>348</td>
</tr>
</tbody>
</table>

coupling is very loose at 50 MHz, so the sensitivity of the SWR trip on the control board, and the sensitivity of the bar graph display attenuator must be increased for this band. R2 on the control board should be changed to 180k. R21 on the REV power display board should be changed to 22k.

<table>
<thead>
<tr>
<th>Component</th>
<th>50 MHz</th>
<th>144 MHz</th>
<th>222 MHz</th>
<th>432 MHz</th>
<th>Coupler forward sample level</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 turns #16</td>
<td>50, 60, 65 long</td>
<td>2 turns #18</td>
<td>165, 195 long</td>
<td>2 turns #18</td>
<td>L3, L6</td>
</tr>
<tr>
<td>5 turns #18</td>
<td>50, 60, 65 long</td>
<td>4 turns #18</td>
<td>165, 195 long</td>
<td>4 turns #18</td>
<td>L4, L6</td>
</tr>
<tr>
<td>50 pf metal mica</td>
<td>18 pf metal mica</td>
<td>18 pf metal mica</td>
<td>pcb only</td>
<td>G9, C11</td>
<td></td>
</tr>
<tr>
<td>80 pf metal mica</td>
<td>22 pf metal mica</td>
<td>12 pf metal mica</td>
<td>pcb only</td>
<td>G10</td>
<td></td>
</tr>
</tbody>
</table>

The forward and reverse outputs should be terminated with a 3k to 5k load resistance for the most linear response.
Low Pass Filter
with dual directional detector

1. Coupler will sample both forward and reflected power levels
2. Each band can be configured for correct signal levels
   • On-board attenuators set the correct signal levels for the detector diodes
Coupler Response
coupling across VHF/UHF bands
Antenna Relays (output)

Transfer switch
Dow Key model 412

SPDT model 402
Antenna Relays (output)
SPDT – Tohtsu model CX600NL
Relay Measurements (CX600NL)

insertion loss

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W6PQL
Relay Measurements (CX600NL)

return loss

REF 0.0 dBC
10 dB/div

RBW 50 KHz
ATTEN 10 dB

VBW ---
INT REF

Ua P TG

Amplitude (dBC)

START 50.000000 MHz
CENTER 900.0000 MHz
STOP 1.750000 GHz

SPAN 1.700 GHz
SWP 811.0 msec

Marker 1: 145.0000 MHz, -32.0 dBm
Marker 2: 220.0000 MHz, -29.6 dBm
Marker 3: 435.0000 MHz, -23.8 dBm
Marker 4: 900.0000 MHz, -27.5 dBm
Marker 5: 1295.0000 MHz, -25.4 dBm

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Relay Measurements (CX600NL)

isolation

![Graph showing isolation measurement results for CX600NL relay. The graph includes markers and frequency details.]
Antenna Relays (input)
Relay Specs (CX120A)

insertion loss
Relay Specs (CX120A)

return loss

Marker 1: 145.0000 MHz, -24.4 dBm
Marker 2: 225.0000 MHz, -22.7 dBm
Marker 3: 435.0000 MHz, -19.7 dBm
Marker 4: 900.0000 MHz, -15.7 dBm
Marker 5: 1295.0000 MHz, -14.0 dBm
Relay Specs (CX120A)

isolation

Marker 1: 145.0000 MHz, -41.5 dBm
Marker 4: 900.0000 MHz, -56.4 dBm
Marker 2: 225.0000 MHz, -37.3 dBm
Marker 5: 1295.0000 MHz, -26.9 dBm
Marker 3: 435.0000 MHz, -33.0 dBm
Control Board Functions

• Sequencer
  – Prevents hot-switching the antenna output relay
• DC power gate
  – VDD and bias (event 2)
• Fan control
• Reverse power lockout (high VSWR)
• Over-temp lockout
• Sequenced LNA power feed and drive power gating if required (event 3)
Coming soon to a band near you

• K2OP – 160 thru 6m
  – 650w on 160m
  – 1kw+ on 75m thru 10m
  – 950w on 6m
  – Broadband transformer design

Very complex switching and filtering, as you can imagine
  – Harmonic content is as high as -9dbc on some bands
    • Thus, a complex output filter is required…the prototype is working well now
      – Combination LPF and diplexer