ARF475FL
128 MHz Pulse Amplifier

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Summary

The ARF 475FL contains a push-pull pair of high voltage RF MOSFETs. It is designed to provide a performance and cost competitive alternative to high power RF parts packaged in the "Gemini" ceramic-metal package. The design presented here uses the ARF475FL in a Class AB linear pulse amplifier as might be used in a 3T MRI application. The gain and peak power performance are superior to alternative designs using 50V parts. The circuit is simple, has good reproducibility and is relatively low cost.

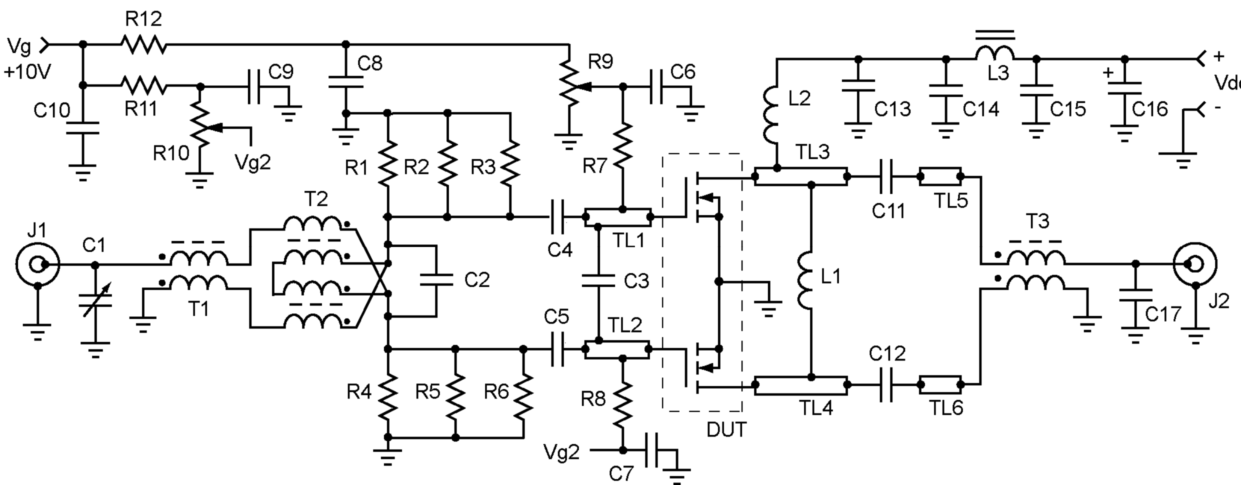


Figure 1 - Schematic diagram

Design

The input impedance of the ARF475FL is quite low. The gate input capacitance, C_{GS} is 750pF. The gate-to-gate impedance at 128 MHz is 0.4 –j 1.5 including the gate equivalent series resistance, bond wire and package inductance. Since the die itself has an f_t in excess of 1GHz, there is plenty of gain available so the gate impedance will be swamped with a resistive load. This will improve the input circuit bandwidth and make it generally easier to reproduce.

The method used for matching is quite simple. The gate-to-gate input impedance is very nearly series resonant at 128 MHz. By adding to the existing inductance of the leads and mounting traces, some additional inductance is obtained, the length of TL1-TL2 in this case. C3 is then added to parallel resonate the lot. This leaves a remaining effective parallel impedance of approximately 100 ohms resistive.

The input transformer T2 is a simple transmission line 4:1 transformer. Balun T1 ensures that the balance of T2 is not disturbed and also allows using a much smaller core on T2. T2 is made with 25 ohm Teflon coax. This is normally expensive and difficult to find, but a suitable substitute is readily available in the form of #22 shielded Teflon hookup wire such as Belden 83305.

The output of T2 is loaded with a series-parallel combination of six 22Ω resistors totaling 14.7 ohms. It provides a very good 'center tap' for T2. These resistors, plus the resonated gate load, give a good match to 50 ohms through the 4:1 transformer. C2 compensates for the leakage of T2 and C1 allows a phase tweak if necessary. The position of both capacitors is fairly critical. The bandwidth of the input match is better than 10 MHz at 2:1 VSWR as shown below in Figure 2.

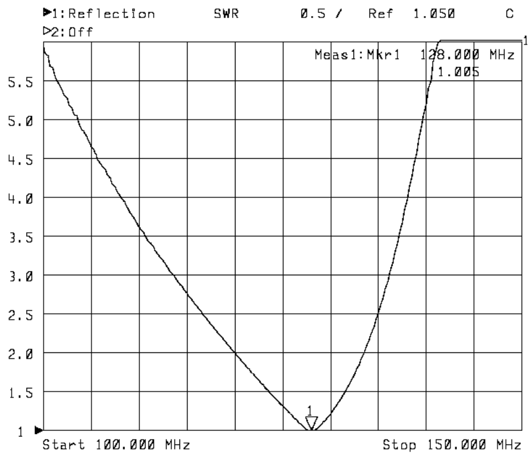


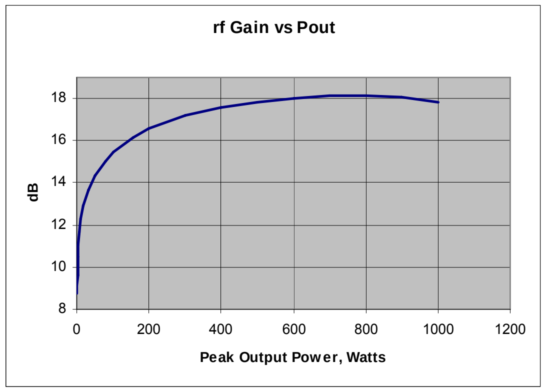
Figure 2 Input VSWR vs Frequency

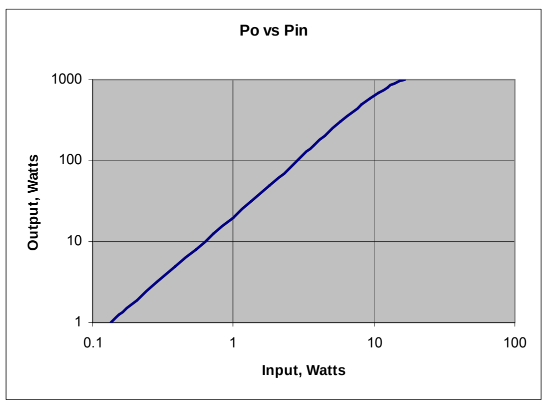
When building the unit, it was useful to install all of the circuit elements except C1, C2 and C3. The ARF475 is lightly coated with thermal grease, seated on the heat sink through the window in the board, and then soldered into the circuit. R9 and R10 are then adjusted for the desired quiescent drain current with 50V on the Vdd line. A network analyzer is then connected to the input. C3 is placed in the proper position along TL1-2 while checking the input match. Depending on the ε_r of the circuit board and other mechanical factors, the 330 pF specified for C3 may need to be adjusted to the next higher or lower 5% value for best match. C2 is then placed while checking that the match improves further. Its value may also need slight adjustment depending on the physical makeup and placement of T2 and its associated coax. Finally, C1 is installed. One should be able to match the input to 1:1 VSWR at the 128 MHz operating frequency.

Parts List for ARF475FL Pulse Amplifier

C1 15 pF poly trimmer
C2 56 pF ATC 100B
C3 330 pF ATC 100B
C4-10 10 nF 1206 50V SMT
C11-C12 22 nF 1812 C0G 250V SMT
C13-C15 4.7 nF 1206 C0G 250V SMT
C16 1000 µF 250V electrolytic
C17 10 pF ATC 100B
L1 30 nH 1.5t #18 tinned 0.375" dia
L2 680 nH 10t #24 enam 0.312" dia
L3 2t #20 on Fair-Rite 2643006302 bead, ~2 µH
R1-R6 22Ω 0.5W 2512 SMT
R7, 8, 11, 12 1kΩ 1/4W axial
R9, 10 5kΩ multi-turn potentiometer
T1 1:1 balun RG-188 on 2861006802 Fair-Rite core
T2 4:1 25Ω coax on 2843000102 Fair-Rite balun core
T3 1:1 balun, 3t 1" dia RG-188
TL1-2 Printed line L = 0.75" w = 0.23"
TL3-6 Printed line L = 0.65" w = 0.23"
0.23" wide stripline on FR-4 board is ~30Ω Zo

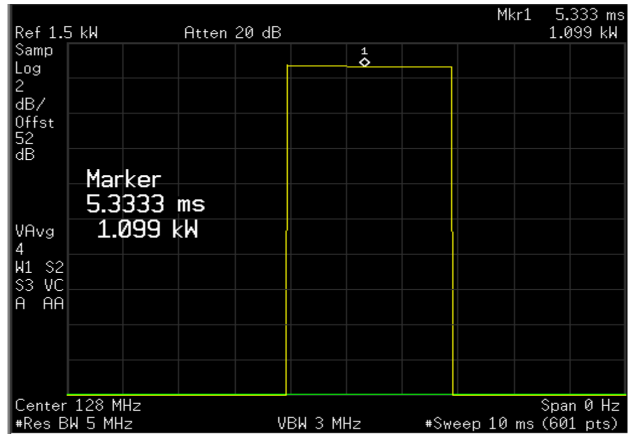
The output circuit uses a similar tactic. The drain-to-drain load impedance is 50Ω. This eliminates the need for a transformer. T3 is a 1:1 balun like T1, but made as a three turn coil of RG-188 Teflon coax. The output capacitance of the devices, a little less than 50 pF for the two die in series at 150V drain supply, is parallel-resonated at the operating frequency by L1. The dc feed is through L2. It is designed to be nearly parallel-resonant at the operating frequency and thus does not unbalance the circuit. The output circuit is trimmed to resonance by compressing or spreading the turns of L1. Note that the coupling capacitors must be rated for the RF currents in this circuit. Small 1206 SMT packages with Z5U or X7R dielectric will not work reliably.

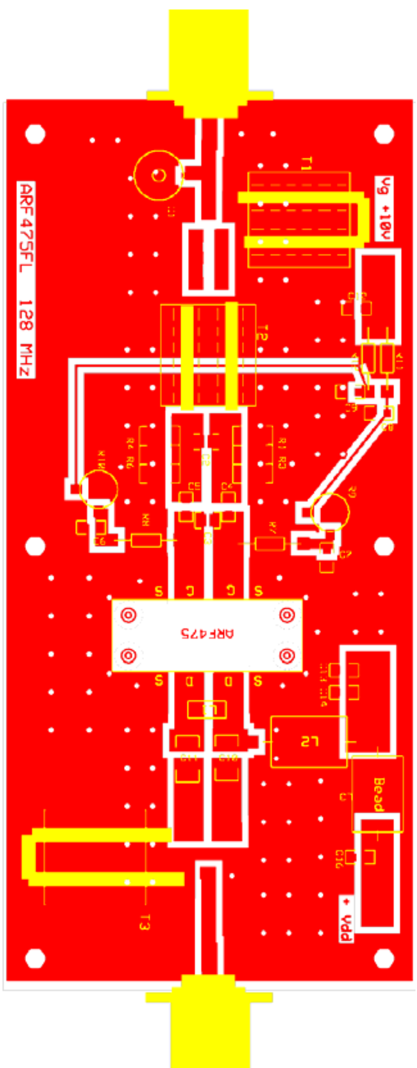


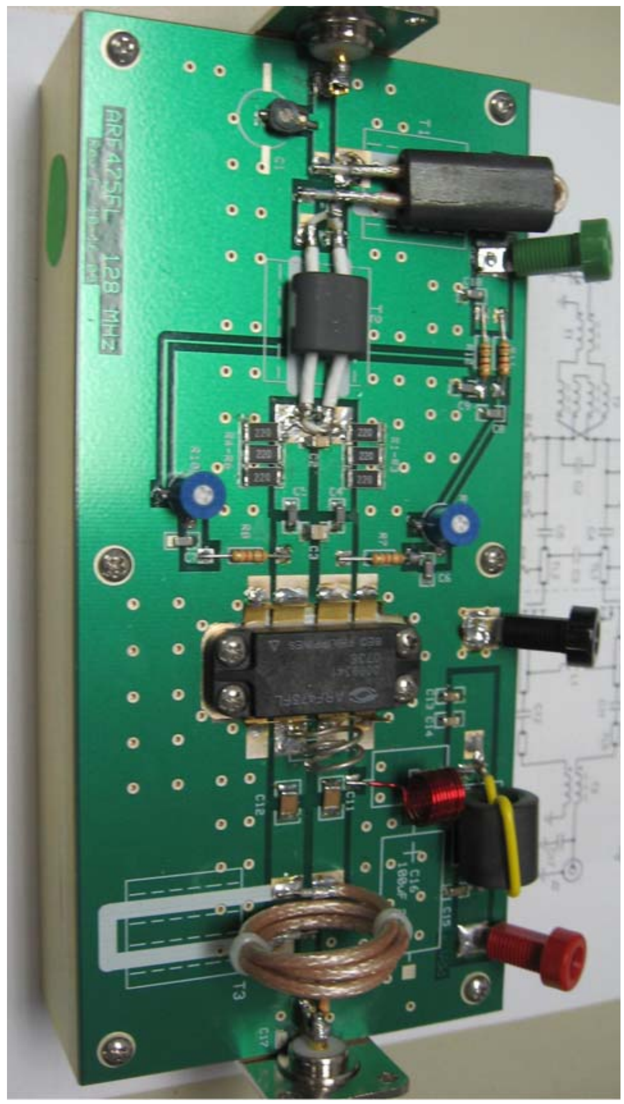


The peak output power can be adjusted above 1300W by increasing the Vdd. However, it should not be run past 175V. A 3:1 margin to the 500V breakdown voltage is critical to reliability and ruggedness. The quiescent bias can be set to as little as 20mA, but better small signal performance can be obtained with heavier bias - 100mA or more. The V_{GS} bias source should be gated with the signal to minimize thermal drift due to static dissipation. While the ARF475FL thermal coefficient of V_{TH} is quite low for a MOSFET, the bias voltage still needs to be thermally compensated in a typical application.

The heatsink is a 7” length of AAVID extrusion 3.25” wide by 1.5” high, with nine fins. A small fan gives adequate cooling for 1kW 3ms output pulses at 20% duty cycle. The circuit board measures 3.25 x 7.0”. The PCB layout follows the schematic very closely. C1, 2, 3 and 17 have not been loaded in this picture. The PCB artwork used to order the board from PCB Express is available on request.







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