A 128 MHz Pulse Amplifier Using the ARF475FL RF MOSFET

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This application note describes the design and performance of a high power pulse amplifier, using a high voltage RF MOSFET offered in a low cost push-pull package

The ARF475FL 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 in this application note 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 50 volt parts. The circuit is simple, has good reproducibility and is relatively low cost.

Design

The input impedance of the ARF475FL is quite low. The gate input capacitance, CGS is 750 pF. 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 1 GHz, there is plenty of gain available, allowing the gate impedance to 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. C2 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

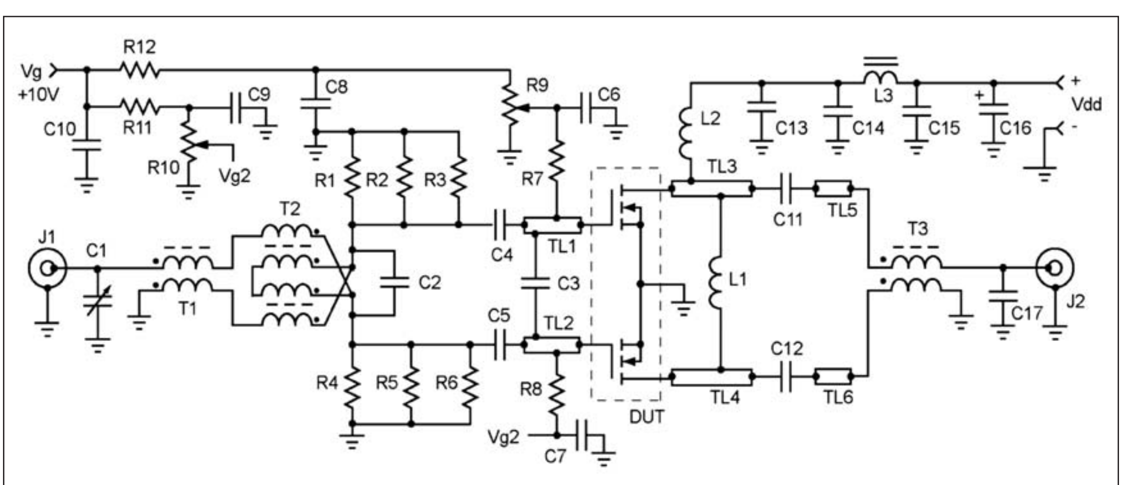

Figure 1 · Schematic diagram of the 128 MHz amplifier.

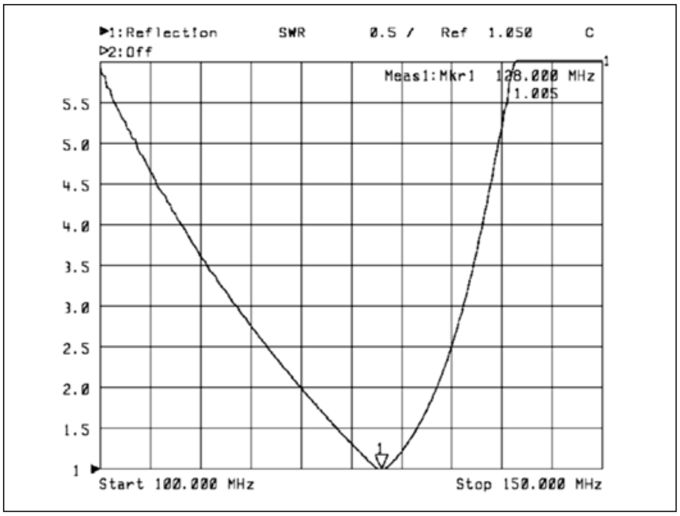

Figure 2 · Measured input VSWR vs frequency.

T2. T2 is made with 25 ohm PTFE coax. This is normally expensive and difficult to find, but a suitable substitute is readily available in the form of #22 shielded PTFE hookup wire such as Belden 83305.

The output of T2 is loaded with six 22 ohm resistors in a series-parallel combination 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 in Figure 2.

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 50 volts on the V_{dd} 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 value specified for C3 may need to be adjusted to the next higher or lower 5% value to get the 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.

The output circuit uses a similar tactic. The drain-to-drain load impedance is 50 ohms. This eliminates the need for a transformer. T3 is a balun, the same as T1, made with a binocular ferrite bead and RG-188 PTFE

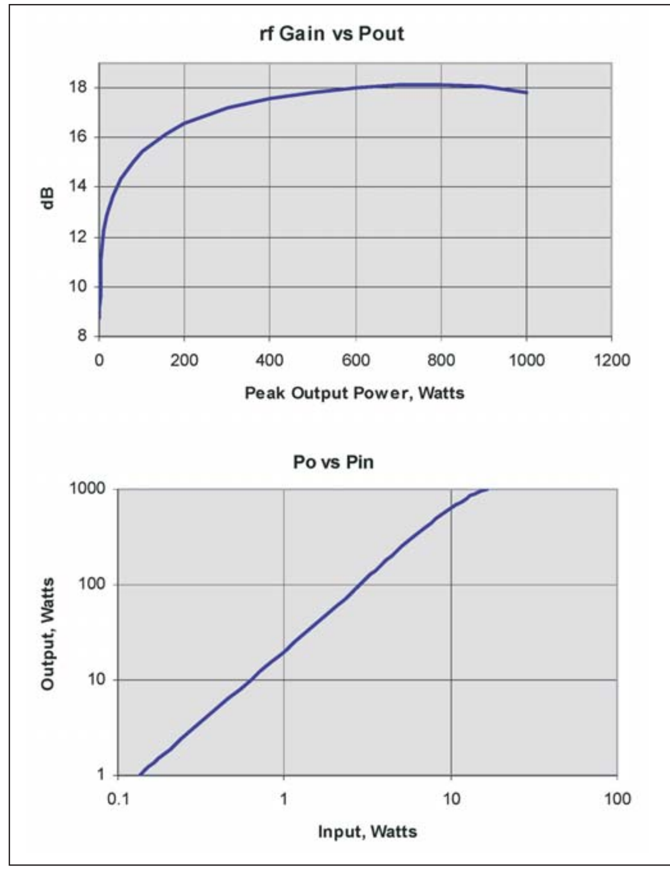

Figure 3 · Performance data for the amplifier.

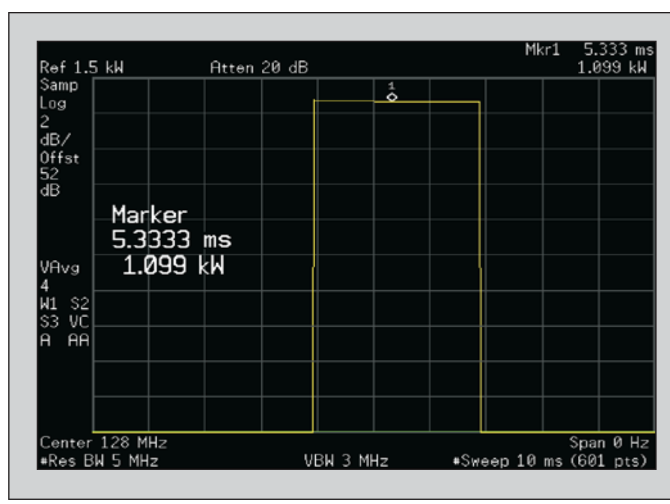

Figure 4 · Pulse power output measurement.

coax. The output capacitance of the devices, a little less than 50 pF for the two die in series at 150 volt 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

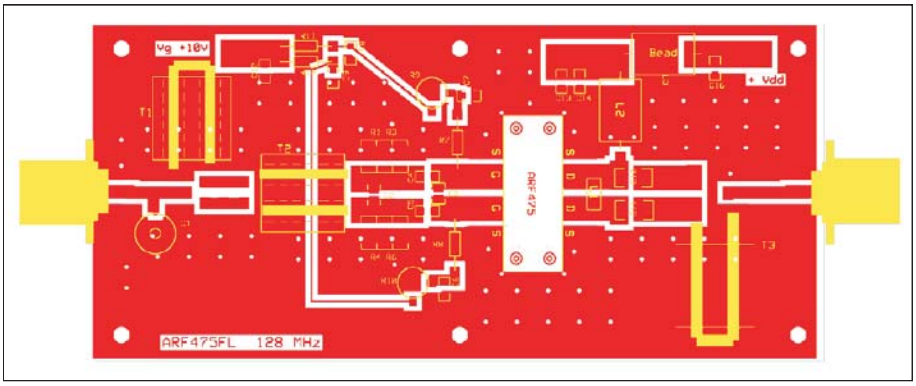

Figure 5 · The PCB pattern closely follows the schematic diagram.

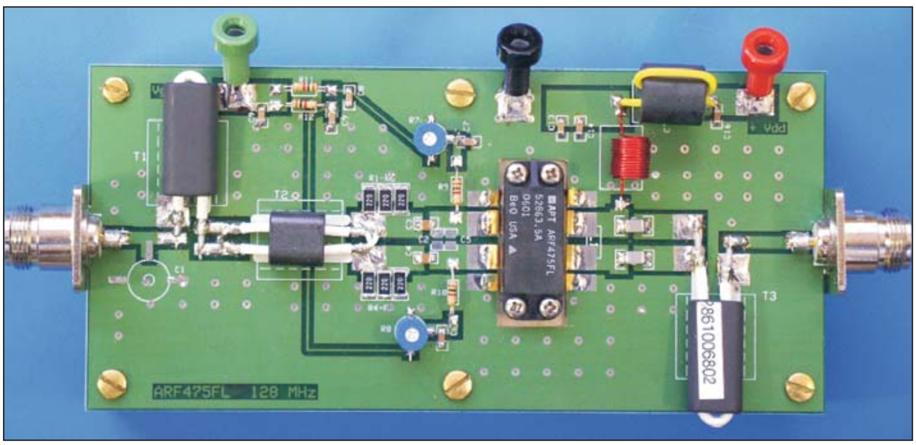

Figure 6 · A photo of the assembled amplifier.

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 1000 watts by increasing the V_{dd}. However, it should not be run past 165 volts. A 3:1 margin to the 500-volt breakdown voltage is critical to reliability and ruggedness. The quiescent bias can be set to as little as 20 mA, but better small signal performance can be obtained with heavier bias—100 mA 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 1 kW, 3 ms output pulses at 10 percent duty cycle. The circuit board measures 3.25" × 7.0", and the PCB layout (Figure 5) follows the schematic very closely. Figure 6 is a photo of the amplifier with most components in place. Note that C1, 2, 3 and 17 have not been placed on the board. The artwork used to order the PCB board from PCB Express is available on request.

Further information and a data sheet for the ARF 475FL device can be found at the Microsemi web site: www.microsemi.com/catalog/part.asp?PARTNO=ARF475FL

Author Information

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C1	15 pF poly trimmer	L3	2t #20 on Fair-Rite 2643006302 bead, ~2 μH
C2	56 pF ATC 100B	R1-R6	22 ohm 0.5W 2512 SMT
C3	330 pF ATC 100B	R7, R8, R11, R12	1 kohm 0.25W axial
C4-10	10 nF 1206 50V SMT	R9, 10	5 kohm multi-turn potentiometer
C11-C12	22 nF 1812 C0G 250V SMT	T1-T3	1:1 balun RG-188 on 2861006802 Fair-Rite core
C13-C15	4.7 nF 1206 C0G 250V SMT	T2	4:1 25 ohm coax on 2843000102 Fair-Rite balun core
C16	1000 μF 250V electrolytic	TL1-2	Printed line L = 0.75" w = 0.23"
C17	10 pF ATC 100B	TL3-6	Printed line L = 0.65" w = 0.23"
L1	30 nH 1.5t #18 tinned 0.375" dia		
L2	680 nH 10t #24 enam 0.312" dia	*Note:*	0.23" wide stripline on FR-4 board is ~30 ohm Z_0

Table 1 · 128 MHz pulse amplifier parts list.