AN561
APPLICATION NOTE

WIDE BAND DESIGN OF PULSED POWER UHF AMPLIFIERS

1. REQUIRED.

A pulsed power amplifier with the following specifications: minimum peak power of 250W at 435MHz, bandwidth of 30MHz (420 to 450MHz), maximum passband flatness of ±0.05dB, pulse width up to 1msec., 15% duty factor and input and output (Z_{in} and Z_{out}) impedances of 50Ohms.

2. PROCEDURE.

First, a transistor must be selected. Then, the circuit Q requirement(s) must be determined. The imaginary terms (if any) of the transistor input and output is then reduced to zero (0) at band center. Then the Chebyshev (low pass) matching filters required for a discrete component circuit must be computed. And last, the distributed component circuit elements are computed.

Note: For this design, a teflon-fiberglass board 1/32-inch thick having a dielectric constant of 2.5 will be employed.

2.1. Step 1.

STMicroelectronics' type SD1563 was selected for its broad bandwidth, low thermal resistance, and ruggedness. From the datasheet for a typical amplifier with 40V Vcc, the impedances are given as:

$$Z_{in} = 2 + j3.2 \qquad \text{(and)}$$

$$Z_{out} = 1.8 + j0.7$$

2.2. Step 2.

Circuit bandwidth required to limit roll-off at band edges to 0.5dB is approximately three times the 3dB bandwidth (BW). Then:

$$BW\ 3dB = 450 - 420 \quad or \quad 30MHz$$

$$BW\ 0.5dB = 3 \times 30 \quad or \quad 90MHz$$

$$bandcenter = f_0 = \sqrt{450 \times 420} = 435MHz$$

$$Q_{max} = \frac{f_0}{BW0.5dB} = \frac{435}{90} = 4.8$$

Examine the selected device thus:

$$Q_{zin} = \frac{X_L}{R} = \frac{3.2}{2} = 1.6$$

$$Q_{zout} = \frac{X_L}{R} = \frac{0.7}{1.8} = 0.39$$

Since $Q_{max} = 4.8 > Q_{zin} > Q_{zout}$, the Q requirements are met.

2.3. Step 3.

The inductance presented by the input of the transistor is resonated out by shunting with a capacitor C_z whose value is:

$$C_z = \frac{X_{in}}{(2\pi f)(R_{in}^2 + X_{in}^2)}$$

$$C_z = \frac{3.2}{(2\pi 435\times 10^6)(2.0^2 + 3.2^2)}$$

$$C_z = 82\times 10^{-12} \qquad 82pF$$

The value of R_{in}, now that it is pure resistance, is:

$$R_{in}' = \frac{R_{in}^2 + X_{in}^2}{R_{in}}$$

$$R_{in}' = \frac{2.0^2 + 3.2^2}{2.0} = 7.12 Ohms$$

Capacitor C_z' required to resonate the inductance presented by the transistor output is determined to be 68.8pF and R_{out}' is 2.1Ohms.

2.4. Step 4.

Chebyshev design tables require the input and output impedances to be real and:

$$w = fractional\ \ bandwidth$$

$$= \frac{2(f_1 - f_2)}{f_1 + f_2} = \frac{2(450 - 420)}{450 + 420} = 0.0689$$

$$r = transformational\ \ ratio$$

$$= \frac{R_{source}}{R_{in}'} = \frac{50}{7.12} = 7.02$$

Inspection of Chebyshev tables show a single section (n=2) filter will exhibit about 0.2dB ripple; however, a two section (n=4) filter will limit ripple to less than 0.002dB. The (n=4) filter will be employed.

Component values for the input filter compute to be:

$$L_1 = 3.5nH$$

$$C_2 = 35.2pF$$

$$L_3 = 12.5nH$$

$$C_4 = 9.7pF$$

7.12 to 50Ohms

The output matching filter is determined in the same manner where:

$$w = 0.0689$$

$$r = \frac{50}{2.1} = 23.8$$

Inspection of Chebyshev tables for a single section (n=2) filter shows that the ripple will exceed 0.22dB. Again entering the two section (n=4) table, the ripple is found to be reduced to less than 0.001dB.

Circuit Q influences the choice of filter sections, thus the maximum Impedance Transformation Ratio (each section) is limited to:

$$Q^2 + 1 = (4.8)^2 + 1 = 24.04$$

Therefore, a single section (n=2) filter with a transformation ratio of 23.8 would be marginal in bandwidth.

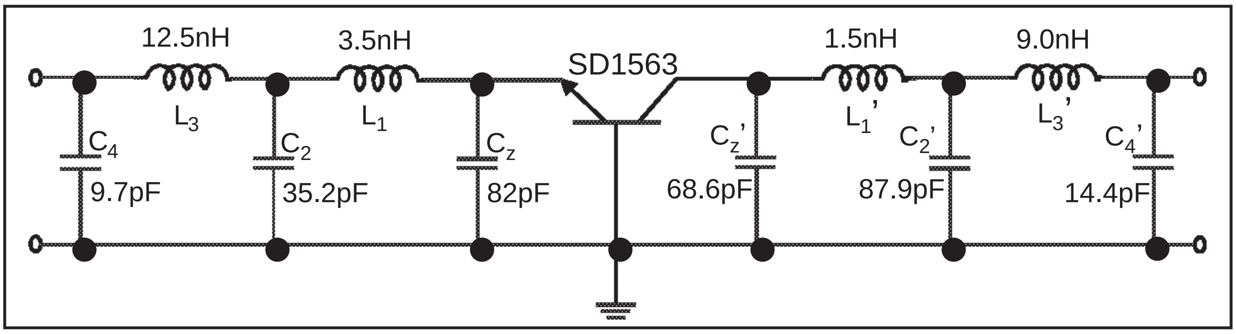
Component values for the output filter compute to be:

$$L_1' = 1.5nH$$
$$C_2' = 87.9pF$$
$$L_3' = 9.0nH$$
$$C_4' = 14.4pF$$

2.1 to 50Ohms

The basic discrete component amplifier is shown in figure 1.

Figure 1: Basic Discrete Circuit



4.5. Step 5.

The Microstrip characteristic impedance is given as:

$$Z_0 = \frac{377h}{\varepsilon_r^{1/2} W[1 + 1.735\varepsilon_r^{-0.0724}(W/h)^{-0.836}]}$$

where W = width, H = height, ε_r = Dielectric Constant.

For a teflon-fiberglass board 1/32-inch thick having a dielectric constant of 2.5, the line width for 50Ohms is found to be 0.09 inches.

The capacity of one (1) square inch of this circuit board is equal to:

$$C = \frac{0.224 \times 1.09\varepsilon_r \times Area}{d(thickness)}$$

$$= \frac{0.224 \times 1.09 \times 2.5 \times 1}{0.03125} = 19pF$$

Capacities in the order of 90pF required for this amplifier would occupy about four to five square inches of board area (a prohibitive use of real estate). Discrete capacitors will be employed.

The length of a Microstrip inductor is approximated as: $l = \frac{11.81L}{Z_0\sqrt{\varepsilon_r}}$

Where l = length in inches and L = Inductance in nH.

For simplicity, a 50Ohm line impedance was chosen for the inductors used in this amplifier. The line width is 0.09 inches and line lengths are as tabulated below:

Table 1: Microstrip Lines

Symbol	Value (nH)	Length (inches)
L_1	3.5	0.563
L_3	12.5	1.790
L_1'	1.5	0.244
L_3'	9.0	1.360

The complete distributed amplifier is shown in figure 2.

Figure 2: Complete Distributed Amplifier (250W / 420-450MHz Pulsed Power)