LOW-COST HIGH FREQUENCY LINEAR AMPLIFIER

By : OM DNR RAO VU2 DNR

INTRODUCTION :

It is the ambition of every average Ham to go in for a higher transmitting power. However, he always aims at low cost with performance, easy to build and fire. And keeping this in mind, the following high frequency LINEAR power amplifier is designed and built. This linear is robust and capable of delivering about 250 Watts with an input power of just 10 mw. Basic prototype design was meant to operate between 1.8 to 14.5 MHz. However if the builder likes to extend the range up to 30.00 MHz, it can be done. For extending the range the hints are given in the text. Cost is greatly reduced by using plastic encapsulated APT power MOSFET devices.

BRIEF DESCRIPTION :

As a class 'D' amplifier, devices are operated in push-pull, driven to act as switches, generating a square wave voltage. The fundamental frequency component of the square wave is passed to the load through a filter. Varying the supply voltage controls power output. Estimated losses in the transformer and,output filter result in an expected efficiency of about 70 percent. However if the switching effects and drain capacitance are removed the efficiently will go up to 88 percent.

CIRCUIT DESCRIPTION AND TECHNICAL DETAILS :

Circuit diagram of the linear amplifier is described in Figure 1, and the component details are described in Table 1. The component layout of the linear is described in Figure 2. The RF signal in put from J-1, is AC coupled to a pair of (low cost) ICs, u-1 and u-2, to provide out of phase driving signals. It also provides hard limiting of input signal level, creating the desired square wave. The required DC bias and its adjustment is done through R-6 and R-8, to control the duty cycle. Below 4.0 MHz operation, these can be symmetrical, but above 10.0 MHz, the difference between the MOSFET turn-on and turn-off times require pre-distortion of the drive signal toassure 50 percent duty cycle of the final stage devices. Best switching speed is achieved when Vdd-1 = 12 volts.

Although the pre-driver IC's EL 7144 C devices provide sufficient drive at the lower sufficient frequencies enough to obtain the rated output, operation at higher frequencies requires a lower impedance, higher current circuit. Complimentary pairs of smaller MOSFETs (2N7016 / 2N7012 or even IRFD-110 / IRFD-9120), operating at 12V, are used for driving the gate of the final amplifier ARF - 440 / ARF - 441.

POWER OUTPUT :

The supply voltage controls the power output of the linear. As a class 'D' power amplifier, it will deliver an output of 250 watts at 50 volts supply, with an overall expected drain of about 10 Amps, which corresponds to I_{DC} = 63 Amp.

For the PA devices ARF 440/ARF 441 are used in this amplifier.

R_{ON} 0.8 ohms and thus R 6.4 ohms

Power out put can be calculated by equation $Po = V^2_{eff} / 2R$

Where effective supply voltage is $V_{eff} = V_{DD} \frac{R}{R + R_{ON}}$

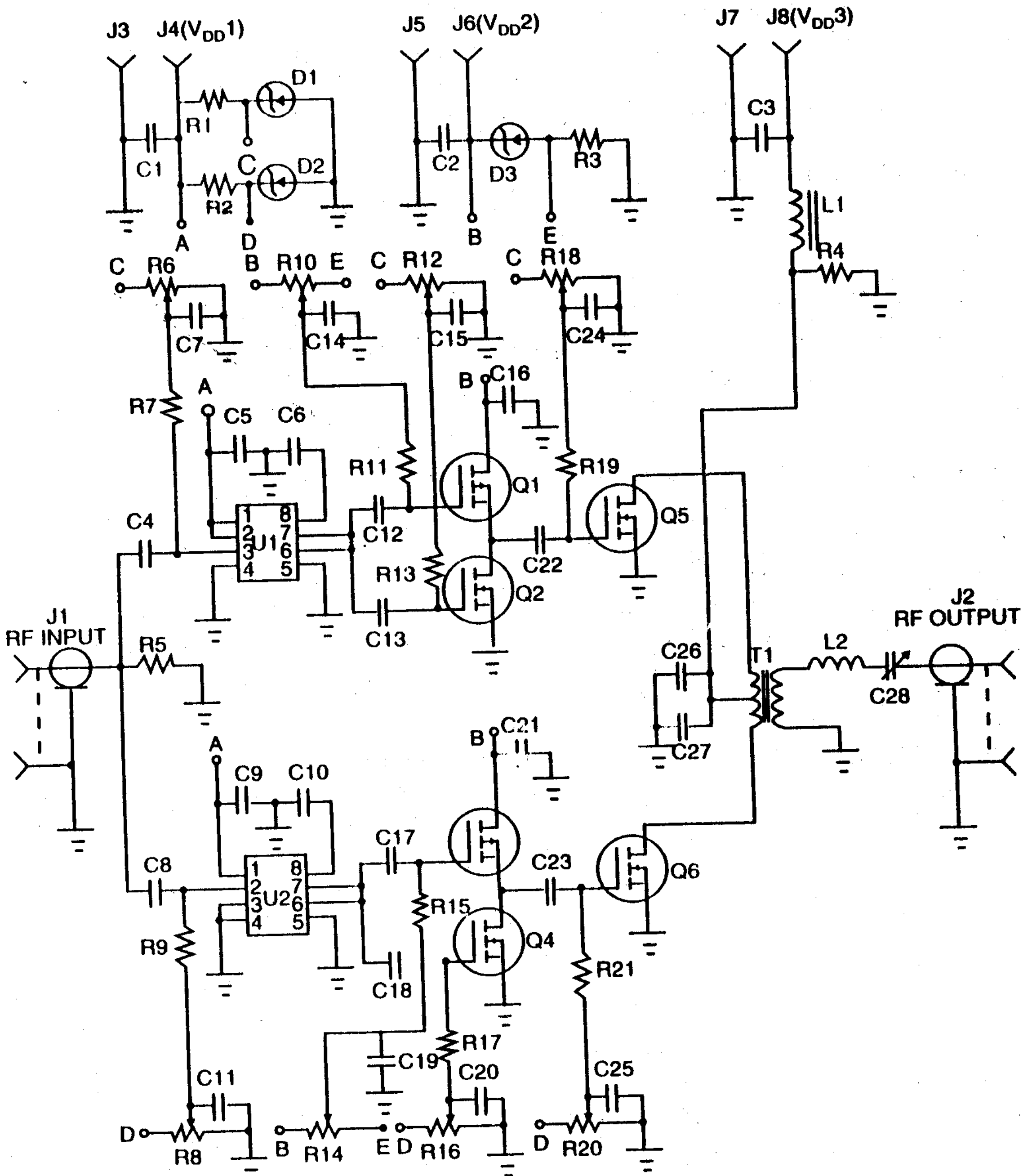

Figure - 1. Circuit diagram of 250 Watts Linear amplifier

BILL OF MATERIALS :

Circuit Reference	Description
C1, C2	Capacitor 33 mF, 50V
C3	Capacitor 20 mF 250
C4 - C27	Capacitor 0.1 mF 50V (Chip type)
C28	Frequency dependent, See Table - 2
D1, D20, D3	Zenar diode, 5.1V, 0.25 Watts, Type 1N751A
J1, J2	Jack, Co-axial socket, Female, BNC type
J3 - J8	Binding post/terminals (Any suitable type)
L1	Coil, 3.5 micro Henry (3.5 T, #24 wire on 768 XT 188, 4C4 toroid
L2	Frequency dependent, See Table -2
Q1, Q3	MOSFET, p-Channel, 2N7016
Q2, Q4	MOSFET, n-channel, 2N7012
Q5	MOSFET, APT - ARF 440
Q6	MOSFET, APT - ARF 441
R1, R2	Resistor 330 Ohms
R3	Resistor 220 Ohms
R4	Resistor 10 Kilo Ohms
R5	Resistor 51 Ohms
R6, R8, R10, R12 R14, R16, R18, R20,	Trimmer Potentiometers, 1 Kilo Ohms
R7 R9, R11, R13, R15, R17, R19, R21	Resistor 4.7 Kilo Ohms
T1	Transformer, wound on ceramic magnetics ferrite 3000-4-CMD 5005, 2t, center tapped primary, 3t secondary, #22 Insulated wire.
U1, U2	Ics, Schematic trigger, Elantec El7144 C

Table -1, List of components used in Linear Amplifier

Frequency Dependent Components :

Freq. MHz	Circuit Ref.	Description
1.8	L2	22 m H, 52t, #24 wire on Micrometals core T200-6
	C28	Capacitor, Padder, 354 pF 2.5 kV
3.5	L2	11.4 m H, 32t, #24 wire on Micrometals core T200-6
	C28	Capacitor, Padder, 180 pF 2.5 kV
7.0	L2	5.7 m H, 20t, #24 wire on Micrometals core T200-6
	C28	Capacitor, Padder, 90 pF 2.5 kV
14.0	L2	2.9 m H, 14t, #24 wire on Micrometals core T200-6
	C28	Capacitor, Padder, 90 pF 2.5 kV

Note : Frequencies above 14.0 MHz can be handled by suitably changing the value of L2 and C28. However, immediate data on the component for frequencies above 20M is not available.

Table - 2, Frequency dependent components

CONSTRUCTION :

Major components layout detail is shown in Figure - 2. PA transistor Q5 and Q6 are separated by about 25-mm apart to line up with leads from T1. Drivers and pre-drivers are installed almost in line for minimum lead lengths. Connect short low inductance leads for pre-drivers to drivers, and similarly use the drivers to the final amplifier. Place the By-pass chip capacitors as close as possible to the ICs and MOSFETs. By pass capacitors and L1 maintain RF ground and keep RF out of the supply line. Providing suitable provision for plug-in type of coil and capacitor effects frequency range/band selection. Only mono band operation is provided, at present on the board.

Efficient Hear-sink has to be provided for the PA to avoid thermal run away.

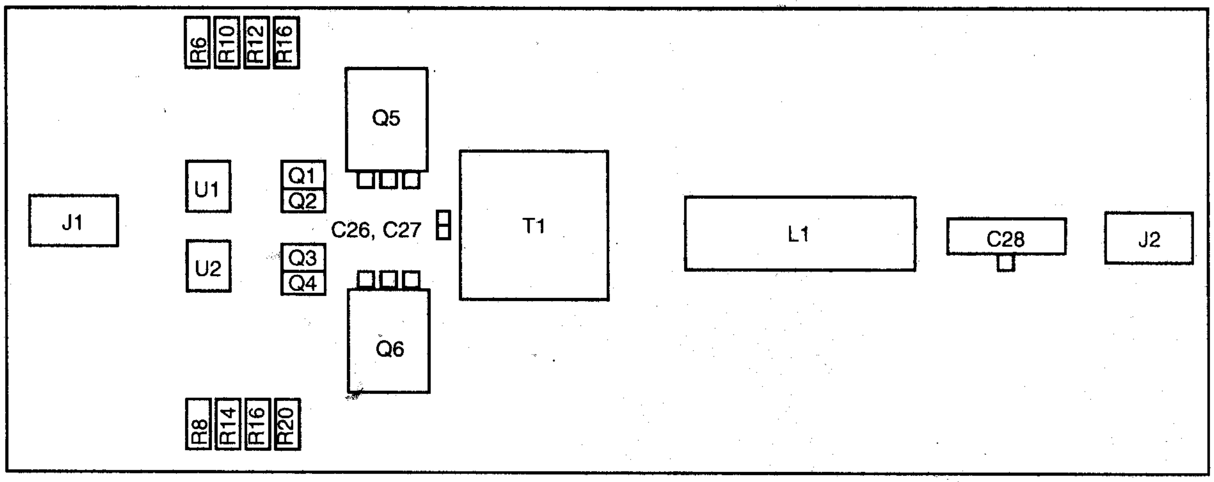

Figure - 2, Major components lay-out diagram

TUNING THE FINAL AMPLIFIER :

Adjust the quiescent currents of each PA device to about 100 ma. The bias requirement for the adjustment will be around 3.5 to 3.8 V. The drivers and the final amplifier are AC - coupled and provided with adjustable bias for flexibility. DC can be used to simplify the design, taking care for proper cut off in the absence of a driver signal.

Driver power consumption should be monitored, since it is part of the system power requirement. DC power consumption ranges from 2.16 W at 1.8 MHz to 15.0 Wat 14 MHz.

PA stage uses series tuned circuit with Q = 5 at the frequency of operation. Tuning is accomplished by adjusting Padder C28 for maximum power. Other filters may be used as long as they have an inductor on the transformer side to keep current from flowing at harmonic frequencies. As mentioned earlier the power output is dependent of Supply voltage.

HINTS AND KINKS :

The switching times of the ARF 440/ARF 441 indicates that full power operation in class B is possible up-to frequencies of 30 MHz. In order to extend the frequency range from 14 MHz band up to 30 MHz, following steps are suggested.

Develop a new output transformer with good broad band performance. Implement a conventional drive circuit using a transmission line transformer and gate swamping. Test the PA in both class B and Class D operations.

FEATURES :

- The pre-driver input is of high impedance and hence not critical.
- The tuned output is used for transmitters and resonant loads. The series tuned output reduces the level of the harmonics so that they contribute negligibly to the output power.
- Untuned output can be used to deliver the maximum power to resistive load. Efficiency and output versus frequency for an untuned load will be higher than for a tuned load. With a square wave output this mode of operation can deliver 27 percent more RF power than tuned class D. Efficiency reaches a maximum of 85 percent at 300- Watts output with a higher value achieved at 100 Watts.

CONCLUSION :

The linear amplifier described in this article is efficient and is easy to construct. Although a couple of components are extra, it ensures non-critically. Designing output transformers at other frequencies than 14 MHz also is not difficult. Home brewers are well come to offer constructive suggestions and feed back information to the author so that their efforts to improve the rig can be implemented in the next article.

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