STUDY OF SOLID STATE RF POWER AMPLIFIERS CONFIGURATIONS IN PLASMA GENERATION

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ABSTRACT

In recent year the worldwide focus has been increasing on economic, efficient power sources in plasma generation. This paper presents a study of topologies for solid state RF power source for low-temperature plasma generation. These power supplies use high power amplifier modules. Every RF generator uses an oscillator as trigger module that is amplified in various classes of the amplifier. High power amplifier module is the main part of the RF power supply. To get high power level cascading of more than one power amplifiers are done to make one high power amplifier unit using RF combiner. The power combiner is used to combine high power from more than one power amplifiers. The first stage of the trigger amplifier is operating in CE mode using a bipolar transistor. Next stage of the high power amplifier is designed in the push-pull configuration for maximum efficiency.

Keywords: *Solid State RF, power Amplifier, Class AB, Impedance Matching, Power Combiner, Power Efficiency.*

I. INTRODUCTION

Low-temperature plasma is used for various applications like surface treatment processes for metallic parts, semiconductor material processes, and so on [1]. Plasma can be generated using high frequency strong magnetic field at low-pressure gas medium. Strong magnetic field or electrostatic field generates plasma using RF power supply in the range of 2-13.56 MHz using solid state devices.

Devices like BJT's or vacuum tubes cannot perform their switching operation perfectly [1]. An amplifier is an electronic device that can increase the power of a signal. An amplifier functions in active mode with input RF signal biased at threshold operating voltage. An amplifier modulates the output of the power supply based on the properties of the input signal. There are many classes of power amplifier like class A, B, AB, C etc. Impedance matching is required for linear amplifiers in the high-frequency power supply. This matching network is connected between its output terminal of a high-frequency power supply and serial or parallel resonant load.

II. CLASSES OF POWER AMPLIFIER

In power amplifier classes, class A is a most active circuit that means Q point is set in the middle of load line and the transistor is active for a full cycle. Such designs typically achieve high linearity and wide bandwidth; however, they do this at the expense of power, so it is less efficient. Class B designs were introduced, where a pair of output circuits work in tandem to deliver the desired output in such a way that only one of them is active during a given half cycle of operation. Specifically, one part of the circuit responds to positive signals while the other is cut off, with the reverse situation occurring during negative signal excursions. This approach greatly reduces the power consumption and standing noise; however, the switching between positive and negative signal swings introduces objectionable crossover distortion. The theoretical efficiency of class B power amplifier is 78% in completely matched load. While practical efficiency is less than 50%. The improvement in power consumption has made Class AB output stages quite common in the design of power amplifiers and integrated operational amplifiers [4].

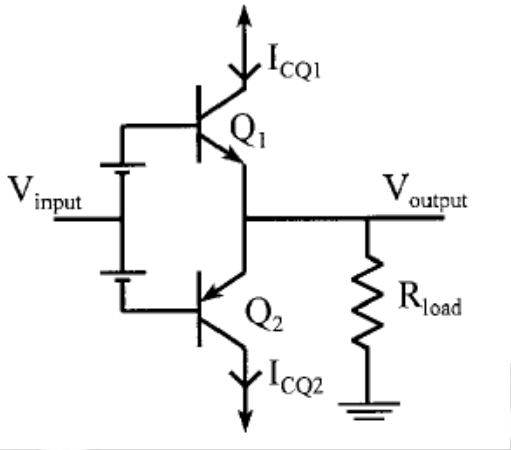

Fig-1 Basic Class AB circuit [4].

III. LOW-TEMPERATURE PLASMA GENERATION

Low-temperature plasma generates using strong magnetic field and is affected by the speed of gas flow and pressure of gas, temperature etc. when low-pressure plasma is established quality factor automatically decreases. High current flows through series or parallel resonant circuit even at a low output voltage before low-temperature plasma flames up. To keep a stable

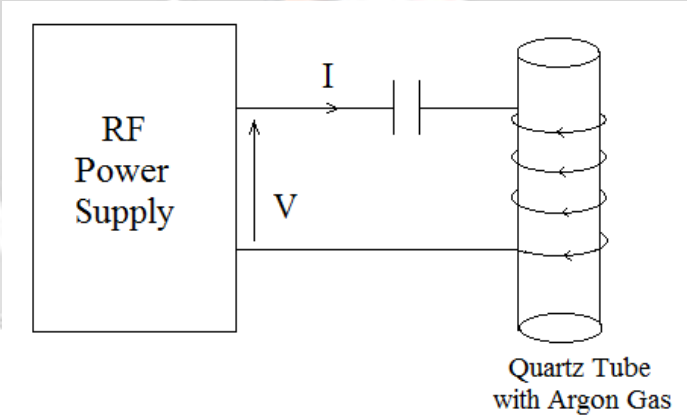

Fig-2 Configuration of Plasma Generator [1]

discharge high voltage is required while the low-temperature plasma is hot. Argon gas filled in the quartz tube and it is placed in the resonant reactor. Now the gas is excited in a resonant reactor using high voltage electric field and then plasma starts to flame up.

It's very difficult to sustain the generated plasma during the discharge, so before the plasma flames up, a low-voltage and large-current are required, and to sustain the plasma high-voltage and medium-current rating is needed. One important part of the system is to match the impedance of the plasma with high-frequency power supply. An automatically adjusted impedance-matching circuit is used, which consists of high-frequency reactors and variable capacitors [5].

IV. THE HIGH POWER AMPLIFIER MODULE

High power amplifier module drives with the help of low power pre-amplifier. Here, low power pre-amplifier is work in common Emitter

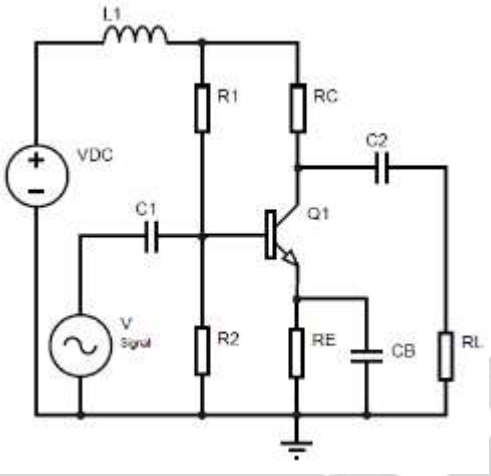

Fig-3 Pre-amplifier in CE mode

configuration, as shown in fig.3 low power signal, is applied to the pre-amplifier and it will gain with given transistor voltage gain. The low power signals are used to drive more than one transistor based pre-amplifiers. The output of pre-amplifier is in the range of few Watts. The output of each pre-amplifier is used to drive a high power amplifier.

High power amplifier gives output in the range of few hundreds of Watt. The output of each high power amplifier combined together by n to 1 combiner to obtain high power from one module. In the high power amplifier, the drain and gate voltage of each transistor can both be knobs for adjusting the operating point of each individual transistor module. The block diagram of solid state RF power amplifier module is as shown in Fig.4 It includes a signal generator, pre-amplifier, high power amplifier, power combiner, RF load [3].

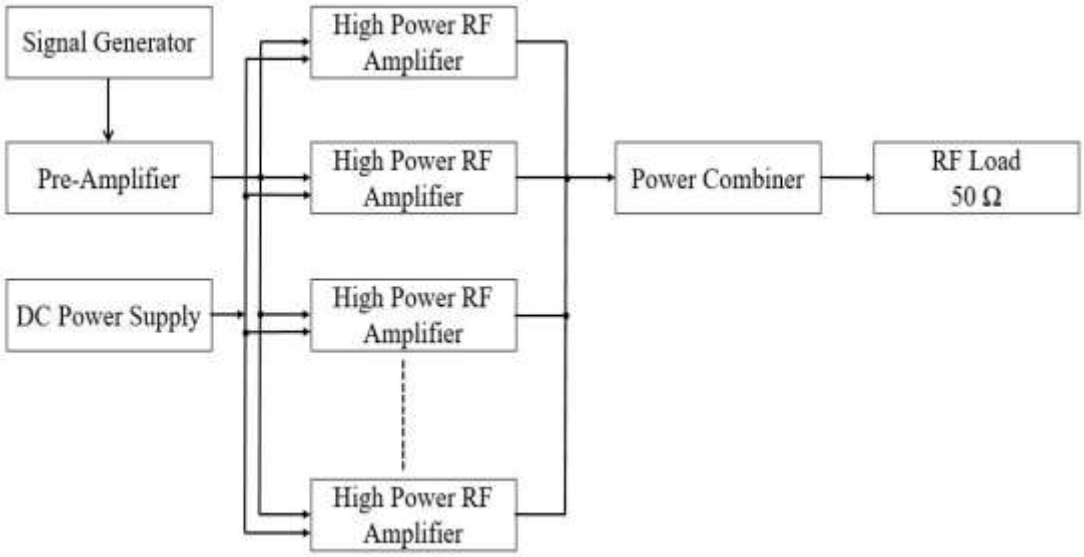

Fig-4 Block Diagram of Solid state RF power amplifier module. [3]

RF Power combiner used for combining several signals of along a single feeder, and used for circuits or different sources where several RF signals need to be brought together. This is achieved while maintaining the characteristic impedance of the system. The additional loss is introducing by using resistors dependent upon the type of combining several signals.

The impedance matching calculation is done by maximum power transfer theorem and it is maximum power transfer across the terminal of the active network occurs when the load impedance Z_L is equal to the complex conjugate of the source impedance Zs or the active network impedance [5]. To transfer maximum power output impedance of 1st stage is equal to the input stage of 2nd stage. This matching is done by the external matching network.

V. CONCLUSION

Various power supply configurations are studied and compared for generation of RF power using a single module. Device or component used in power supply is simple and conventional devices would be selected to ensure availability and replacement. The power efficiency and linearity in class AB configuration are better than other classes of the amplifier. Hence, a major focus of the project work is to tune the RF amplifier using the class AB configuration. Multiple such units can be combined using combiner at the later stage.

VI. REFERENCE

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