

# Space-Charge-Grid Amplifier

MELVIN C. SPRINKLE\*

A new low-power amplifier using the space-charge-grid tubes first publicized as audio output tubes almost four years ago. By the designer of the Musician's Amplifier.

FROM TIME IMMEMORIAL, it seems, the audio enthusiast has been searching for wider frequency range and lower distortion in his amplifiers. These desirable features are expensive, and cost is an important consideration to the average audio fan. So, the effort has gone on to get the most for the least. The amplifier to be described represents what is believed to be the highest quality yet attained for the required financial investment. The remarkable performance is made possible by two important components: a new and radically different tube type and a high-quality low-cost output transformer.

In spite of its well known limitations which increase cost, the triode tube has for years been the standby of the audio crowd. The beam-power tube overcame a number of the limitations of the triode, but many builders never accepted the beam power tube as the equal of the triode. Thus the argument has raged for some years on the beam tube vs. the triode, with good points on both sides. Now, the National Union Radio Corp. has developed for commercial use a new tube type which combines the best features of the triode and the beam tube, and which opens a new era in high-quality amplifiers. This tube is known as the NU 2160 and is a space charge tube. Its plate family of curves resembles those of triodes, but its efficiency and drive requirements are like a beam power tube.

The space charge tube has been described in the literature,<sup>1,2</sup> but for the

\* Peerless Division, Altec Lansing Corp.  
<sup>1</sup> Electronics, Vol. 20, No. 8, August 1947, p. 121.

<sup>2</sup> AUDIO ENGINEERING, Vol. 31, No. 9, October 1947, p. 20.

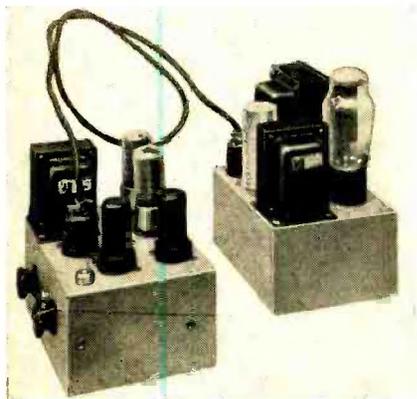


Fig. 1. Separate chassis for the amplifier and power supply simplify mounting in many applications.

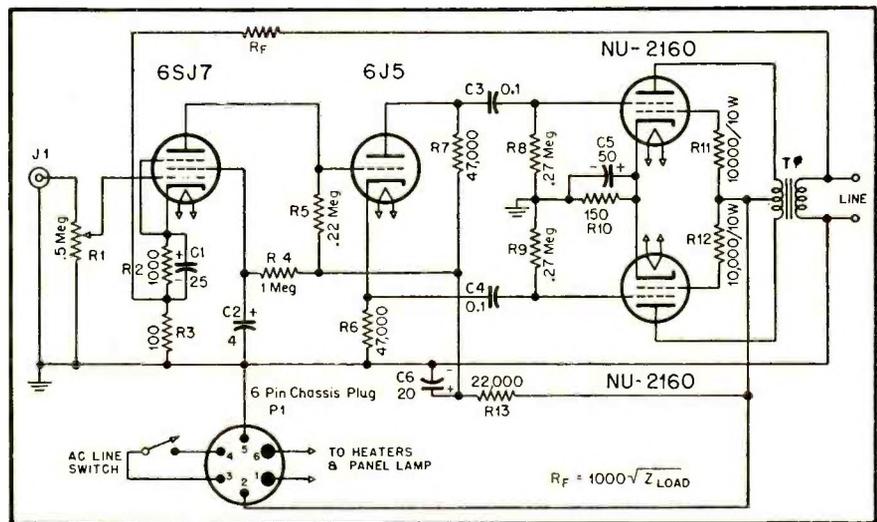


Fig. 2. Schematic of the space-charge-grid amplifier chassis.

benefit of those who do not have access to the references, its characteristics are briefly summarized. The space charge tube is a tetrode, with a cathode, two grids, and a plate. The grid nearest the cathode is operated at a positive d.c. voltage with respect to the cathode, the effect being to counteract the negative space charge and produce a larger cloud of electrons at the plane of the first grid. This cloud acts as a virtual cathode. The second grid is then the control electrode, being operated with a negative bias in the conventional manner. The operation of the space charge tube is similar to a triode with a large effective cathode. It should be pointed out that it is not possible to connect an ordinary tube as a space charge tube because so doing would cause excessive current in the first grid. In the NU 2160 the current in the first grid has been lowered by mounting a pair of side rods between the space charge grid and the cathode, and connecting these rods to the control grid. The side rods thus shield the space charge (No. 1) grid from the cathode except in the vicinity of the lateral wires of the grid. They also have an effect in reducing harmonic distortion.

The positive voltage on the space-charge grid is supplied from the plate supply through a 10,000-ohm resistor. The space charge grid is *not* bypassed, and the omission of the bypass capacitor produces three beneficial effects: the power output is increased slightly for a given average cathode current, the output is less affected by changes in external load impedance, and the odd har-

monic distortion is reduced. It has been mentioned that the plate current family resembles triode curves. To this must be added the fact that the plate resistance is low—2,500 ohms—the  $\mu$  of 16 is medium, and the transconductance is 6,500 micromhos. The uniformity and regularity of the plate family indicate that these parameters are fairly constant and therefore the distortion is low. The tube is operated with a bias of about 18 volts on the control (No. 2) grid so that operation out of a resistance-coupled stage or phase inverter is very practical.

Through the courtesy of National Union, the writer was provided with a pair of NU 2160's for experimental use. As of the present, National Union is planning to market the NU 2160 through radio parts distributors, but material uncertainties make the general availability of the tube a question mark. It is also not known whether other tube manufacturers will make space charge tubes for sale through their distribution channels.

## Design of Amplifier

Examination of the data sheets provided with the tubes, showed that the tube was ideal for a low-cost amplifier, the power output as calculated being of the order of 6 watts for two tubes in push-pull. The Peerless S-508-A output transformer, originally designed for type 6V6 tubes, has ratings as to plate current and primary impedance which suit it to the 2160. Its design, based on the 6V6 plate resistance, means that it will

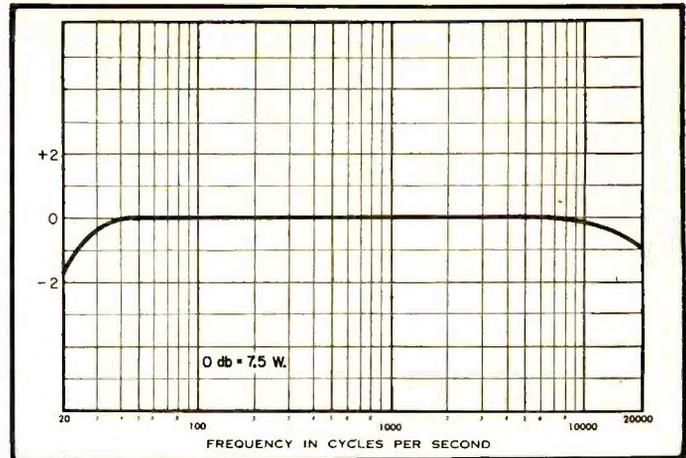


An efficient speaker with 0.1 watt input at 1000 cps will produce a sound level of around 83 db. This sound level has been classified on the *Electronic Industries* sound level chart as "very loud radio in home." At a power output of 0.1 watt the IM distortion in this amplifier is about 0.15 per cent and at a 10 db higher level, which is roughly representative of peaks in the program material, the IM distortion is 0.25 per cent. Thus at all usable levels, the IM distortion is too small to worry about.

The total cost of the parts to build this amplifier and power supply, using the transformers specified for its performance and other parts of first grade is about \$35.00. This does not include the space charge tubes since no firm price has been put upon them. However, they should certainly be no more expensive than 6L6 tubes, for example. Thus the cost puts it well within the reach of the audio enthusiast who longs for a better amplifier but whose "Chancellor of the Exchequer" has other ideas on what to buy.

It was not intended that this amplifier take the place of a deluxe amplifier, such as the Musician's Amplifier, where the ultimate in quality is desired and where the performance requirements are rigorous. This amplifier "folds up" at power levels where the Musician's Amplifier is still below 2 per cent IM. However, this amplifier is especially commended for the average home, especially when cost is an important consideration. At the 1950 Audio Fair it was compared on A-B test with larger amplifiers of equal quality and until the level became so loud that it was deafening,

Fig. 5. Curve showing power output vs. frequency over the range from 20 to 20,000 cps.



there was no audible difference. In the author's home it has done everything that a home amplifier is called upon to do. There is not enough gain to operate directly from a magnetic pick-up cartridge but with a preamplifier, many of which have been described in these pages, it reproduces all that is on a record. There is, however, plenty of gain for an FM tuner.

#### PARTS LIST

$C_1$	25 $\mu$ f, 25 v. electrolytic	$R_1$	0.5 meg, audio taper vol. control
$C_2$	4 $\mu$ f, 450 v. electrolytic	$R_2$	1000 ohms, 1 watt
$C_3, C_4$	0.1 $\mu$ f, 600 v. paper	$R_3$	100 ohms, $\frac{1}{2}$ watt
$C_5$	50 $\mu$ f, 50 v. electrolytic	$R_4$	1.0 meg, 1 watt
$C_6, C_7$	10-10 $\mu$ f, 450 v. electrolytic (FP type)	$R_5$	0.22 meg, 1 watt
$C_8, C_9$	40-40 $\mu$ f, 450 v. electrolytic (FP type)	$R_6, R_7$	47,000 ohms, 1 watt (5% or matched)
$L_1$	Peerless C-325-A filter choke. 10 H. at 120 ma; d.c. resistance, 240 ohms	$R_8, R_9$	0.27 meg, $\frac{1}{2}$ watt
		$R_{10}$	150 ohms, 10 watt
		$R_{11}, R_{12}$	10,000 ohms, 10 watt
		$R_{13}, R_{14}$	22,000 ohms, 1 watt
		$R_{15}$	0.22 meg, 1 watt
		$T_1$	Peerless S-508-A output transformer. Pri. Z: 8000 ohms plate-to-plate; Sec. Z: 4, 8, 12, 16 ohms. Frequency response $\pm 1$ db from 30 to 15,000 cps.
		$T_2$	Peerless R-480-A power transformer. 350-0-350 v. at 120 ma; 5 v. at 3 amps; 6.3 v. at 5 amps.
		$V_1$	6SJ7
		$V_2$	6J5
		$V_3, V_4$	National Union 2160
		$V_5$	5U4G