Grounded grid ampfliers
by Robert F Durnford

A THESIS Submitted to the Graduate Committee in partial fulfillment of the requirements for the degree of Master of Science in Electrical Engineering
Montana State University


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The comparisons included are for two of the three normal frequency ranges. Audio and normal radio frequency ranges are experimentally compared and the third, very high frequency, will be compared without experimental verifica-tion.

It Is easily seen that commercial requirements of amplifier characteristics will be different. The comparison will be specific and compare frequency response, tendency to oscillate* and power requirements. From these the reader will be able to determine which circuit is best for special applications*

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Robert L. Dunford

# ABSTRACT

Grounded grid amplifiers have been mentioned briefly in articles and books for several years, but to the best knowledge of the author, there has not been a direct comparison between this amplifier and the conventional types. The purpose of this thesis is to make a comparison, and to point out the advantages and disadvantages of the grounded grid amplifier compared to the normal type.

The comparisons included are for two of the three normal frequency ranges. Audio and normal radio frequency ranges are experimentally compared and the third, very high frequency, will be compared without experimental verification.

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# INTRODUCTION

In literature dealing with amplifiers a number of abbreviations are common and familiar to the technical man, even though they are not accepted in the general English vocabulary. Accepted abbreviations, such as KC for kilocycle, as are used in the radio engineering literature will be assumed to be well known to the reader.

The object of the research leading to this thesis was to obtain a practical comparison between the grounded grid amplifier and the conventional grounded cathode amplifier, and to determine advantages and disadvantages of each. There has undoubtedly been considerable research done along this line, although the writer knows of no actual comparitive results. The more important articles are found in the "Literature Cited and Consulted" section.

This investigation was thought to be worthwhile because of the rapid trend toward use of very high frequencies. It was known by the writer that triode amplifiers do not function properly when signals of the very high frequency range are encountered.

As a general rule, the experimental comparison was done prior to the analytical work. This seemed the most logical approach, as it appeared impractical to develope analytical work which could not be experimentally verified because of insufficient laboratory equipment. The exception to this is in the case of the very high frequency comparison. Lack of very high frequency equipment limited the experimental work.

All experimental data was obtained for amplifiers built by the author. Although these circuits were not built for best performance, they were built with the same general care given to normal circuits. It was felt that to provide a practical comparison, the circuits should be tested with both good design and faulty design. The grounded grid and conventional circuit were equally effected by poor design.

No special vacuum tube nor equipment was used. There are available specially constructed tubes which are well suited for use in grounded grid amplifier circuits. These special tubes will not function satisfactorily in the conventional circuit.

## AMPLIFIERS IN GENERAL

Amplifiers are necessary in all work dealing with radio, long distance telephone, and television. The amplifier is an electrical device, a vacuum tube and associated circuit, designed to increase the voltage or power of a signal. As such, the amplifier should provide an output which is similar in wave shape but stronger than the input signal. In the case of class C amplifiers the output may have a different wave shape but it must be such that circuit elements can resolve it to the same wave shape as the origional input signal. If the amplifier is to be used to amplify different frequencies, as is generally the case, then the amplifier should have a flat frequency characteristic. That is, it should give uniform amplification to all frequencies used.

There are several types of amplifier circuits. The more common types are the untuned amplifiers used for low frequency (audio) amplification and the tuned grid-tuned plate type used for radio frequencies and higher.

The tuned circuit has resonant components which are subject to stray electric and magnetic fields. If these circuit components are so located that energy from the output circuit can be picked up by the input circuit, then the circuit may be able to oscillate. High gain triode amplifiers may oscillate because of energy transfered from the plate to the grid by the plate to grid capacity. Oscillation is a generation of output that is independent of normal input signal. Oscillation is a very undesirable characteristic and must be avoided in amplifiers. It is found that the higher the frequency to be amplified the greater the tendency to oscillate and the greater the difficulty in suppressing these oscillations.

The usual type of amplifier has the cathode of the tube grounded, and the signal is fed into the circuit between grid and ground. The output is obtained between the plate of the tube and ground. In the grounded grid circuit the grid is grounded, as the name implies, and the signal is fed into the circuit between the cathode and ground. The output is again taken between plate and ground.

## AUDIO AMPLIFIER COMPARISON

The audio amplifier is normally an untuned amplifier. This is because of the difficulty involved in obtaining a tuned circuit which has a linear response to the wide range of frequencies encountered. A tuned amplifier could be built to amplify any one audio frequency, but the circuit elements would be large and cumbersome. In addition to this, it is very seldom that a single audio frequency would be amplified. The usual case would be to amplify the entire range of frequencies which are audible. The audible range for the average ear is generally taken to be from 50 cycles per second to 20 thousand cycles per second. A tuned circuit is, by definition, critical to frequency and therefore is not applicable to a frequency range of this type.

Since the audio amplifier generally is required to amplify the entire audio range, it must have a flat response over this range. With this in mind, the conventional circuit of Fig. 1 was constructed. With this circuit the experimental data was taken for the amplification (output/input) versus frequency curve shown in Fig. 3. The circuit was then changed to the grounded grid circuit of Fig. 2, and experimental data taken for the grounded grid amplifier amplification versus frequency curve shown in Fig. 3.

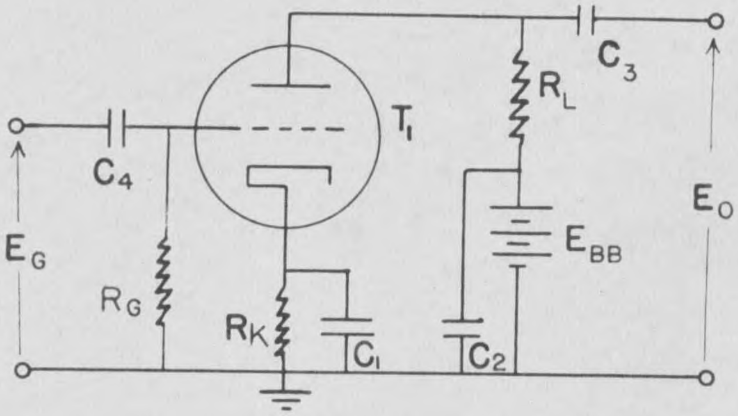



FIG. 1

CONVENTIONAL AMPLIFIER CIRCUIT

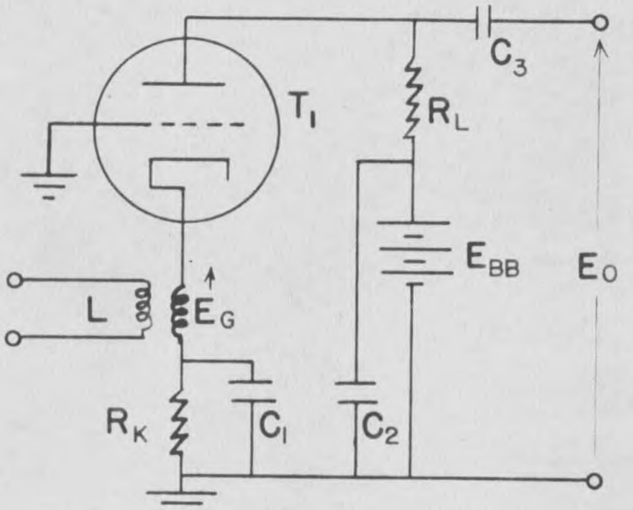



FIG. 2

GROUNDED GRID AMPLIFIER CIRCUIT

$T_1$ = 6N7

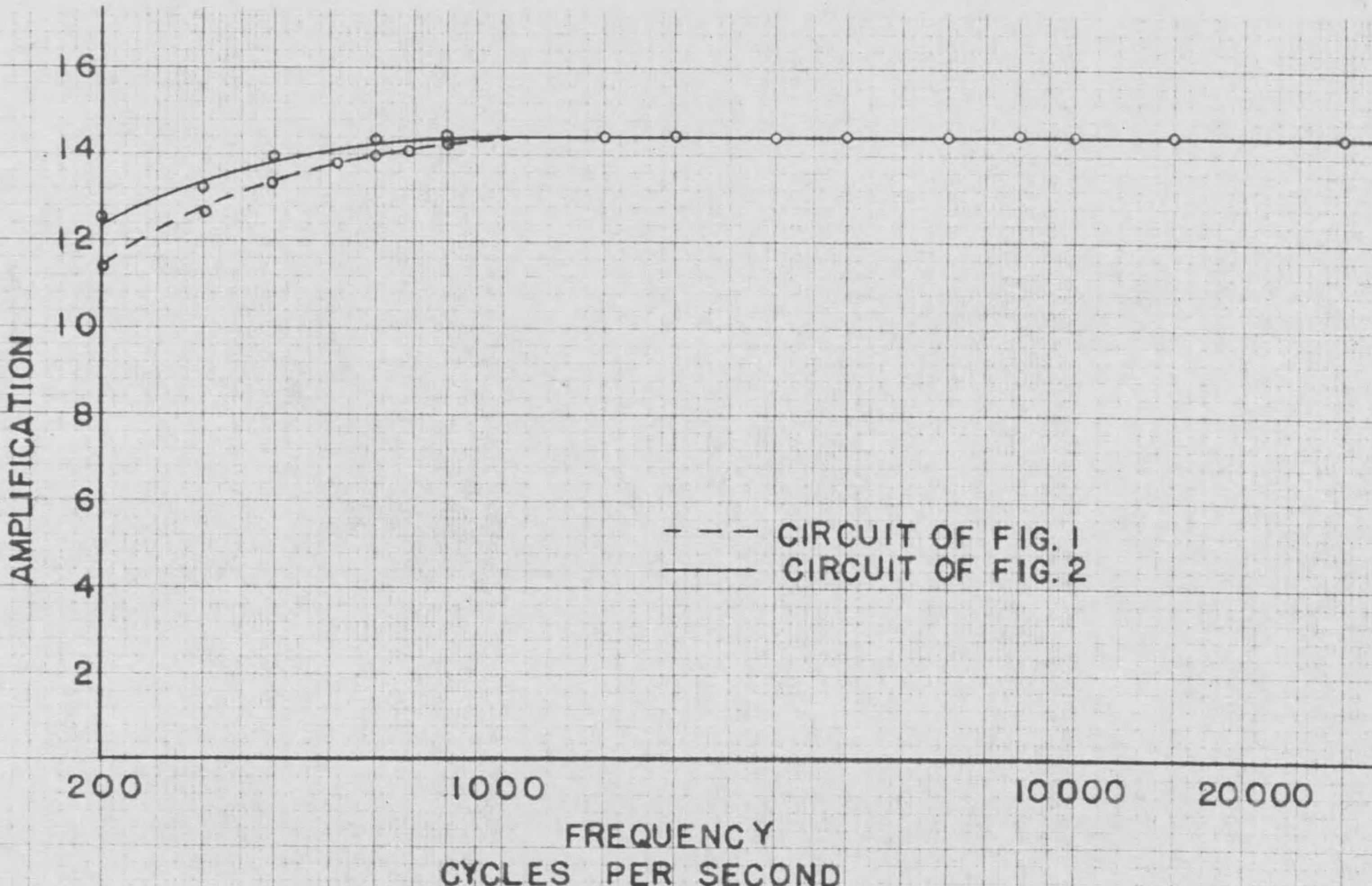
| | |
|---|---|
| $C_1$ = 40 μFDS | $R_L$ = 10,000 OHMS |
| $C_2$ = 40 μFDS | $R_K$ = 833 OHMS |
| $C_3$ = 1 μFDS | $R_G$ = 0.5 MEG OHMS |
| $C_4$ = 1 μFDS | $E_{BB}$ = 320 VOLTS |

It should be noted here that both amplifiers are of the self biasing type. That is, the plate current passing through a resistor in the cathode circuit places the cathode at a positive dc voltage with respect to ground. The grid remains essentially at ground potential. The by-pass condenser serves to maintain the ac potential across this resistor at a zero value.

In the grounded grid circuit, Fig. 2, the signal is fed into the circuit by the secondary of an audio frequency transformer in the cathode circuit. It is possible to introduce the signal into the cathode circuit through a condenser connected to the cathode if an impedance is placed between the cathode and ground. It was found that this impedance caused negative feedback, voltages caused by the ac component of the plate current which oppose the input signal. Because of this negative feedback it was found to be more satisfactory to use the transformer as shown.

The amplification of the circuit was calculated by the usual methods. For the conventional circuit the equation[1] $K = \mu \frac{R_L}{R_p \; R_L}$ was used. This equation is for mid frequency range and yields a value $K = 16.4$ . For the grounded grid circuit equation (1) page 19

1. Terman, F. E., 1937, RADIO ENGINEERING, P 177
McGraw-Hill Book Company, Inc., New York and London




AUDIO FREQUENCY AMPLIFIERS

GAIN CHARACTERISTICS

FIG. 3

$K = \frac{(\mu + 1)R_L}{R_p + R_L}$ was used. The value is $K = 16.9$ .

The curves of Fig. 3 show that both circuits yield very flat characteristics for the audio range. However, the grounded grid circuit maintains flat response over a little wider range of frequencies. In both circuits the amplification falls off at the lower frequencies. In the conventional circuit this is because of the increased reactance of the condensers $C_4$ and $C_1$ shown in Fig. 1 . In the grounded grid amplifier the reduction of amplification at low frequency is caused by the increased reactance of $C_1$ and because of the characteristics of a transformer at low frequency. Since the by-pass condenser $C_1$ appears in the same position in both circuits, the input condenser $C_4$ and transformer cause the difference in characteristics.

The equations for amplification for both circuits show that any circuit change would effect both amplifiers to the same extent. These equations contain the same terms with the exception of the $(\mu + 1)$ term in the grounded grid equation.

Fig. 3 shows no great advantage of one circuit over the other at this frequency range. A later discussion of general characteristics will point out the advantages of each.

## RADIO FREQUENCY AMPLIFIERS

The amplifier of Fig. 4 was first constructed without neutralization and was to be used as a normal radio frequency amplifier for comparison with the grounded grid amplifier. This amplifier oscillated at all times. The circuit elements were then rearranged to minimize the inductive coupling between the two tuned circuits, but it was found that the circuit still functioned as an oscillator rather than as an amplifier. An effort was then made to prevent oscillation by completely shielding the input circuit from the output circuit. Both circuits were completely shielded external to the tube. The circuit still oscillated, and from this it was assumed that the oscillation was caused by inter-electrode capacity within the tube. The tube used was a 6N7 which does have fairly high inter-electrode capacities.

In order that some experimental comparison could be obtained, the circuit of Fig. 4 was modified to provide neutralization. The neutralizing circuit feeds a portion of the output back to the input circuit such that this energy overcomes the signal fed back through inter-electrode capacity. This circuit would not be too practical for variable frequency amplifiers, as neutralization required adjustment for each frequency in order that neutralization

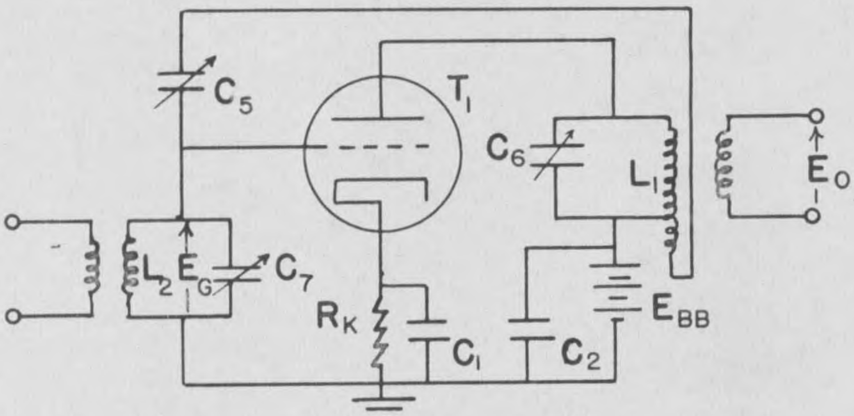



FIG. 4
CONVENTIONAL AMPLIFIER CIRCUIT

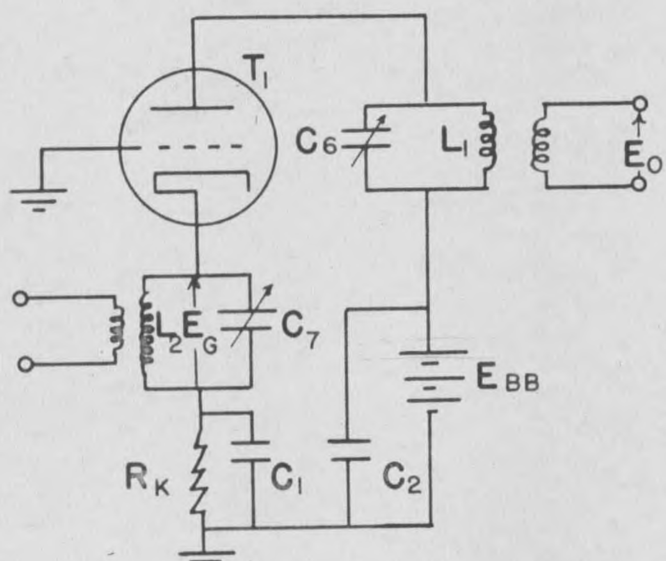



FIG. 5
GROUNDED GRID AMPLIFIER CIRCUIT

$C_1$ = 40 μFDS
$C_2$ = 40 μFDS
$C_5$ = 0 – 50 μμFDS
$C_6$ = 30–360 μμFDS
$C_7$ = 30–360 μμFDS

$T_1$ = 6N7 TUBE
$R_K$ = 833 OHMS
$E_{BB}$ = 200 VOLTS
$L_1$ = 250 μ HENRY
$L_2$ = 250 μ HENRY

was not too great. The circuit was adjusted carefully so that neutralization was just enough to avoid oscillation.

Several types of grounded grid circuits were experimentally tried. The problem was to obtain a satisfactory method of introducing the signal into the cathode circuit. In the first method the signal was introduced through a condenser connected between the cathode and the tuned cathode circuit. The circuit was very similar to that of Fig. 5. This circuit functioned but there was apparently a loss of amplification caused by negative feed back. The next trial used a condenser connected between the cathode and an impedance, largely resistive, located in place of the cathode tuned circuit of Fig. 5. Negative feed back was again present. It was concluded that inductive coupling to a tuned cathode circuit would be most satisfactory.

The grounded grid amplifier of Fig. 5 was then constructed. This amplifier did not oscillate. This suggested a possible advantage of this amplifier over the usual type. The components of the tuned circuit were shifted to increase the magnetic coupling in an attempt to cause oscillation. Oscillation did not occure even with rather direct magnetic coupling between the output and input circuits.

The circuit was then adjusted and experimental data