Class 'K' Modulator

An Experimental Method of Plate Modulating 90 Watts Input to the Final with a Single 807

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One of the simplest (although least used) means for obtaining high-level plate modulation is the class A Hising, or choke-coupled modulator. The principal advantage of Hising modulation over the conventional class AB or B push-pull method is that the Hising system uses a garden-variety filter choke in place of a more expensive modulation transformer.

Hising modulation has little use in medium- and high-power rigs for several reasons. In the first place, since the plate efficiency of a class A amplifier seldom exceeds 30 per cent, the modulator tube must be disproportionally large to handle the extra plate dissipation. The power wasted in the modulator plate might just as well be put to use elsewhere in the transmitter. Another drawback to the use of Hising modulation is that the modulator draws full plate current continuously; whereas with class B modulation, plate current is a function of the applied audio voltage, and the associated power supply is allowed to rest between voice syllables and sentences.

The theoretical maximum efficiency of a class A amplifier is 50 per cent. However, this figure is seldom realized in practical class A amplifier circuits; in order for the amplifier to deliver an output equal to half the input, the peak plate voltage swing would have to equal the d-c supply voltage. This condition can be approached if the amplifier is overdriven; but distortion is introduced when the grid is swung into the plate current cutoff region. And if the grid is swung into the grid-current region on the positive half-cycle, peak clipping is very likely to occur (see Fig. 1).

However, if the amplifier tube is operated at a high-plate-current point on its characteristic curve (either by reducing bias or by raising screen voltage), the grid voltage can be swung nearly to cutoff without too much distortion being introduced. This is because the flattened portion of the peak would occupy only a small fraction of the entire plate-current cycle. Then, if the driving source is capable of delivering the required grid losses with good regulation, the grid voltage can be swung far into the grid-current region without producing excessive distortion (see Fig. 2).

The obvious disadvantage to a circuit such as that described in the previous paragraph is that the static plate current is extremely high. Now if some system were devised to reduce the plate current of the amplifier during the intervals no
The Class K Amplifier

The circuit shown in Fig. 3 meets these requirements. This amplifier, developed by Richard Klensch (K2AZJ) and the author, is fundamentally a class A 0 zero-bias amplifier with audio-controlled modulator-screen clamp tube. For want of a shorter name, Klensch calls it the "class K" amplifier.*

The 807 is operated at zero bias so that the grid must be swung many volts negative before cutoff occurs. Transformer coupling and low-plate-impedance triode drivers are used so that positive peaks are not clipped appreciably when the 807 draws grid current.

Conceivably, the same results can be obtained if the 807 is operated class A 1 and the screen voltage increased to produce the high-plate-current operation. A cursory attempt was made to obtain this type of operation, but the experiment was abandoned because of the difficulty encountered in producing the required screen-voltage variation with audio input.

The clamp tube in the 807 screen circuit is used in much the same manner as with r-f power amplifiers, except that an audio voltage is used to develop the clamp-tube bias instead of an r-f voltage. Thus when no audio is applied to the amplifier, the 6V6 conducts to reduce the 807 plate current. When an audio signal is applied to the amplifier, the 6V6 average plate current is reduced in proportion to the amplitude of the audio. Thus the 807 plate current is proportional to the audio level.

The Class K Modulator

Class K modulation is not screen-grid modulation; it is not efficiency modulation; it is not a controlled-carrier system. It is high-level plate modulation. The clamp tube controls the average plate current of the modulator tube only; not of the r-f amplifier plate current.

The circuit shown in Fig. 3 could just as easily use transformer coupling instead of choke coupling. But this would defeat the purpose of the class K modulator, as modulation transformers usually cost considerably more than chokes.

For the sake of convenience, the modulator was built in the same chassis with a commercially-made audio amplifier unit using push-pull 6V6's in the output stage. The 6V6's supplied far too much drive for the 807 grid; so the author triode-connected 6V6's to reduce the gain of the amplifier and at the same time improve the audio regulation.

T 1 is the output transformer of the amplifier unit. Originally intended for push-pull 6V6's to a 500-ohm line, the transformer made a good driver for the 807.

The 807 grid must be swung about 20 volts on peaks; and the maximum average d-c grid current is about 4 ma. The 6V6 develops from zero to 30 volts grid-leak bias, depending on the amplitude of the audio, causing the 807 screen voltage to vary between ten and about 150 volts.

Since the plate current of the 6V6 contains audio, the 807 screen was bypassed by C 2 . This condenser bypasses most of the audio so that the 807 screen voltage is allowed to follow only the amplitude of voice syllables. If C 2 were made larger, less audio would be impressed on the 807 screen; but at the same time the screen voltage would be unable to follow voice syllables and would be maintained at a rather high average level. The values shown work satisfactorily.

The 807 plate current varies between a static value of about 10 ma. and a full-output value of about 100 ma. At full output the amplifier voice modulates 90 watts (600 v. at 150 ma.) about 85%. The efficiency of the amplifier is a function of the audio level, but is about 50% at maximum output.

Distortion

Since it is a rather involved procedure to measure distortion with the use of complex waves such as occur in voice, the author used a sine wave for this test. Because the clamp tube for some reason does not respond to sine waves so well as voice, the tube was unclamped by means of a 27,000-ohm resistor connected from the screen to ground. At 36 watts output the entire

* An idea similar to this was presented in the October, 1950 issue of CQ by W2IJU. An error exists in the wiring schematic in that the junction of R 16 and C 14 should be returned to the -150 volt bus rather than to ground. Also 304TL tubes will probably perform better than 304TH's. A follow-up story on these systems will be published in an early issue.—Editor.

Fig. 3. Parts list and wiring diagram of the class K modulator.
amplifier, including speech amplifier, drivers, and 807, showed a total harmonic distortion of only 12%.

The class K modulator was used with a Command transmitter running between 90 and 100 watts input. Tests conducted on the air indicated the speech was of good quality, although the 'scope pattern did show some peak flattening on the r-f envelope.

**Design Considerations**

This article is not intended as a “how to build it” story. A hastily constructed class K amplifier of guesswork design is very likely not to operate the first time it is turned on. The circuit shown in Fig. 3 is the result of many hours of experimentation and at least five debilitated 807's. The information presented here is intended only as a guide to anyone further interested in further developing the class K amplifier.

First, the driving source must be capable of delivering grid swing to the 807 without bogging down when the 807 draws grid current. The driver should be a triode or a pair of triodes to provide a low source impedance. The driver transformer must be able to supply grid current for the 807 and maintain good voltage regulation. A properly-matched triode-connected 6AQ5 will drive the class K 807.

Second, several very important measures must be taken to reduce the average plate dissipation of the 807. In the class K amplifier of Fig. 3, the rated plate dissipation of the 807 is exceeded—of this there can be little doubt. Since the plate current, and therefore the plate dissipation, of the class K 807 is a function of the applied audio level, the class K amplifier will not tolerate jazz music, Tarzan yells, or singing. Also, in order to keep the 807 static plate current down, the time constant of C1 and R1 should be no higher than is necessary to allow the clamp-tube average grid voltage to follow the amplitude of voice syllables. The time constant of C2 and R3 should also be kept to a minimum, but not so low that the screen grid voltage is allowed to follow the audio cycle. The resistor and condenser values shown in Fig. 3 work satisfactorily.

Another condition affecting the average plate dissipation of the 807 is the amount of hum present in the driver plate supply. Excessive hum will trigger the clamp tube and will allow the 807 to conduct unnecessarily.

The value of R2 must be determined by experiment. The function of this resistor is simply to drop the supply voltage for the 6V6 screen. A greater modulator screen voltage variation can be obtained by using a better-regulated clamp-tube screen supply. In fact, the modulator screen voltage variation can be controlled by controlling the clamp-tube screen-voltage regulation.

L1 should be at least five henries, and should be capable of carrying the r-f amplifier plate current plus the maximum d-c modulator plate current.

With Heising modulation it is usually necessary to insert a d-c dropping network between the modulator plate and the final r-f amplifier to produce 100% modulation. This network wastes power, however, and for that reason was not used. The modulation percentage was great enough—about 85%.

Power tetrodes are subject to parasites in the class K amplifier almost as certainly as they are in r-f amplifiers. Therefore, when constructing a class K amplifier, observe the standard precautions: Keep the grid, screen, and plate leads short, bypass screens and cathodes close to the tube sockets, etc. It may even be necessary in some cases to use parasitic suppressors in the grid, plate and screen circuits.

Although as it now stands, the class K amplifier/modulator is little more than a “trick” circuit, the author hopes that further development of the basic circuit will disclose methods by which the class K amplifier can be made a more practical and foolproof modulator for amateur radio use.