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A NEW APPROACH TO LOW DISTORTION IN A TRANSISTOR POWER AMPLIFIER

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Summary

In response to the varied needs of the broadcasting industry, an improved 10 watt all transistor monitor amplifier has been developed and designed.

Through a hybrid-complementary symmetry circuit, ultra linear amplification is achieved and the frequency bandwidth is increased. The new unit generates almost no heat, a problem with existing amplifiers using electron tubes.

Introduction

The list of demands made by all phases of the electronics industry on amplifier design trails endlessly on and on. Existing amplifiers work hard for the industry but we just don't seem to appreciate it. Still more is wanted.

Product engineers have one set of demands which are echoed by broadcasting engineers who have a few more of their own. And if the hi-fi conscious public knew what they were missing in audio reproduction they'd start a deafening roar.

Contemporary demands are for a low distortion, high fidelity all-transistor power amplifier that does not require laboratory adjustment and selection of PNP power transistors. The list also stresses increased bandwidth, reduced generation of heat-reduced space requirements - reduced maintenance and increased lifespan.

To satisfy these requirements we in Broadcasting Studio Engineering at RCA have developed a hybrid-complementary symmetry circuit To demonstrate the potentials of this advanced circuit system we designed a 10 watt all-transistor monitor amplifier. Application of the hybrid-complementary symmetry circuit to this unit results in low distortion and with the elimination of electron tubes this amplifier generates relatively little heat. It requires only about one half the space now used by monitor amplifiers - a boon to space-starved broadcasting studios. Maintenance is cut proportionately and the life of this unit is multiplied about 10 times over contemporary models.

In the 18 months devoted to designing this circuit and its application, our biggest headache was to overcome the requirement of most existing amplifiers - that of a power transistor with a beta cut-off frequency of over 30,000 cycles per second for low distortion when operating at 15,000 cycles a second. As you well know, today's power transistors have a beta cut-off frequency of only about 6,000 to 9,000 cycles per second. Here are some of the reasons for distortion at the midband frequency when employing power transistors.

1. Beta mismatch distortion will occur since in a class B amplifier, one-half of the output signal will be larger than the other. There is a wide variation in the transistor current gain (beta) of most types of power transistors.

2. The input impedance of a transistor (Figure 1) has an effect on the gain and distortion of the driver and the output stage. The common emitter input impedance is equal to

$$Z \text{ in} = r_b + (B + 1)\, r_e$$

The base resistance r_b emitter resistance r_e and the current gain Beta are all inversely proportional to the current flow in the emitter. The input impedance can change from 2,000 ohms at an emitter current of one milliampere to 15 ohms at one ampere.

3. The changes in the large signal current transfer ratio with the input base current drive, is another reason for distortion in a high power transistor amplifier. This graph (Figure 2) shows how rapidly the current transfer ratio of a power transistor decreases with collector current. The current transfer ratio at 100 milliamperes is 140 but at one ampere it decreases to 60.

Local Negative Feedback

This new approach, the hybrid-complementary symmetry circuit, (Figure 3) employs negative feedback to shift the dependance for ultra-linear amplification from the critical selection of the power transistor to the circuit design. Negative feedback may be used to improve frequency response and reduce distortion. However, in a transistor amplifier employing 4 or 5 stages, too much loop feedback will result in oscillation. The phase shift in each stage of a transistor amplifier is great. Therefore, the total phase shift of the amplifier greatly limits the maximum amount of loop feedback. Thus, loop feedback is not as successful in reducing distortion in a transistor power amplifier as local feedback. An unbypassed emitter resistor provides local negative feedback. This external emitter resistor must be larger than the internal