MEASURING AUDIO POWER OUTPUT

By
Philip Watson
and
Leo Simpson

Power output measurement is one of the more important tests we should apply to any new amplifier. It is relatively simple, yet can yield a good deal of valuable information about the amplifier's performance. This article discusses the advantages of the measurement, the simple precautions needed to perform it correctly and the British and American standards laid down for testing commercial amplifiers.

One of the most important tests which can be carried out on a new amplifier is that for power output. It will help to establish more certainly than anything else whether the amplifier as a whole, and particularly the output stage, is operating as intended. Failure to reach the specified figure is a clear indication that operating conditions need checking or modifying before proceeding with any other tests.

Yet it is surprising how seldom this test is made or, if it is made, how seldom it achieves a useful degree of accuracy due to the manner in which it is conducted.

This is all the more so since it is a relatively simple test, capable of good accuracy and requiring little in the way of equipment not normally accessible to many audio enthusiasts.

In an amplifier which uses an output transformer there are two ways in which this test may be approached. One is to measure power developed in the primary circuit of the output transformer and the other the power available in the secondary and which is available at the voice coil of the loudspeaker.

Where the circuit does not employ an output transformer, the power at the output socket and available for the voice coil of the loudspeaker is, fairly obviously, the only measurement that has to be made.

Regardless of the approach chosen, both involve the same broad principles, namely feeding the audio power into a load resistor of the appropriate value, measuring the audio volts developed across it at the overload point and, from the figures, calculating the audio power output.

Assuming the use of an output transformer, the measurement of primary power is useful mainly in developmental work, as when it might be desired to establish the correct load for a set of unpublished operating conditions. Its main advantage is that it is largely independent of losses or variables in the output transformer which might otherwise confuse the issue.

Secondary power is a more useful figure when we wish to know just how many watts are available to drive the loudspeaker. It is less decisive as a measure of the output stage operating conditions. However, if a reasonable estimate can be made of the output transformer losses it nevertheless provides a useful guide to the amplifier's performance.

It is most useful where, a design having been worked out and accepted, it is desired to establish that any individual amplier made to it does in fact approach the output claimed and is therefore unlikely to contain any major faults.

In the case of a transformerless output stage there are no consequent losses to cloud the issue, so that a power output meaurement provices, at one and the same time, an indication that the output stage is functioning as intended, and a figure which can be quoted as the output power available to drive the loudspeaker or other load.

Inasmuch as the main purpose of an amplifier is to deliver a specified amount of power to an appropriate load, one would expect that this would be the natural measurement an enthusiast would look forward to making when he had tightened the last nut and bolt and deposited the last blob of solder. Yet so many seem content to simply give the system a listening test, and, providing it sounds "good and loud," accept it as OK.

And even when results are disappointing, and they seek someone's advice, it is seldom that they can quote precise figures to support their claim that it is not delivering the power it should. They are usually content to mentally compare it with some other amplifier, rated at so many watts, then pluck a figure out of the air to suit their own unit, depending on whether it sounds louder, the same, or weaker.

In the case of high-power PA amplifiers and guitar amplifiers, which may be rated as high as 100W, or even some domestic equipment which may run as high as 30W, measurement — rather than subjective reaction — is even more important. It is virtually impossible to run such amplifiers "full bore" into a loud speaker load on the bench, or to assess anything worthwhile from such a test should it be attempted.

It should also be appreciated that other vital amplifier characteristics (sensitivity is one example) are normally quoted on the basis of maximum power output, so we must be able to measure power output before these other characteristics can be assessed. On the other hand if, when a power output measurement is made, we can also measure (for example) the level of signal being fed into the amplifier, the test will yield both power output and sensitivity figures.

Having thus made a case for this test, let us take a closer look at what is required to perform it. First, the load resistor, or "dummy load" as it is usually called. This is to replace the loudspeaker, which cannot be used for several reasons, the main one being that it simply is not accurate enough, in terms of impedance, for the purpose.

Impedance values quoted for speaker voice coils are purely nominal and are quoted for one frequency only. The actual value likely to be presented in a typical test set-up could vary by two to one from the nominal.

In its place we substitute a resistor. Ideally, this should be a non-inductive, close-tolerance unit, capable of dissipating the anticipated power without damaging heat rise or change of value. In practice, we can tolerate the small amount of inductance inherent in a simple wire-wound unit, and a resistance tolerance of 5 per cent would be adequate in most cases.

In regard to power handling ability, it should be appreciated that resistors are normally rated on a "free air" basis and should be down rated if they are enclosed in any way. Except for intermittent use a good rule-of-thumb is to half the wattage rating when the resistors are to be enclosed in a metal instrument case, provided with reasonable ventilation.

The value of the load resistor will depend entirely on the particular job to be done. It could range from (typically) 10,000 ohms for a primary measurement of a valve type amplifier, down to (typically) 8 ohms for a voice coil measurement.

In practice, it is most convenient to make up a load box containing a representative group of heavy-duty resistors, complete with the necessary switching, terminals, etc., to make for greatest convenience. A typical unit is described elsewhere in this issue.

Where the load is to be substituted directly for the voice coil the arrangement is so straightforward as to warrant little comment. The primary measurement is, however, somewhat different. Because there is both AC and DC present in the primary circuit, we must provide circuits for each. Simply substituting a resistor for the transformer primary would result in an intolerable voltage drop and failure of the output stage to function correctly.

The transformer is therefore left in circuit, but with all secondary load removed. It thus acts as a high impedance choke, and has little effect on the load as seen by the output stage. On the other hand it continues to function as a low resistance path for the DC supply. The dummy load — equal in value to the required primary impedance — is then connected in parallel with the primary winding, where it is seen by the output stage exactly as if it had been reflected from the low impedance secondary circuit.

Next, the voltmeter. This needs to be a good quality AC instrument, with a suitable selection of ranges. In addition, a DC blocking capacitor will be needed whenever measurements are to be made on the primary side of a transformer. Even if the meter is connected directly across a transformer primary, there may be a small DC voltage present, due to the resistance of the primary winding. There is no such problem when measurements are made in secondary circuit and the normal AC ranges may then be used.

For measurements at voice coil impedance, the sensitivity of the meter is not particularly critical. Anything above about 100 ohms per volt should be perfectly satisfactory. For higher impedance measurements, such as those encountered in the primary circuit of valve amplifiers, the meter impedance should be at least 1000 ohms per volt, and even this value can introduce errors in some cases.

For example, a 10,000 ohm load resistor shunted by a 50,000 ohm meter (1,000 ohms volt, 50 volt scale) will be reduced to 8,300 ohms approximately, a significant error.

To produce a true 10,000 ohm load in such circumstances it would be necessary to start with a resistor of about 12,500 ohms.

Voltmeter accuracy is the most important factor, since the voltage figure is squared in the formula, and even minor errors will be aggravated. For example, a reading of 9 volts instead of 10 (a 10 per cent error) will result in a figure of 81 being found in the formula in place of the correct figure of 100 — an error of 19 per cent!

Valve or solid-state voltmeters can be used, and these would automatically solve any problems concerning sensitivity. However, where a unit is mains operated, with the possibility that one side of the input may be "earthy," due care must be taken to see that this does not conflict with any other "earths" inherent in the amplifier or associated test equipment.

In our own laboratory, we have access to a digital voltmeter and there is no doubt that this makes the job a good deal simpler. Not only is the direct readout free from possible ambiguity, but the inherent high accuracy of these instruments eliminates all doubts as the validity of the final calculations.

Next, we require a test signal. The requirements are not unduly stringent. A frequency of 1000Hz is usually chosen, and the waveform should be a reasonably good sine wave. If a regular audio oscillator is not available the audio output from a conventional signal generator may be used. This usually is about 400Hz and anything between this figure and, say, 1,500Hz should be quite satisfactory.

Most audio oscillators are capable of generating a reasonably good waveform but anything exhibiting either an obvious peakiness or squared-wave characteristics should be avoided.

A useful refinement to any such audio generator is the provision of a calibrated output. This will enable a sensitivity measurement to be made at the same time as the power input is determined. Together, these two figures give a very clear picture of an amplifier's behaviour.

Finally the CRO. Not a great deal need be said about this since almost any instrument worthy of the name should be suitable. Its job is to indicate the overload point of the amplifier, as shown by just perceptible flattening or other irregularity of one or both halves of the sine wave. Connected across the load, or between the "hot" side and chassis, it will reveal the first signs of overload or clipping, and the need to reduce the signal level or gain to preserve a non-distorted waveform.

When all these items have been connected to the amplifier in the appropriate manner the amplifier is driven up to the overload point, backed off slightly, and the AC voltage developed across the load resistor measured as accurately as possible. From voltage and resistance the power may be calculated according to the following formula:

$$W = E^2/R$$

Where:

W is the power in watts.

E is the RMS audio output volts, and

R is the load resistance in ohms.

The foregoing is directed mainly at those who build or design amplifiers and who wish to confirm that an individual unit comes up to the predicted performance figure.

However, there is another situation involving power output measurement; the need to test a commercial amplifier to confirm that it comes up to the manufacturer's specifications. This is a situation which confronts us regularly in our own laboratory when we are required to check equipment submitted by advertisers for our Trade Review columns. And, while the approach is broadly similar, there are a number of additional factors which have to be taken into account.

These involve such things as the total harmonic distortion for which power output is quoted, the method of rating used by the manufacturer, and

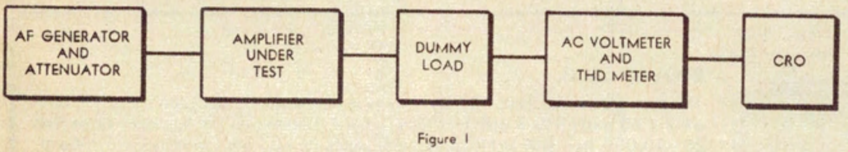

Figure 1. Block diagram showing the set-up for measuring "Continuous Power Output" or "Rated Power Output".

so on. Fortunately, quite precise industrial standards have been laid down which provide guidelines for amplifier power measurement.

There are two which are generally recognised. The first and most stringent is that by the American Institute of High Fidelity Manufacturers; the IHF Standards of Measurement for Amplifiers, IHF-A-201, which was published in late 1965. The other standard is the British Standard 3860: 1965.

Other organisations besides the I.H.F.M. have sought to set up standards for the measurement of amplifiers but these have not been as stringent as the above two specifications and the organisations themselves have not gained the same recognition as the I.H.F.M.

The method of testing which we have detailed in the first part of the article is similar to, but less stringent than, that described in the American standards under the definition "Continuous Power Output" and in the British standards as "Maximum Power Output." The main difference is that these standards require that the manufacturer specify a value of total harmonic distortion at which the power is measured, and that the test set-up includes a distortion meter to measure this. (Typical distortion limits are 1 per cent for average high fidelity applications and 0.1 per cent for very high quality amplifiers.) Other terms used in place of "Continuous Power Output" are "Sine Wave Power," "RMS Power," and "Continuous Tone Power."

More precisely, the British Standard defines "Maximum Power Output" as follows:

"The maximum measured output power that the amplifier can deliver continuously to a stated load resistance at a frequency of 1000 c/s without exceeding a specified value of (total) harmonic distortion." As explained elsewhere in the standard specifications, "continuous" implies a test of not less than 30 seconds' duration.

A similar definition, and one which has caused some confusion by reason of its similarity, is quoted for the term "Rated Power Output." The difference between these two is mainly one involving the normal spread of tolerances in commercial components, and which results in no two amplifiers, nominally the same, being absolutely identical.

For this reason amplifier manufacturers normally quote a "Rated Power Output" for their products, and this is meant to imply that the figure quoted is the guaranteed minimum power output which any individual amplifier will deliver. If the manufacturer values his reputation, most units would deliver something more than this value (for the specified harmonic distortion). An individual unit could deliver the same value, but none should deliver less.

In simple terms, the difference between the two terms is the safety margin the manufacturer allows himself in order to compensate for component tolerances.

A block diagram of the equipment used for verifying rated power and determining continuous power output is shown in figure 1.

Another definition often encountered is "Music Power Rating." This seeks to allow for the fact that most amplifiers can deliver a short burst of power which is greater than the continuous power it can deliver. This characteristic is dependent, in turn, on

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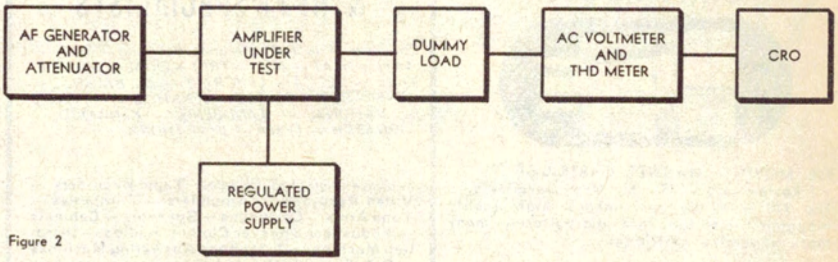

Figure 2

Figure 2. An early method used to measure "Music Power". It had many limitations and is seldom used.

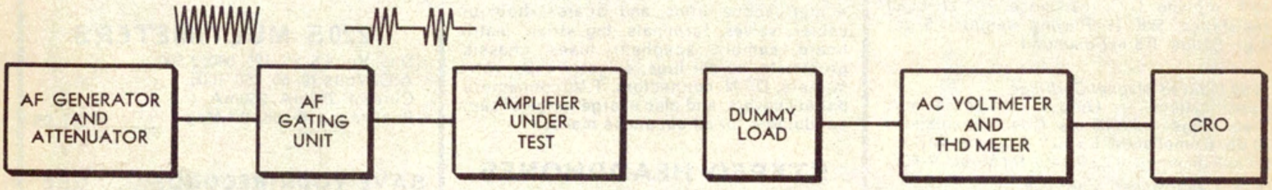

Figure 3

Figure 3. The tone burst method of measuring "Music Power". While better than the system shown in figure 2, it still has some limitations.

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the regulation of the power supply and the fact that the average level of music is considerably lower than the maximum or peak level.

Originally, the I.H.F.M. sought to measure music power with an external regulated supply connected to the amplifier. (Figure 2.) This maintained the supply voltages at the quiescent (no-signal) level regardless of the current drain. The power measurement was made at the reference distortion, in the same way as continuous power measurement. While this method did give an approximate idea of the amplifier's performance on music signals, it is unrealistic and impractical for several reasons. For one, the dissipation rating of output transistors can be exceeded at the higher power levels permitted by the external supply.

Further, there is no ripple superimposed on the regulated supply to add distortion to the waveform near the clipping level, or to add hum to the input signal. Also, apart from such criticisms, there is the inconvenience involved in connecting a regulated supply to an amplifier for testing purposes.

For these reasons a new test was introduced by the I.H.F.M. to give a more realistic approximation of the short term power capability of an amplifier. The test involves applying gated sine waves in bursts of 10mS duration at a low repetition rate. (Figure 3.)

(See Electronics Australia, April 1968, "A Synchronous Gating Unit For Tone Burst Testing.")

The so-called "Tone Burst" test has also been called the "Transient Distortion" test by the I.H.F.M. and the resulting parameter is called the "Dynamic Power" rating. While this test certainly does give a better indication of the short-term power capability of an amplifier it should be realised that an amplifier cannot always deliver this power on the peaks of typical music signals. The actual "music power" of an amplifier at any instant will vary and depends on the immediately preceding amplifier conditions.

In normal conditions the amplifier is not operating at zero output conditions as it does in the tone burst test. For every musical transient that follows a quiet passage there are many which follow moderately loud passages and on these latter transients the amplifier could not deliver the same level of power that it might on the transient following the quiet passage. Thus, an amplifier's music power will lie between the "Dynamic Power" and the "Continuous Power" ratings.

The "Dynamic Power" test has another flaw in that it is intended to indicate the power developed at the same total harmonic distortion as that specified for the rated power output. Distortion measurements on pulsed sine waves are difficult to perform, to say the least, so this forms another region of uncertainty.

In most cases, "Dynamic Power" will be higher by about 20 per cent than the "Continuous Power Output." If it is any higher it indicates a poorly regulated supply. Amplifiers with an electronically regulated supply will give the same power output on "Dynamic Power" and "Continuous Power" tests.

The "Peak Power" rating is one much-favoured by advertising departments in the past but now, fortunately, it is falling into disuse. The people who used it sought to justify it on the basis that the power on a sine waveform is not constant.

The "peak power" figure is arrived at by multiplying the peak voltage (1.4 times the RMS voltage) by the peak current (1.4 times again) to produce a figure twice that which would be produced by using RMS values. The process is about as valid as rating a 100W lamp at 200W peak power. Use of the term "Peak power" has led to the term "RMS power" being coined to distinguish the RMS derived figure from the peak derived figure. However, the term "RMS power" is mathematically incorrect.

We at Electronics Australia consider the "Continuous Power" test to give the best indication of the quality and capability of an amplifier.

Having explained the various power ratings we can describe the points which must be considered when verifying the manufacturers' specifications of an amplifier. Firstly, as mentioned above, the oscillator used in the test must generate a pure sinewave. For accurate distortion measurements the total harmonic distortion should be less than one-fifth of the anticipated distortion of the amplifier under test.

The most important point as far as the actual power measurement is concerned is the accuracy of the voltmeter. While routine checks can be carried out with a multimeter of average accuracy, verification of amplifier performance specifications really requires a voltmeter with an accuracy of 1 per cent of F.S.D.

According to the British standard, the load used for the amplifier should not vary from its nominal value by more than 5 per cent, while dissipating any power up to the amplifier's maximum. The I.H.F.M. standard recommends that it should not vary from its nominal value by more than 1 per cent while dissipating the maximum output of the amplifier, and also that its reactance will not be more than 10 per cent at any frequency up to five times the highest test frequency. This is an expensive requirement.

While the resistors used for the load must be accurate, care must also be taken to ensure that contact resistance is low in the various connections between amplifier and load. This is particularly important when measuring power into 4-ohm or 2-ohm loads.

The mains supply should be within 2 per cent of the mean of the supply range specified by the manufacturer. The British specification further states that tests should be carried out to determine the effect of supply variations over certain limits.

The final stipulation made by the British specification is that all amplifiers should be in use for at least 1 hour before measurements are recorded and that solid state amplifiers should be in use for at least two hours before measurements, to ensure that conditions in the amplifier have stabilised.