You don't need fancy gear to check out audio amplifiers: just an input signal from a PC sound card, a multimeter, a loudspeaker, a wirewound resistor and a dummy load made from some electric jug elements suspended in water.

You don't need a bench full of expensive equipment to test audio amplifiers. Here's how to go about it using gear that's readily to hand.

By JULIAN EDGAR

Amplifier Testing without high-cost gear

IF YOU'RE ANYTHING like me, you can't resist picking up a bargain – especially when it's a cheap piece of electronics that someone in their, er, wisdom has decided no longer has the right fashion look. Take audio hifi amplifiers, for example. Visit (in declining order of salubriousness) secondhand stores, garage sales, roadside rubbish collections and the tip and you'll find a host of amplifiers that are available at ridiculous cost (as in, ridiculously low . . .).

Consider, for example, the Rotel 712 integrated stereo amplifier shown on these pages. It cost me just $8.00. Yes, that's right . . . eight bucks. What was wrong with it, you ask? Answer: nothing.

Similar bargains can be had in lots of places. Recently, I bought a Rotel (yep, I like that brand) RX-203 stereo receiver for . . . wait for it . . . $3. So what was wrong with that one? Well, I haven't tested it yet but I'll wager that it also works fine.

Talking about testing, until recently I thought that any meaningful testing of an amplifier needed stuff like oscilloscopes, standalone frequency generators and specialised audio test gear that I didn't even know about. But then, through the advice of three learned men, I saw the light – the amplifier "test light", so to speak. Those three wise men advised me that all I needed was a digital multimeter, my trusty PC, a few cheap resistors . . . and a jug element!

A jug element? It all sounded so crazy that it might just work.

But do the figures really matter? After all, the reason that you buy an audio amplifier is to listen to it. The answer is yes, especially if you've

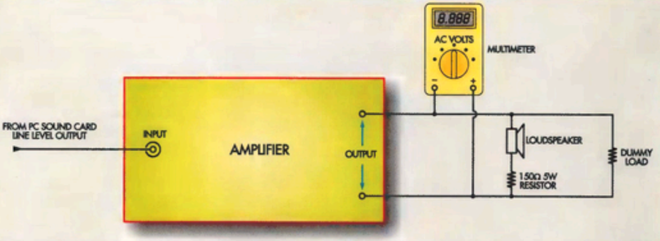

Fig.1: all the tests require a set-up like this. The PC's sound card output is connected to the amplifier's input, while the amplifier's output drives both the dummy load (the jug elements immersed in water) and the monitoring speaker (via a 150Ω resistor). The multimeter is used to measure the AC voltage at the amplifier's output.

heard the distorted sound that some appear people to like.

What's required

The first things that you need for amplifier testing are your ears – both to assess the purity of a quiet test tone and also to listen for any background noise that might exist when there shouldn't be any.

You'll also need a decent digital multimeter. These days "decent" applies down to multimeters costing from about $60, so almost any recent meter will do. It also helps if it can measure frequency in addition to the usual AC volts and resistance. However, that's not vital – it's just a good check.

A cable that connects your PC's sound card output to the amplifier inputs will also be needed. Typically, this will be a cable with a 3mm stereo plug at one end and two RCA plugs at the other.

On the output side of the amplifier, you'll need to connect a monitoring speaker. This will only ever be used at low volumes (no test tones will destroy it), so it can be one of your normal hifi speakers.

To reduce the power into the speaker (so that you won't be deafened), you'll need to connect a 150Ω 5W wirewound resistor in series with it. That will set you back about 30 cents – or nothing if you can salvage one from your junkbox (I got one from an old photocopier).

And now we come to the jug element, or elements. Yes, you'll need one or two electric jug elements (ie, the 240V sort that you can buy at any supermarket) and a Pyrex or high-temperature glass bowl that you can fill with water before suspending the elements within it. If you haven't already guessed, this is our amplifier load – and a beauty it is, too.

Making the load

Turning the jug elements into the load is easy. If you use two (as I did), gradually unwind turns of wire from each element until the remainder left on each ceramic former has a resistance of 16Ω, as measured with your multimeter. Then, when you wire the modified elements in parallel, you'll have a very high power load with a total resistance of 8Ω.

Alternatively, you can make each element 4Ω and then wire them in series for an 8Ω load. It really doesn't matter how you do it – you just want lots of windings and a resistance that matches the load the amplifier expects to see.

This secondhand amplifier – bought for just $8.00 – was the guinea pig for much of the testing described here. Using just simple tools and techniques, its power output, frequency response and signal-to-noise ratio were all measured, along with the response of its tone controls.

The amplifier test load is formed by two slightly modified electric jug elements suspended in a jug of cooling water. This load can sink very large power outputs – if the water starts getting hot, simply swap it for some cold water.

You can also make 2Ω and 4Ω loads, just by modifying the above procedure.

Next, place the elements in that bowl of water and then use heavy-gauge wire to connect the jug elements together and to the amplifier.

Warning: if you are testing a high-power amplifier, this water can become hot enough to burn. Ensure that small children, pets, local religious proselytisers and the like cannot come in contact with it.

Generating the test tones

To generate pure sinewave test tones, you'll need to download some frequency generator software off the web. This is available either free of charge or with a 30-day free trial period. We used PAS Products Frequency Generator version 2.6 (from **www.pas-products.com**) but there are plenty of other programs around – a web search will soon find them.

Practice playing with the generator while monitoring the sound through your normal PC speakers until you are able to do two things: (1) generate sinewave signals over a 20Hz to 20kHz (20,000Hz) range; and (2) vary the volume level. The latter requirement is important – some frequency generators make it difficult to vary the amplitude (volume) of the test tones and so you should check that this function exists.

Measuring power

This one's really exciting – everyone knows about amplifier power and being able to measure the output with your own eyes, hands and ears is great fun. Here's how you do it:

(1). Ensure that the load is covered by water, then connect it to one channel of the amplifier.

(2). Wire the monitoring speaker in parallel with the load – ie, connect it to the same channel. Don't forget that you need to install a 150Ω 5W resistor in series with the feed to this speaker – see Fig.1.

A 150Ω 5W wirewound resistor is wired in series with the loudspeaker so that the test tones can be monitored at full amplifier power. This resistor can be bought off-the-shelf for about 30c or better still, salvaged for nothing from discarded equipment.

(3). Set your multimeter to "VOLTS AC" and connect it across the same channel.

(4). Connect the line-level output from the sound card to the corresponding input of the amplifier.

(5). Start the frequency generator software on your PC and select a frequency of 1000Hz.

(6). Set the volume control on the frequency generator software to give an amplifier input voltage of 1V (you can measure this at the input to the amplifier). If the sound card's output won't go that high, set it to a lower value that you carefully note.

Fig.1 shows the complete test set-up.

When you turn up the amplifier's volume control (you did remember to switch it on?), you should hear a faint 1000Hz test tone coming from the speaker. At the same time, there should also be an AC voltage level on the multimeter.

If everything is working as it should, turn up the amplifier volume, listening intently to the test sound and watching the changing figures on the multimeter. When the volume reaches a certain point – called "clipping" – the sound from the speaker will suddenly and clearly distort. Take note of the multimeter reading and then quickly turn the volume back down.

On my $8.00 Rotel unit, the lefthand channel yielded a result of 19.6V before clipping. So how do we turn this into a maximum power figure? It's easy – just square the number (ie, multiply it by itself) and then divide that by the resistance of your dummy load. The formula is: $P = V^2/R$.

In this case, we have 19.6 x 19.6 + 8.5 = 45 watts (45W).

I then repeated the test for the other channel and got a figure of 48W. Not bad, eh? My $8.00 amplifier has a bit of punch!

Checking frequency response

Now you might be saying that it's great that this amplifier has 45-odd watts per channel, but that's only at 1000Hz. What about over the rest of the frequency range? This introduces the idea of frequency response – just how flat is the response of the amplifier across its frequency range?

Testing this is again very easy and

the set-up is the same as shown in Fig.1.

Leave everything in place as it was for the previous test but wind the wick down to about "2" or "3" on the volume dial (ie, adjust it to what normally would be a quiet listening level). Now decrease the test tone frequency to 20Hz (you will no longer be able to hear it from your speaker – the frequency is too low). Make sure that all the tone controls are set to flat (zero adjustment) and switch off the loudness button.

Next, measure the input voltage to the amplifier – it should be the same as it was for the previous test – ie, 1V (or your nominated figure). If the input voltage has changed, adjust the output of the frequency generator until it is again 1V (or the nominated test figure), then measure the output voltage of the amplifier and note this value.

Next, change the input frequency to 100Hz and adjust the generator until the input signal is the same as for the previous measurement. As before, measure the output voltage from the amplifier and note this value.

Keep doing this right through the frequency range, up to 20,000Hz. Of course, you don't need to do the measurements all in small increments. Table 1 shows the results of this testing on the Rotel amplifier.

As you can see, with a constant input voltage, the highest output from the right channel was 2.2V while the lowest was 2.1V. So it doesn't vary much, does it? But how do we express this variation in that unit beloved of audio engineers – decibels or dB? Again, it's easy: simply divide the highest figure by the lowest, take the logarithm of the result, then multiply by 20.

So, from the table of data:

[log (2.2/2.1)] x 20 = 0.4dB

So between 20 and 20,000Hz the biggest variation away from a ruler flat response for this channel is just 0.4dB. The other channel measured a little worse at 0.5dB. Those are very good specifications for an amplifier – those eight dollars are looking better and better all the time!

Signal-to-noise ratio

The signal-to-noise ratio is a measure of how quiet an amplifier by itself is: for example, when all the sound stops, you shouldn't be able to hear anything – no hiss and no hum. Well, not because of the amplifier, anyway.

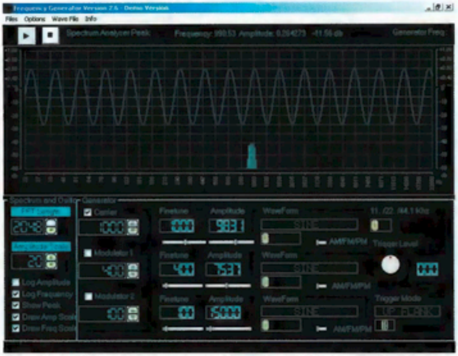

Fig.2: this audio frequency generator software is available for a 30-day free trial period via a web download. Just about any frequency generator software is suitable for the amplifier testing procedure described in this article.

Table 1: Frequency Response Measurements

Frequency	20Hz	100Hz	1kHz	5kHz	10kHz	15kHz	20kHz
R-Channel Output	2.17V	2.15V	2.20V	2.10V	2.10V	2.12V	2.10V
L-Channel Output	2.23V	2.15V	2.12V	2.14V	2.18V	2.10V	2.15V

This table shows the output voltages measured for both the left and right channels at seven different input frequencies. As can be seen, the left channel of the old Rotel amplifier has a slightly wider variation than the right channel. However, simple calculations (see text) show that even this varies by only about 0.5dB. Note: input signal voltage held at a constant 1V.

Table 2: Bass Control Response

Frequency	20Hz	50Hz	100Hz
Bass Control Max.	11.1V	9.9V	7.3V
Bass Control Min.	0.40V	0.48V	0.67V

As shown here, the Rotel amplifier's bass control has its maximum effect at just 20Hz. These are the "raw" voltage outputs when the bass control is turned and some simple calculations show the adjustment range to be about ±14dB. Note: input signal held at 1V; output signal is 2.16V with control "flat" (ie, centred).

Remember how when we tested the maximum power output on the Rotel, we achieved a maximum output before clipping of 19.6V? That's one of the figures we need for this test. The other is gathered by again measuring the voltage output with the volume control wound almost fully up but this time with zero signal input.

However, if we simply pull the signal input lead out of the amplifier, it's likely that electrical noise will be picked up from the surroundings. To overcome this, we wire a 1kΩ resistor across the input. As well as preventing noise pickup, this also keeps the amplifier "happy" as it's seeing some input resistance.

Again the dummy load, speaker and multimeter can be left connected as we had them before. Now wind up the volume control to the level at which clipping previously occurred (eg "8" on the knob) and read the no-input-signal output voltage. It will be very low. In the case of the Rotel, it was 2.6mV.

So at full power, the output was 19.6V (that's 19,600mV) while with no input, the output is 2.6mV at the

Another Secondhand "Bargain" Amplifier

It was another "cheapy" buy although not in the same class as the Rotel covered in the main text. I bought this Bose professional amplifier by tender (so no extensive testing was allowed prior to purchase) for just $480. That's pretty good when the new price is US$2000 and the thing can develop no less than a claimed 450W per channel into 8Ω loads!

Unfortunately, once I'd got it home, I found that my new purchase wouldn't develop any watts into any channels. Instead, it just blew the circuit breaker on the external power board. Inside the case, the transformer was simultaneously getting hot and it proved very expensive to replace.

The replacement fixed the problem and I was ready to do some testing. So how much power output did it deliver? Well, with one channel driven, try 560W into an 8.5Ω load! And that's with no apparent clipping (this amplifier incorporates internal soft clipping circuitry). Its signal-to-noise ratio wasn't as impressive though and measured just 88dB – way below the best of SILICON CHIP's designs.

same volume control position. To turn this into the signal-to-noise ratio, we do the same sort of calculation as for frequency response, ie:

$[\log(19{,}600/2.6)] \times 20 = 77.5\text{dB}$

Now a 77.5dB signal-to-noise ratio isn't wonderful – in fact, one of the three wise men told me that it's about par for the course for FM radio. But where I'm using this amplifier – with computer fans constantly humming away in the background – I can never hear any noise from the it, anyway. (Well, that's my excuse!)

And that brings us to another simple testing technique. Connect the amplifier to its normal speakers (no resistor needed) and make sure that there is no input signal. That done, turn the volume right up and listen intently to the speakers. The more noise that you can then hear, the poorer the signal-to-noise ratio of the amplifier.

Bass & treble controls

Measuring the action of the bass and treble controls is very similar to measuring the frequency response – except this time you're the one causing the change in the response.

To begin, set the amplifier test system up as for testing frequency response – ie, dummy load, monitoring speaker, constant input signal level, and your multimeter in parallel with the load and speaker. Most bass and treble controls are centred around 100Hz and 5000Hz respectively, so start testing with those frequencies.

As an example, let's look at the action of the bass control. With a 100Hz input signal (say at 1V level), the output might be 2.16V with the bass control flat, 7.3V with it at maximum, and 0.67V with it at minimum. Note these figures, then repeat the procedure for 50Hz and 20Hz input signals.

Table 2 shows the results for my Rotel amplifier. This reveals that the maximum effect of the bass control is at 20Hz – an unusually low frequency. It also shows that it can boost the signal output from a "flat" 2.16V level to 11.1V, or reduce it to just 0.4V.

Expressing these as dB figures uses the same old equation:

$[\log(11.1/2.16)] \times 20 = 14\text{dB gain}$

Similarly, the bass cut was almost symmetrical at 14-15dB, while the treble (centred around a high 15kHz) proved to be ±12dB.

Conclusion

It's possible to gain a lot of information about the performance of an audio amplifier with very little effort and just a few basic test tools.

Give it a go some time – you'll quickly find out just how good (or bad) that bargain really is.

Important Points To Note

(1) The frequency response tests in this article assume that the digital multimeter has a frequency response up to at least 20kHz. Many DMMs are not this good and may have a frequency not much in excess of 1kHz. Such meters can be used for the power test at 1kHz but not the frequency response or treble control checks.

(2) When doing power output tests on valve stereo amplifiers, both channel outputs must have dummy loads. **Operating a valve amplifier without a load may cause serious damage.**

(3) The power tests in this article are equivalent to the continuous (RMS) power output of an amplifier, even though they are carried out for a short duration. Running an amplifier continuously under these conditions may cause damage.

(4) If you want to experiment further with Internet software for audio testing, including having your PC operate as an audio oscilloscope, refer to "Digital Instrumentation Software For Your PC" and "Sound Card Interface For PC Test Instruments". Both these articles were published in the August 2002 issue of SILICON CHIP.

The printed edition of this magazine is available for $8.80 including postage within Australia or on-line for the same price from **siliconchip.com.au**

Footnote: my thanks to the three wise men: Leo, John and Bob. **SC**