Improving the overload performance of the Ultra-LD Mk 3

By LEO SIMPSON

Isn't the Ultra-LD Mk3 amplifier module (SILICON CHIP, July to September 2011) supposed to be perfect? How could anyone possibly improve its performance? Well, as much as it pains us to admit it, "It ain't perfect and it can be improved". In this case, we are talking about how to improve its performance when it is grossly overloaded.

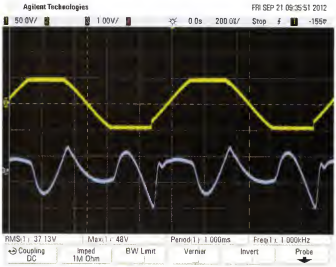
Most of the time when listening to music, we are careful not to drive an amplifier into clipping – and that applies particularly when listening to a very high quality sound system.

After all, what is the point of spending thousands of dollars on a fine music system in order to be able to enjoy the very best sound quality, and then driving it into overload?

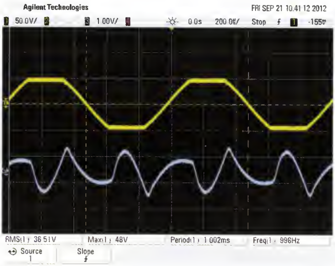
It will then distort badly and sound horrible.

Having said that, it is relatively easy to drive a hifi system into clipping. You know how it goes; you are enjoying the music immensely and the volume is wound well up and then along comes a crescendo which is just a bit louder than you had remembered. The amplifier briefly overloads and you probably think that's just a bit too much for the system.

On the other hand, while the above over-drive scenario refers to program material with a wide dynamic range, a similar situation can occur if you are driving the amplifier with heavy rock which has very little dynamic range. If you



Scope1: the top (yellow) trace shows a 1kHz signal with 2.6dB of over-drive, while the lower (blue) trace shows the resultant harmonic distortion product. Note that the negative clipping condition is worse than the positive.



Scope2: this grab shows the same over-drive conditions as Scope 1 but with the BAV21 diode fitted to the circuit. Notice that the clipping of the negative cycles is subtly improved.

are running the system pretty much flat-out, it only takes a slight increase in signal level to take it into overload.

In fact, over the years when we have been developing and refining the Ultra-LD amplifier in its variations we have seldom deliberately over-driven the amplifier or if we did, it was more or less incidental to the process of obtaining THD versus power graphs. And even if we did over-drive it, it would not have been grossly overloaded.

One of our readers, Doug Ford, of Doug Ford Analog Design Pty Ltd (www.dfad.com.au), recently alerted us to the problem of the undesirable overload characteristic of the Ultra-LD module.

His company needed a few power amplifier modules and because it was easy to do so, they built a few of the Ultra-LD Mk2 modules. They did not need lots of power but did need a reasonable swing at around 10kHz.

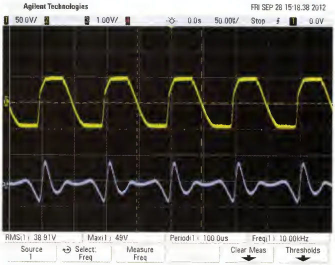
To put it in Doug's words, he "promptly discovered that the amp's clipping behaviour at 10kHz was appalling". He backed it up with a scope screen grab and also suggested the addition of a high voltage small signal diode to fix the problem. Another scope grab showed the effect of the fix, which was good.

Some time has passed since Doug's email until we had the chance to do the same mod ourselves and verify that first, it largely cured the "appalling" overload problem and second, to determine its effect on the THD performance of the module, in normal operation before the onset of clipping.

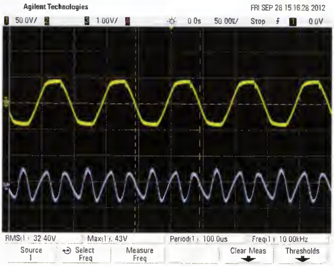
The answers to those questions are yes, it works well and second, it has no measurable effect on the THD before clipping.

Scope grabs 1 & 3 demonstrate the overload behaviour of an Ultra-LD module driving an 8-ohm load and driven with a 1.7V signal at 1kHz and 10kHz, respectively.

As you can see, in both cases the resulting waveform is not



Scope3: the top (yellow) trace shows a 10kHz signal with 2.6dB of over-drive, while the lower (blue) trace shows the resultant harmonic distortion product. Note that the clipping behaviour is considerably worse than that shown in Scope1.



Scope4: this grab shows the same over-drive conditions as Scope 3 but with the BAV21 diode fitted to the circuit. Notice that the clipping behaviour is considerably improved, with no trace of the "sticking" condition previously evident.

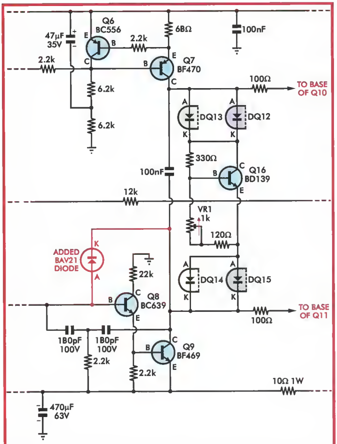


Fig.1: reproduced from the July 2011 issue, this section of the main circuit diagram shows the simple modification to cure the overload distortion problem. Solder in just one low-cost diode and it's done!

simply a clipped sinewave but is quite severe on the negative excursions of the signal, whereby the overload "sticks" and takes a significant time (about 5 or 6 microseconds), for the amplifier to resume linear operation. It is more noticeable with a 10kHz signal because the amplifier recovery time is relatively longer with respect to the 100µs period.

Each of the scope grabs 1 & 3 shows the badly clipped and distorted sinewave as the yellow upper trace while the lower (blue) trace shows the resultant harmonic distortion; not pretty.

Scope grabs 2 & 4 show the same signal over-drive conditions at 1kHz and 10kHz but now the signal diode has been added to the circuit and the clipping behaviour is much more benign with no tendency of the overload to "stick". In both cases, the harmonic distortion is about the same, at something less than 5%; not good but much more acceptable.

Harmonic distortion graphs

Not being satisfied in verifying that the "cure" was effective, we then took the trouble to measure total harmonic distortion with and without the diode fitted. So first, we tested just the Ultra-LD Mk.3 amplifier module, as installed in the integrated stereo amplifier featured earlier this year.

We took graphs for THD versus power and THD versus frequency at 1kHz & 100W into an 8-ohm load, thus duplicating the tests shown in Fig.1 on page 32 and Fig.3 on page 33 of the July 2011 issue of SILICON CHIP. So our recent test results are very similar to those in July 2011.

We then repeated the tests with the diode fitted and again, the results are virtually identical. The blue trace of Fig.2 below shows the unmodified amplifier while the red trace shows the modified circuit, with diode.

Baker clamp diode

So what causes this asymmetrical overload problem in the Ultra-LD amplifier?

It occurs in the voltage amplifier stage (VAS) involving Q8 & Q9. We have reproduced the relevant part of the circuit in Fig.1.

In effect, Q8 is an emitter follower (with slightly less than unity gain) followed by Q9 which is a common emitter amplifier with a constant current collector load provided by the current mirror comprising Q6 & Q7. Q9 provides virtually all the voltage gain of the amplifier and its collector voltage must swing over a range of about 95V when maximum power is being delivered.

It is on the negative swings of the drive signal that Q9 runs into trouble because its collector needs to swing as low as possible, almost into saturation.

All goes well until the amplifier is over-driven, in which case, Q9 is driven well into saturation and then it has a significant delay when coming out of saturation.

The way to prevent Q9 from being driven deep into saturation is with the addition of a Baker clamp diode; named after Richard H. Baker who described this generic circuit in 1956.

The idea of the diode is to prevent the saturation voltage of the transistor from being less than the diode's forward voltage. In this particular case, the diode, D3, is connected between the base of Q8 and the collector of Q9.

In normal operation, the base voltage of Q8 sits within about a volt or so of the negative supply rail (ie, at around -56V) while the collector of Q9 swings around 0V, at anywhere between say, ±45V, depending on how hard the amplifier is being driven.

In effect then, the added diode is always reverse-biased

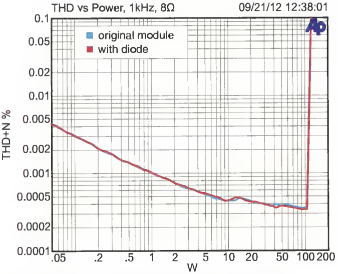


Fig.1: these curves show total harmonic distortion versus power into an 8-ohm load at 1kHz with and without the BAV21 diode fitted. As you can see, the two curves are virtually identical.

and for all intents and purposes, is not "in the circuit".

However, when the amplifier is being driven into clipping, the base voltage of Q8 is more than 1.2V (ie, 1.2V is the sum of the base-emitter voltages of Q8 and Q9) and it will actually be higher than the collector voltage of Q9, because Q9 is almost saturated.

In this case, D3 is forward-biased and it conducts to reduce the base current drive into Q8 and Q9. In so doing, it limits the amount of over-drive in Q9. Or to put another way, it reduces the gain of the VAS for negative signal excursions when over-driven.

All of which is confirmed in the actual behaviour of the Ultra-LD circuit when diode D3 is added. The distortion graphs essentially tell us that diode D3 has no effect on performance when the amplifier is not being over-driven and clearly does have a beneficial effect when over-drive into clipping is occurring.

Adding the diode

The added diode is a small signal type and it should have a PIV rating of 100V or more. Doug Ford suggested a BAV21 and we concur. These are available from element14 and Rockby Electronics and have a PIV rating of 200V. However, connecting it into circuit is a little tricky because you need to gain access to the base of Q8 and the collector of Q9.

If the amplifier module needs to remain in situ, you can solder the anode of the diode to the zero ohm resistor which is connected to the base of Q8, while the diode's cathode is soldered to the exposed and vacant solder pad for the collector of Q9 (pin 2). One of our photos shows the details.

Alternatively, if you are assembling a new module and have access to the underside of the PCB, you can simply solder the diode directly between the base of Q8 and the collector of Q9.

By the way, this modification can also be applied to the earlier versions of the Ultra-LD amplifier and the same improvement will be obtained. Will you hear the difference? Probably not, unless you habitually over-drive your system.

But you can rest assured in the knowledge that it is "better". SC

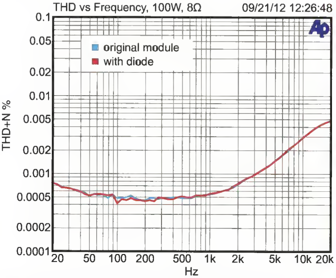
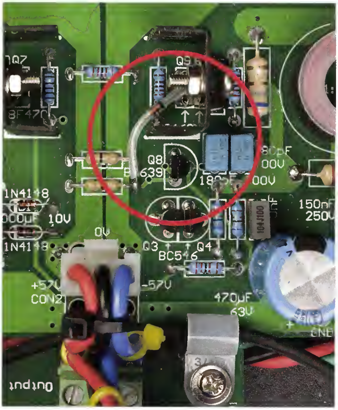


Fig.2: similarly, these curves show total harmonic distortion versus frequency at 100W into an 8-ohm load – again, with and without the BAV21 diode fitted. The curves are again virtually identical.

Two ways of achieving the same result: if you can access the back of the PCB, the BAV21 diode can be soldered direct to the pads for Q8's base and Q9's collector (diode cathode to Q9) as shown above. If it is too difficult to get the board out, you can solder the diode in as shown below. In this case, insulate the leads with short lengths of spaghetti.



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