An 'ultra-fidelity' power amplifier

Part 3
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Part 1 of this series of articles, published in the June '86 issue, dealt with the basic theory of operation of the new power amplifier circuit. In Part 2, published in the July issue, the construction of the power amplifier module was described in detail. This article firstly deals with the specifications of the power amp module, how they are measured and how the measurements should be interpreted, then discusses some aspects associated with the circuitry and construction of an appropriate power supply.

IN PART 1 of this series of articles I stated that the philosophy behind the design of the AEM6000 power amplifier was to provide excellent subjective and objective performance. The accent on the subjective performance is necessary because it is now widely recognised that the conventional objective measurement techniques do not adequately characterise the differences between the various power amplifier designs.

The essential point is that power amplifiers with apparently very similar objective performance as determined by the conventional measurement techniques can sound significantly different. It appears that either our perception of things like total harmonic distortion and frequency response (both of which are usually measured using sine waves) is much more highly developed than we think, or there are other types of distortion mechanisms occurring which are not measured using conventional techniques.

I think that most audio engineers would hold the opinion that the latter is probably the more likely explanation. On the surface it would appear that the conventional techniques are fairly naive, although this may be only partially true, particularly when the techniques are expanded or enhanced. An interesting example of this relates to a type of "dynamic" distortion which was originally known as TIM (transient intermodulation distortion), but now tends to come under the general heading of SID (slew-induced distortion). This type of distortion is produced when the slope of the signal to be amplified approaches the slew rate of the amplifier. The slew rate is defined as the maximum rate of change of output voltage of which the amplifier is capable.

Obviously, a measurement of the amplifier slew rate will provide some information regarding the likelyhood of SID occurring. In fact the best way to overcome the possibility of SID occurring is to design the power amp with good slew rate figures and then to limit the maximum possible signal slope by use of a simple RC low-pass filter set at a frequency well above the audio pass-band. One way of measuring SID is to carry out standard THD measurements but at very high frequencies say at around 50kHz or 100kHz. So here is an example where a "dynamic" distortion mechanism can be detected and measured using static techniques. This is not always the case, ofcourse, and it is possible that many distortion mechanisms exist which simply do not respond to static measurements.

Even though the standard specifications of a power amp do not entirely reflect the resulting sound quality characteristics, the objective performance of an amplifier is an important first step in evaluating the success of the design.

I have listed the measured specifications for the prototype amplifier in Table 1 here. These are supplemented by a ser-

TABLE 1.
SPECIFICATIONS: AEM6000

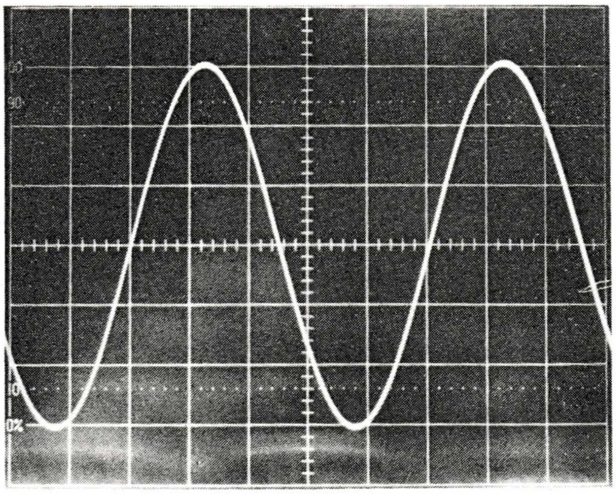
Supply voltage .... 50 – 0 – 50 to 75 – 0 – 75 volts dc.
Power consumption .... <300 mA at idle.
Output power 50 – 0 – 50 supply .... >100 W into 8 ohms
>150 W into 4 ohms
75 – 0 – 75 supply .... >240 W into 8 ohms
>360 W inot 4 ohms
(Output is measured using a continuous sine wave ("RMS"))
Damping Factor .... >300 (100 Hz 8 ohms)
>300 (1 kHz 8 ohms)
>100 (10 kHz 8 ohms)
Frequency response (determined by passive input filters only)

Optional input capacitor	**+ Fitted.**	**Not fitted.**
+0 -0.1 dB	<20 Hz to >25 kHz	dc to >25 kHz
+0 -0.5 dB	<10 Hz to >48 kHz	dc to >48 kHz
+0 -3 dB	<4 Hz to >130 kHz	dc to >130 kHz

Total Harmonic Distortion 8 ohm load.

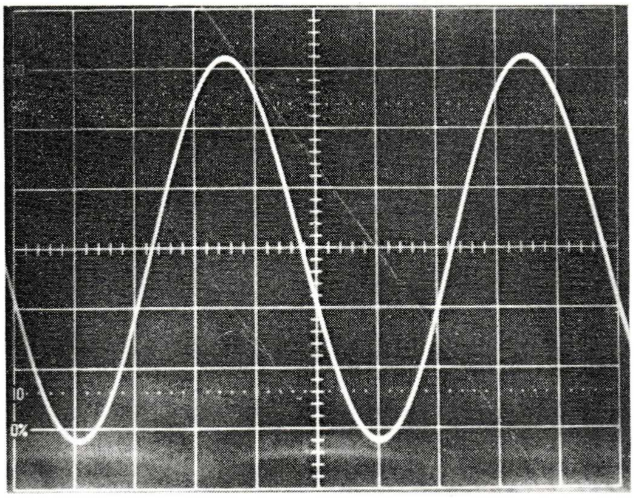
Frequency	1 W	10 W	100 W	200 W
100 Hz	<0.005%	<0.005%	<0.005%	<0.005%
1 kHz	<0.005%	<0.005%	<0.005%	<0.005%
10 kHz	<0.006%	<0,006%	<0.006%	<0.006%

Signal-to-noise ratio
(re full power output
with a 200 ohm source impedance connected)
400 Hz – 20 kHz noise bandwidth .... >118 dB A-weighted
20 Hz – 20 kHz noise bandwidth .... >105 dB A-weighted
Total equivalent input noise
20 Hz – 20 kHz noise bandwidth .... <5.3 μV A-weighted
i.e: <103 dBm A-weighted
Slew rate (input filter removed) .... > 60 V[usec



X = 0.2 msec/div, Y = 20 V/div; 1 kHz full power sine wave.

This CRO photograph shows the amplifier's output when driven by a 1 kHz sine wave at just below full power (around 220 W into an 8 ohm load).



X = 20 usec/div, Y = 20 V/div; 10 kHz full power sine wave.

Showing a 10 kHz sine wave with the amplifier driven to full power output (around 220 W into an 8 ohm load).

ies of CRO photographs which are helpful in establishing the performance of the amplifier under a variety of operating conditions.

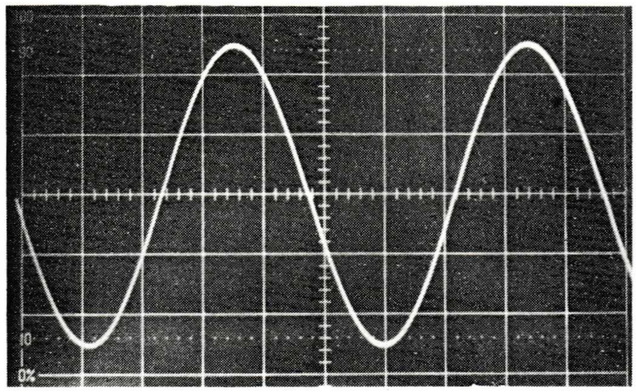
Power supplies

One crucial area that affects both the objective and the subjective performance of the amplifier is its power supply. Many otherwise good power amplifier designs are ruined by inadequate power supplies which often represent too high a source impedance to the supply rails of the circuit. In this design I elected to provide independent power supplies for the two channels. This helps to ensure good individual channel performance and facilitates the provision of high current supplies using commonly available components. Many commercial manufacturers of power amplifiers place great importance on the ability of the power amp to source very large currents. It should be remembered, however, that the amount of current that the power amp will be called upon to deliver is determined by its maximum output voltage and the impedance of the load.

Most of the enormous current supply ability of some power amps can never be used as long as 8 ohm, or even 4 ohm, loads are connected to them. I believe that the dominant reason for the subjective improvement in sound quality that results from this design approach is due primarily to the improved power supply regulation.

The dc power supply rails of all power amplifiers are modulated by the output signal and by 100 Hz hum if a full-wave bridge rectififer has been used in a stabilized power supply. This modulation of the power supply is often coupled into the signal path within the power amp by various parts of the circuit which attach directly to the rails. This power supply interaction can often seriously degrade the performance of the power amplifier. The ability of a power amp design to reject the supply signals is sometimes referred to as the power supply rejection ratio (PSRR) and is a very important, although infrequently measured or stated parameter of a design.

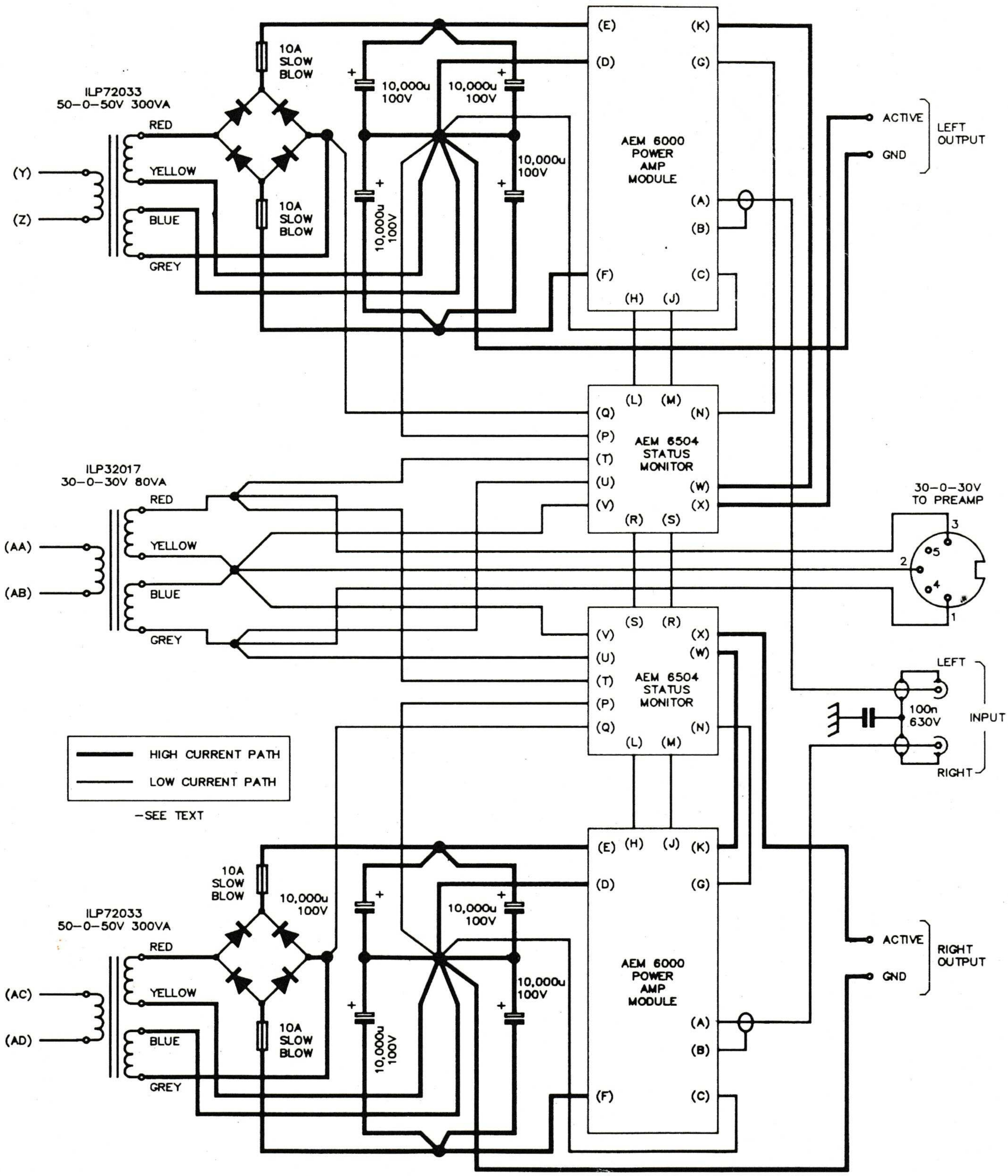
The AEM6000 power amplifier module has benn specifically designed to maximize the PSRR through the use of fully differential circuitry and through a careful design approach which enables successive stages within the power amp to cancel the power supply injected signals inserted from previous stages. This design approach decreases the dependence of the amp on the power supply regulation although good regulation is still an advantage. This is one of the factors which contributes to the excellent subjective performance of this design.



X = 2 usec/div, Y = 20 V/div; 100 kHz full power sine wave.

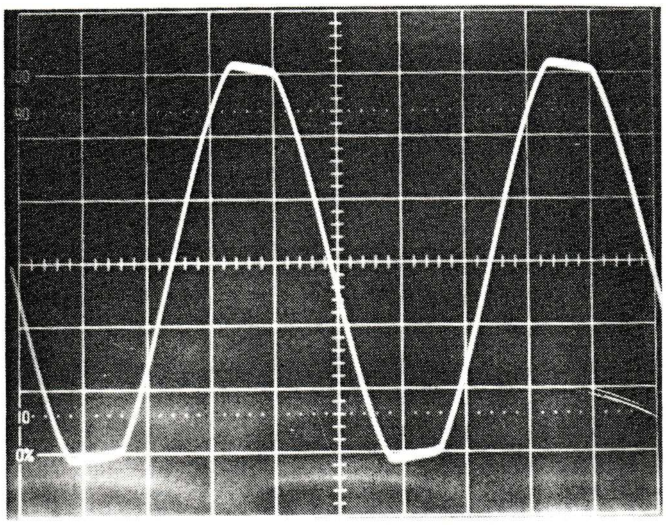
Output of the power amplifier when driven by a 100 kHz sine wave with the same input amplitude as that used for the 10 kHz and 1 kHz photographs. Notice that the amplitude here has decreased. This is due to the passive RC low-pass filter fitted to the input of the power amp. The maximum signal slope of this sine wave is around 33 V/usec which occurs at the zero crossing of the waveform. The ability of the power amp to reproduce such a high frequency sine wave cleanly is a result of its excellent slew rate performance of around 60 V/usec.

The power supply recommended for use with the 6000 is a fairly conventional one featuring a pair of low-impedance toroidal power transformers rated at 50 – 0 – 50 V and 300 VA. An important point often misunderstood about trans- ▶



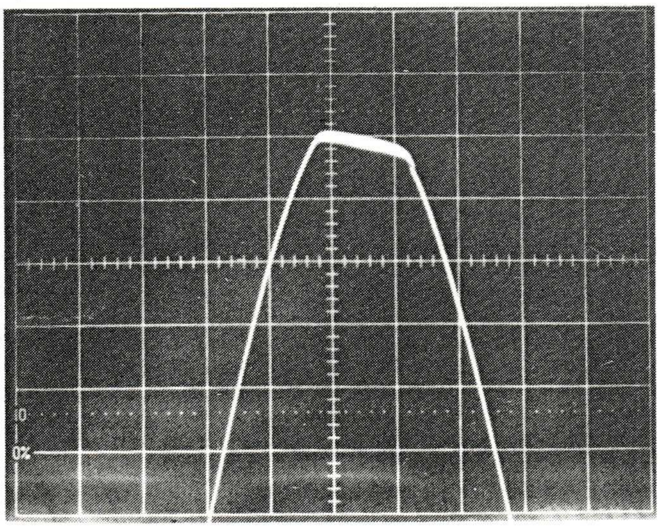
former VA ratings is that this rating does not represent the maxiumum amount of power that can be pulled from the transformer. Most transformer maufacturers use the VA rating of the transformer to represent the power at which the output voltage of the transformer has dropped 5% below its no-load voltage. Considerably more power can be drawn from the transformer, although at the expense of lower output voltage. For many power transformers, the relationship between the secondary voltage and the power pulled remains approximately linear well beyond the rated VA. A 300 VA transformer, for example, is quite capable of delivering 600 VA, albeit with a consequently decreased secondary voltage.

The transformer secondary is connected to a high current bridge rectifier and then to the main electrolytic filter capa-



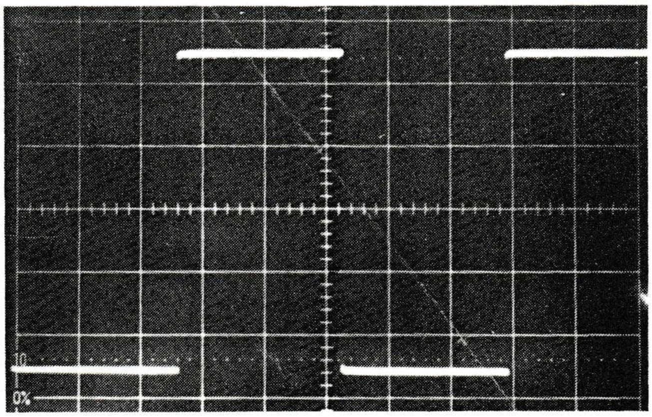
X = 0.2 msec/div, Y = 20 V/div; 1 kHz full power sine wave, driven into overload (clipping).

This photograph shows the resulting waveform when the output of the power amplifier is driven hard into clipping with a 1 kHz sine wave. The slightly sloping, clipped peaks of the waveform are due to the power supply used during the prototyping of the power amp which employed only a single pair of 10 000 uF capacitors. Clipping occurs at aproximately 62 V which is equivalent to around 240 W "RMS" into an 8 ohm resistive load.



X = 5 usec/div, Y = 1 V/div; overload recovery.

This shows a close up of the output waveform that results when the amp is driven hard into clipping using a 2 kHz full power sine wave. Note that the power amplifier goes into and comes out of overload quickly and with no sign of oscillation or instability. The thickening of the top of the waveform is a result of hum on the power supply rails and is normal. The slight glitch that is evident as the power amp comes out of clipping results from the fact that during the overload the negative feedback loop of the power amp is also overloaded, being driven hard against the opposite rail in an attempt to overcome the non-linearity caused by the overload.



X = 2 msec/div, Y = 2 V/div; 100 Hz square wave.

This photograph shows a 10 Vp-p square wave on the output of the power amp at a frequency of 100 Hz with an 8 ohm resistive load. Notice that the top and bottom of the waveform are flat and do not show the usual downward slope associated with most 100 Hz square wave tests. This results from the fact that this amp employs a dc-coupled feedback loop and input stage. If the optional input capacitor is used, a slight downward slope will be introduced. This in itself does not represent a fault and the addition of a good quality capacitor to the input of the power amp is unlikely to degrade performance.

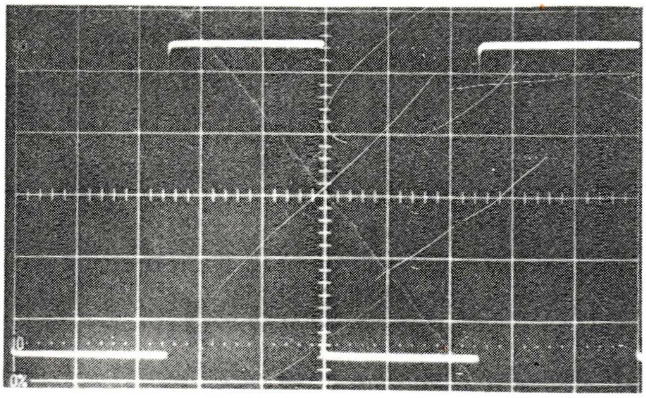
citors. Obtaining good quality large-value high-voltage electrolytic capacitors can be difficult. There are some excellent units manufactured by Siemens rated at 33 000 μF available, but unfortunately these are rated at 63 V and therefore unsuitable for use with the 6000 power amp module when the 70 V rail is employed. These capacitors would be perfect if you are constructing the module in the 100 W version and are therefore using the 50 V rail.

The power supply filter capacitors used in the prototype power amplifier are again Siemens types, rated at 10 000 μF[100 V. In order to achieve sufficient capacity, four of these capacitors must be used for each channel. Some other makes are also available, such as Elna types which are also rated at 10 000 μF[100 V rating. Unfortunately, it seems quite difficult to obtain anything substantially bigger than this at the present time.

A circuit diagram for the recommended power supply is included here. Construction details of the power supply for application in the AEM6000 Ultra-fidelty Stereo Power Amp will be included with next month's article, although it is not complicated and should be able to be constructed by experienced builders.

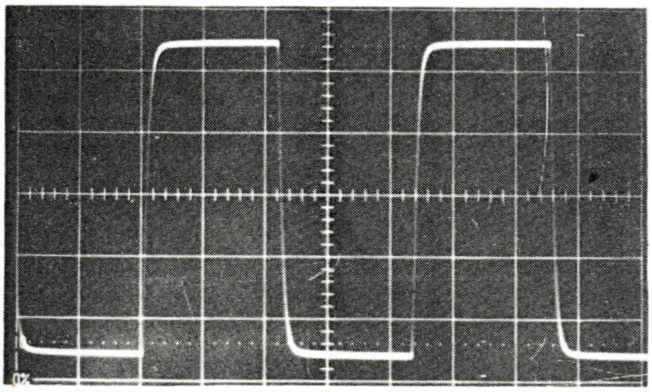
One of the most important points to be considered is the type of hookup cable used for the power supply wiring. The common "heavy duty" hookup wire (24 × 0.2 mm) is not sufficient for this purpose. Use at least the 32 × 0.2 mm plastic insulated wire but preferably, something even heavier. Heavy duty automotive cable can be used or alternatively, use lengths of one of the low resistance audio cables. In the prototype unit I used Monster Cable (Monster Cable is a registered trademark of Monster Cable Products Inc., distributed in Australia by Convoy International Pty Ltd), which is sold through various hi-fi outlets.

The cable I used comes in a figure-8 cross-section but it is easily split and used for the wiring between the bridge rectifier and the filter capacitors, and then from the filter capacitors to the MOSFET power amplifier stages. The total im- ▶



X = 0.2 msec/div, Y = 2 V/div; 1 kHz square wave.

This photograph shows the output at 10 Vp-p into an 8 ohm resistive load with a 1 kHz square input. Notice that the leading and trailing edges of the waveform are free of ringing which might otherwise indicate instability.



X = 20 usec/div, Y = 2 V/div; 10 kHz square wave.

Again, output at 10 Vp-p into an 8 ohm resistive load, but driven at 10 kHz this time. The slightly rounded leading and trailing edges are due to the band limiting introduced by the input RC filter which attenuates very high-frequency Fourier components well in excess of 20 kHz, which are necessary for fast leading and trailing edges. Since the human ear is a low-pass filter also and will not respond to frequencies well beyond 20 kHz, the absence of these harmonics has no audible effect on the performance of the power amplifier. In fact, if the input filter is removed, the possibility exists that the power amp can be driven into slew-induced distortion which will seriously degrade its acoustic performance. The purpose of the input filter is to limit the maximum possible signal slope so that it cannot approach the slew rate of the power amplifier circuitry. The curve shown here is a perfect band-limited square wave .

pedance from the power amp modules back to the main filter capacitors must be kept as low as possible. The distortion performance of the power amplifier will be seriously degraded if the impedance in this wiring is not kept to a minimum.

In next month's article the remainder of the construction details for the AEM6000 'Ultra-fidelty' Stereo Power Amplifier will be discussed. We have arranged for the manufacture of a high quality diecast front panel heatsink for use with the amp and we will be describing the construction of the associated chassis, 240 V wiring, standby power-on circuit and surge current limiter.