

A Technical Guide to High Current Capability Amplification

In 1977 we completed a long-term investigation of existing solid state amplifier design, and concluded that some new directions were needed. Early solid state designers, for the most part, had become fascinated with the ease with which large values of overall feedback could be applied to solid state circuits. They concentrated on reducing harmonic distortion to the exclusion of all else. Designs based on such excessive and obsessive use of feedback tended to measure well on standard distortion tests but they generally exhibited a harsh, irritating sound quality that detractors dubbed the transistor sound, even though it had nothing to do with the use of transistors themselves.

At Harman Kardon we had been using sophisticated arrangements of local feedback loops with overall loops in our last tube amplifiers of the middle sixties, and we applied the technology to solid state. We reduced overall feedback to below 25dB – as compared to 60dB and more in competing products – and noted substantial improvements in sound quality. Our design techniques were almost immediately copied by esoteric manufacturers, and low feedback became the audiophile standard.

Meanwhile, we discovered another key element in improving overall sound quality that is providing the amplifier with a high current capability. A few premium-priced Class A designs available had previously achieved high current output as available in products of Class A operation. We found from our research and listening experiments that high current itself was actually more significant than Class A operation in determining sound quality.

At the same time we became aware of the work of Dr. Matti Otala, a Finnish professor of electrical engineering who demonstrated that ordinary loudspeakers imposed short-term current demands that were not met by existing designs. Dr. Otala's research confirmed our own findings, and eventually we hired him to assist us in designing a new generation of power amplifiers with power supplies and output stages equal to the task of driving real world loudspeaker loads. The Citation XX, introduced in 1980, was our first high current amplifier. Every subsequent design, including the amplifier sections of our lowest powered AV receivers, has had exceptional current capability in relation to its nominal power rating.

In 1987 we introduced our high voltage, high current power amplifiers which utilized new transformer technology to mate the amplifiers optimally to different loudspeaker loads. High current amplifiers impose considerable stress on their own power transformers when forced to operate continuously into low impedance loudspeaker loads. By making the power supply voltage to the output devices switchable, current flow through the outputs is reduced without damping or loss of dynamics. An amplifier with switchable power supply voltage will put the same or greater power into 4 Ohms as into 8 Ohms, and with absolutely no increase in distortion. In our view, it is an extremely sensible way to design a power amplifier.

High current capability as a design criterion is only applicable to power amplifiers. CD players, tuners and cassette decks are never required to put out significant amounts of electrical current however, amplifiers are. All Harman Kardon power amplifier circuits, including those in our receivers, are designed to deliver high continuous current in relation to their nominal rated power.

To understand the importance of high current, we must examine what an audio power amplifier does in relation to a loudspeaker.

In a physical sense, an amplifier performs work – it does not simply transit information. It provides a source of alternating current for an AC motor that motor being the loudspeaker itself. The fluctuations in current comprise the audio signal.

The loudspeaker itself makes physical movements in order to energize the air in the listening space, and the force of those movements is a function of the electrical current presented to the speaker by the amplifier.

Wattage, the electrical measurement specified for amplifiers in standard ratings, consists of current times voltage, or Amperes times Volts. Loudspeakers in general, with the exception of the piezo type and electrostatic, are current devices – that is, their output is proportional to current flow through the voice coil circuit, not to voltage. Voltage is only important for overcoming the resistance both of the connecting wire and the voice coil, and for ensuring current flow. Actual current delivery is what really counts.

Most solid state amplifiers produced today are more or less constant voltage devices which will maintain constant signal voltage levels in the face of widely varying loudspeaker impedances, and will vary current flow according to the fluctuating impedance at the loudspeaker terminals – but only up to a point. Their ability to do so is determined by their current capability, which in turn is a function of power supply engineering and storage capacity.

Interestingly, this fact is ignored in the standardized testing of amplifier power. Amplifiers are typically tested into a stable, precise, 8 Ohm resistor, which doesn't closely resemble a loudspeaker impedance at all. An 8 Ohm resistor makes very slight demands for current, and with a 40 Volt output working into it, will permit the generation of 100 Watts of power with less than 3 Amperes of current.

The problem is that we listen to loudspeakers, not resistors. Loudspeakers are typically inefficient devices with numerous electrical and mechanical reactances in addition to the DC resistance of the voice coil circuit. These reactances alternately interfere with current delivery or short the outputs of the amplifier, thereby making tremendous demands on the power supply. The feedback tells the amplifier to attempt to maintain constant voltage and to make such adjustments in current flow as are necessary to do so.

At this point things get interesting. The adjustments in current flow necessary, firstly to overcome the mass of the woofer, the amplifier's own electrical route to ground, and secondly to deal with momentary impedance nulls may require the amplifier to deliver, on a transient basis, six times the current that is required by a perfectly resistive 8 Ohm load. Producing a 100 Watt output into a nominal 8 Ohm dynamic loudspeaker might very well require an instantaneous current capability of 20 Amperes. An especially reactive 4 Ohm loudspeaker requiring a 200 Watt output could impose current requirements on an amplifier in excess of 50 Amperes.

For example, when we designed the Citation XX in 1980, we specified a 100 Ampere peak output as we discovered loudspeakers that would demand this level of current supply at high output levels. Today, even in our entry-level receivers, we engineer current capabilities that far exceed those for competing products.

If the amplifier is unable to supply sufficient current, it cannot properly damp a woofer, and is therefore unable to maintain a level frequency response across the audio spectrum. Since a low current amplifier will not be able to maintain constant voltage either, its output waveform will be distorted.

Most inexpensive amplifiers are prevented from even trying to supply large amounts of current by protection networks, which limit the underrated output circuits just to keep them from overheating.

It is often noted that Harman Kardon's lowest powered receivers sound more dynamic and powerful than competing units with two or three times the rated power. This is because the competing units commonly have less than half the current capability. As with cubic inches in a car engine, there is no substitute for current capability in an amplifier.

At this point, you may ask why every one else is not delivering high current if it is so important. Manufacturers of limited production, high-end audio amplifiers generally do design their equipment for high current operation, but the manufacturers of mass-produced, moderately-priced equipment often do not. High current capability is a function of power supply design and requires large value capacitors and high power transformers, both of which are bulky and expensive. Even with an adequate power supply, high current cannot easily be achieved with an IC output stage. We choose to put our manufacturing cost in our power supplies and in our signal circuitry, while our competitors prefer to buy circuitry for front panel displays and convenience functions. Life presents us all with choices and Harman Kardon have chosen to build components that sound good, rather than appear ostentatious.

As with the design and implementation of wide bandwidth circuits, the use of high current amplifiers is another area where a long-time Harman Kardon philosophy has proven to be more valid than ever in the world of digital audio and multi-channel systems. The system headroom provided by high current amplifiers, and their ability to deal with wide swings in speaker impedance loads and the heavy use of low frequency signals, is critical to the proper playback of movie soundtracks in the home theater setting.

The power supply for a consumer audio component has two functions. It changes the alternating current from the wall socket into direct current and it stores that current at a certain predetermined voltage to supply the transistors in the amplification chain. The energy storage capacity of the power supply is basically determined by the operating voltages and electrical capacitance values of the large filter capacitors, which hold the electrical charge. Pricing increases sharply with both voltage rating and capacitance, and this is often an area where other manufacturers may not invest. However, even the smallest Harman Kardon receivers have capacitor banks rated in the tens of thousands of microfarads.

Another area where others may be tempted to cut corners is in the power transformer, which charges the capacitors. Transformers are rated in Watts (conventionally expressed as Volt/Amperes) and again, the higher the rating, the higher the cost to the manufacturer. Our least costly receivers have power transformers exceeding 100 Volt/Amperes. Incidentally, large transformers and filter capacitors tend to be heavy which can increase shipping costs.

The most costly esoteric amps will have power transformers rated in excess of 1000 Volt/Amperes charging banks of capacitors with cumulative capacitance ratings in the hundreds of thousands of microfarads. There is no question that such supplies represent the preferred approach when final cost is no object. Such a brute force power supply can drive virtually any speaker under most conditions with absolute stability and minimal distortion and the amplifier that possesses such a supply will be able to double power delivery each time the load impedance halves.

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