DSA
Dynamic Sounds Associates

www.dynamicsounds-assoc.com

Product Description

The Dynamic Sounds Associates Amp I

125 watt Solid State Mono-block Class A power amplifier

Realizing his most ambitious design challenge to date, Dynamic Sounds Associates Founder and Principal Designer Douglas Hurlburt has produced the **Amp I**, a solid state mono-block amplifier designed to produce >125 watts of Class A power into 8 ohms.

This is all-JFET/MOSFET design uses DC coupled circuit topology following a source follower input with blocking capacitors to provide a constant input impedance and prevent input DC offsets from damaging speakers. Some of the significant features of this ground-breaking amplifier are:

- The amplifier has no loop feedback to prevent transient intermodulation distortion and to provide a very wide power bandwidth without concern for output phase shifts caused by speaker loading or amplifier time delay.
- The output stage uses 8 of the legendary Hitachi power MOSFETs in a push-pull configuration to achieve >125W of Class A power output into an 8 ohm load.
- Throughput gain:
    - Unbalanced Input – 25dB
    - Balanced Input -- 25dB or 31dB (User selectable)[1]
- The -3dB power bandwidth exceeds 200kHz without overshoot or “ringing”
- Maximum output voltage 100V peak-peak (35 V RMS)[2]
- The amplifier has separate power transformers, power supplies and voltage regulators for the amplifier, driver, and output stages.

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[1] A 6dB attenuator on each leg of the balance input is present to compensate for the additional gain provided by using a balanced input. The use of this attenuator is user selectable when the balanced input is chosen.

[2] This corresponds to 150W into 8 ohms

- There are dedicated AC power input connectors on the back panel for the amplifier and driver power supplies (18gauge) and the output stage high voltage supply (14 gauge).

- The output stage has 0.1F (100,000μF) of total filter capacitance including 80,000μF following the output stage voltage regulator to handle any form of transient signal.

- The power supplies for the amplifier and driver stages have an additional 8000μF of filter capacitance prior to their individual voltage regulators to ensure ripple free amplification and low noise.

- The output stage is configured around two internally mounted heat sink “towers” which are cooled by ultra-low noise fans to provide many years of reliable operation. The replaceable air filters for the tower fans are accessible for the bottom of the amplifier.

- An additional ultra-low noise chassis fan provides air circulation through the chassis to maintain a low internal ambient temperature. The replaceable air filter for this fan is accessible on the back panel of the amplifier.

- The output DC offset voltage and output stage bias current can be monitored from the front panel using a built in volt meter. Provision for adjusting these values is through the top panel.

- The small footprint chassis: 17” (W) x 11”(D) x 18” (H) makes it easy to fit in any audio environment.

- There are large handles permanently mounted on the back panel for moving the amplifier and protecting the back panel connectors. A pair of “lifting handles” is also provided for use in lifting the amplifier from it’s packaging and moving. These can be removed after the amplifier is in a permanent location if desired.

The proof of the design’s genius will, of course, be in the listening -- but be prepared to experience a limitless sense of dynamic expression coupled with a sonic imprint that is natural, sweet and always musical (the signature sound of all DSA components).

For more information, please contact DSA’s Director of Sales and Marketing David Sckolnik at 386-873-2388 or david@dynamicsounds-assoc.com

APPENDIX

DESIGNING FOR CLASS A POWER

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A.1 WHY?

The first question to be asked has to be, "Why design a Class A power amp, are you crazy?" When I embarked on this journey this was the typical response that I received from more than one audiophile—and one well respected designer of audio electronics. The cons seemed to be numerous, including:

- "It's a room heater"
- Heavy transformers and heat sinks
- "You'll need high capacity circuit breakers in your listening room"
- "Why bother, Class AB, and now Class D amps are just so much better (lighter, cooler, more efficient, cheaper, etc.)"
- Very inefficient compared to other approaches

There were many more, but they primarily focused on how hard it is to get Class A done right (i.e., keeping it cool, and not blowing up). There were also some who grudgingly admitted that pros for Class A included:

- Low distortion---especially at the zero voltage crossover point
- Great dynamics and high bandwidth were possible
- Linear power supplies instead of switching power supplies
- Reduced EMI

In spite of the negative comments, I was convinced that the pros outweighed the cons and a big, linear, Class A solid-state power amplifier was what I wanted to design and build[3]. I also believe that the performance of the DSA *Amp I* has not only met all of the initial design goals—it has obliterated them! Yes, it runs warm but does not require a dedicated air conditioning system; it has "explosive dynamics" resulting from a bandwidth that exceeds those of typical power amplifiers by almost an order of magnitude. And, it is capable of painting a sound stage that is rock solid, well defined, and without congestion from the lowest levels to ear shattering volumes.[4]

Now that the DSA *Amp I* has been realized, how was the design—primarily of the output stage—realized, and what—if any—were the tradeoffs that had to be considered? It

[3] The focus for all of the DSA designs has been to use solid-state devices instead of vacuum tubes. I prefer the flexibility that solid-state offers, but I choose to use FET devices instead of bi-polar because their operating mechanisms, and characteristics, are very similar to those of vacuum tubes.

[4] Reading some of the latest audiophile magazines, it would seem that high powered Class A amps are making a comeback.

helps to start with an understanding of how a Class A solid-state power output stage operates since it is the "heart" of the amplifier.

A.2 UNDERSTANDING THE SOLID STATE CLASS A OUTPUT STAGE

For a solid-state power amplifier to operate in the push-pull Class A regime it is required that the output devices never lose bias current. In other words, the "push" and the "pull" devices are always conducting. This ensures that the amplifier is always exerting maximum control over the loudspeaker being driven; but it also implies a low operating efficiency and a large amount of DC power going into heat. A simplified diagram of a solid-state push-pull output stage is shown in **Figure A1**. The drive devices (MOSFETs shown here)[5] have gate-to-source voltages V_{T1} and V_{T2}, with bias currents I_{B1} and I_{B2}, respectively, set by the fixed bias voltage V_B. The loudspeaker presents a particular load resistance (typically a function of frequency) however it has a nominal or specified resistance, R_L, which can be used for analysis purposes. The small resistances[6], R, are used to linearize the changes in bias currents.

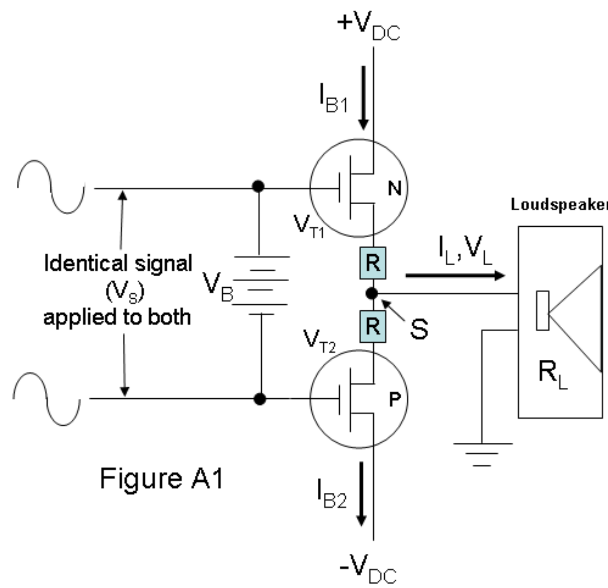

Figure A1

The equations that govern this simple circuit are:

$$I_{B1} - (I_L + I_{B2}) = 0 \quad (1)$$

where the "-" implies that current is leaving the summing junction S. And,

$$V_{T1} + R \bullet I_{B1} + V_{T2} + R \bullet I_{B2} = V_B \quad (2)$$

These can be rewritten as:

$$I_{B1} - I_{B2} = I_L \quad (3)$$

and

$$I_{B1} + I_{B2} = [V_B - (V_{T1} + V_{T2})] / R . \quad (4)$$

In the presence of a signal which changes the currents in the circuit, we have

[5] The same circuit can also employ bi-polar transistors. Typically multiple paralleled output devices of each polarity will be required to handle the necessary power levels for both FETs and bi-polar devices.
[6] Typically small fractions of an Ohm.

$$\Delta I_{B1} - \Delta I_{B2} = \Delta I_L \quad (5)$$

and

$$\Delta I_{B1} + \Delta I_{B2} = - (\Delta V_{T1} + \Delta V_{T2})] / R .$$

With the reasonable first-order assumption that $\Delta V_{T1} \sim -\Delta V_{T2}$, the latter becomes

$$\Delta I_{B1} + \Delta I_{B2} = 0 \ . \quad (6)$$

. Combining equations (5) and (6) gives

$$2 \bullet \Delta I_{B1} = \Delta I_L = -2 \bullet \Delta I_{B2} \quad (7)$$

The limit for Class A operation is where one of the devices no longer has bias current after which the amplifier goes into Class B operation[7], thus the maximum value of ΔI_{B1} is when I_{B2} =0. (Equally, the maximum value of ΔI_{B2} is when I_{B1} = 0.) This bias current, I_{B0}, is the steady-state or "quiescent" bias current. Because the maximum load current for Class A operation is $2 \bullet I_{B0}$, the value of I_{B0} sets the Class A upper power limit for a given load resistance.

A.3 DETERMINING MAXIMUM POWER LEVELS

The power output of an amplifier can be specified in two different ways, and this fact is often used by manufactures to obfuscate the true power levels and whether or not they represent Class A power, Class B power, or some combination of Class A and B, referred to as Class AB.

The two basic (and identical) equations for power level are:

$$\text{Output power} = (V_{L\text{-}RMS})^2 / R_L \quad (8)$$

$$\text{Output power} = (I_{L\text{-}RMS})^2 \bullet R_L \quad (9)$$

The notation "RMS" indicates that the values of load current and voltage are "average" values for a continuous sine wave. (The difference between RMS and peak values is $X_{Peak} = X_{RMS} \bullet 2^{1/2}$, where "X" is voltage or current.) For an amplifier to operate in the Class A mode, equation (9) is appropriate since Class A operation implies that the output devices are conducting current throughout the complete voltage cycle and the bias current is the dominant factor. Consider a Class A amplifier operating at 125W into 8 Ohms. From (9) we have

$$125 = (I_{L\text{-}RMS})^2 \bullet 8 \text{ , or } (I_{L\text{-}RMS})^2 = 15.625$$

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[7] In Class B operation only one of the output devices is conducting current. As to which one, it depends on the direction of the instantaneous voltage waveform.

and $I_{L\text{-}RMS} \sim 4A$. However, this is the so called "RMS" value of I_L. To handle the complete waveform in a Class A mode, it is necessary to look at the peak current which is given by

$$I_{L\text{-}peak} = I_{L\text{-}RMS} \bullet 2^{1/2} = I_{L\text{-}RMS} \bullet 1.414 \sim 5.7A.$$

We have shown previously that the load current is twice the bias current I_{B0}, thus the required value of I_{B0} to provide 5.7A of $I_{L\text{-}peak}$ is ~ 2.85A. To provide some margin at the upper power limit, and to allow for some reduction in bias current with increasing output-stage heat sink temperature, the output-stage of the DSA *Amp I* is biased at a nominal 3A. This corresponds to a nominal maximum Class A power level of 144 W.

The DSA *Amp I* can also provide up to 100V of peak-to-peak output voltage[8] which, using (8) results in

$$100 / (2 \bullet 1.414) \sim 35.4\ V_{RMS} \Rightarrow (35.4)^2 / 8 = 156\ W .$$

Thus, any additional amount of power above 125 W – 144 W will be provided in a Class B mode.

These values imply that the DSA *Amp I* is well "balanced" for driving an 8 Ohm load since the power limits for Class A operation and voltage limited operation are reasonably close.

From an efficiency standpoint, the *Amp I* is relatively inefficient as expected of a Class A amp. While the voltage rails for the output stage are regulated at ± 55VDC, the input voltages to the output stage regulators are ± 65VDC; and, it is this latter, higher voltage that has to be considered in calculating the efficiency. The total DC power dissipated in the output stage---including the regulators—is

$$130\ (V) \bullet 3\ (A) = 390\ W.$$

Hence, at 125W of output power, the *Amp I* is operating at an efficiency of only 32%.

A.4 OPERATION AT OTHER LOAD RESISTANCES

Having knowledge of the DSA *Amp I* output bias current and maximum output voltage, we can now determine Class A and Class B power levels given different load resistances.

- **Using a 4 Ohm load**

Before we can use equations (8) and (9) to analyze the operation of the DSA *Amp I*, we need to look at the required peak current into the load at full output voltage, given by:

$$100 / (2 \bullet 4) = 12.5\ A ,$$

[8] This limit is established in the amplifier-stage and not the driver or output-stages.

However, due to the over current protection in the output-stage voltage regulators (See **Section 4.4.2**), the maximum **average** load current that can be provided by the *Amp I* is ~7 A without activating the protection circuit. Using equation (9), we then have

$$7^2 \bullet 4 \sim 200\text{W}$$

representing the maximum **average** power the *Amp I* can provide to a 4 Ohm load without exceeding the 7A limit controlled by the protection circuit in the output-stage voltage regulators. Nevertheless, since most music consists of a wide range of signal levels and frequencies, the *Amp I* can actually provide a much greater power level into a 4 Ohm load without triggering the protection circuits. This is largely due to the 39,000 μF capacitors that are on the output of the output-stage voltage regulators. These capacitors are a reservoir of charge to support instantaneous current for a few signal cycles to avoid drawing the excess current from the output-stage regulators. The regulators recharge the capacitors between the peaks loads of the output signal.

A detailed simulation was performed of the output-stage and the associated voltage regulators with the protection circuit. This simulation looked at two different **continuous** waveforms[9], a sine wave and a square wave, and at two different output voltage levels as shown in **Table A1**. The purpose was to estimate the time required for the protection

Sine Wave	Square Wave
28 VRMS	78 V p-p
35 VRMS	100 V p-p

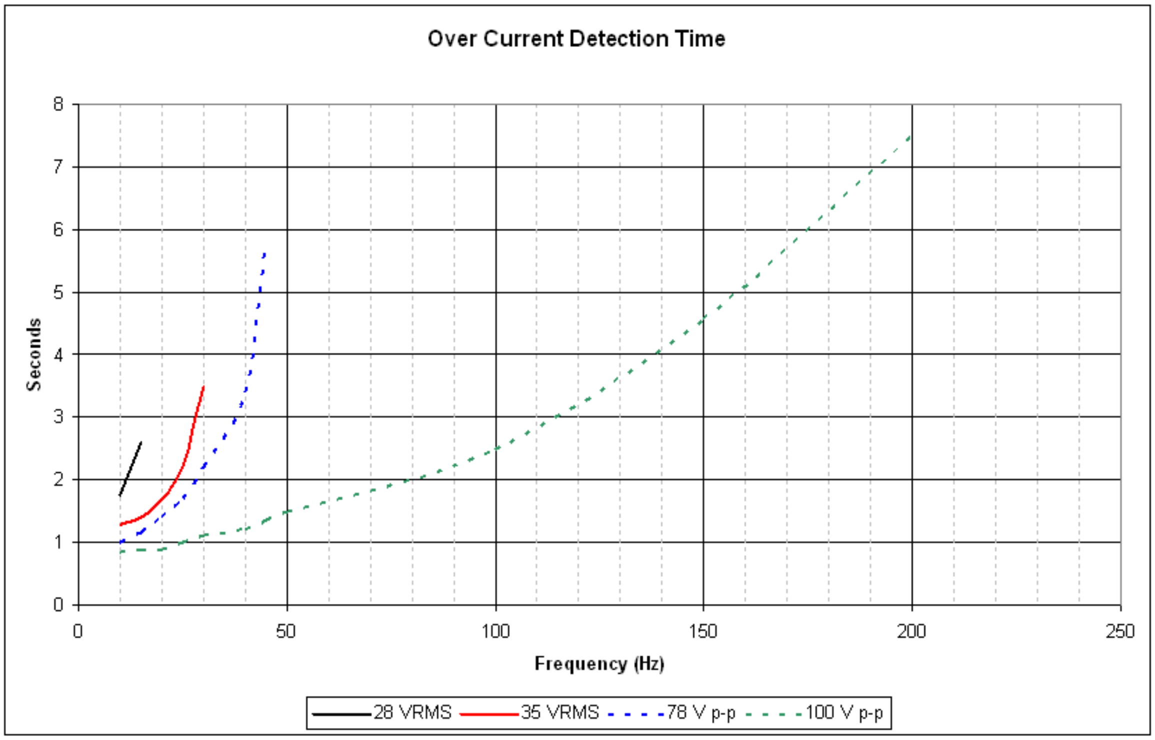
Table A1

circuit to trigger a shutdown as a function of frequency and output voltage when driving a 4 Ohm load. The RMS voltages shown have the same peak-to-peak values as their corresponding square wave voltage values. The reason for looking at both types of waveforms was to show the impact of square waves which have a greater charge draw on the 39,000 μF capacitors than sine waves of the same peak-to-peak voltage. The results are shown in **Figure A2**.

From **Figure A2** we can see that for the case of continuous sine wave signals, even at full output voltage (35 VRMS), the protection circuit will only be tripped at frequencies of 30 Hz, or below and the time for the protection circuit to trip is a strong function of the frequency. A continuous 30 Hz full-amplitude sine wave will take about 3.5 sec before it causes the protection circuit to trip.[10] However, at 10 Hz, it will only take about 1.5 sec due to the greater load the lower frequency places on the output-stage regulators and the

[9] The simulation only considered the case of a continuous signal. The majority of listening material does not involve continuous frequencies, but is a mixture of many frequencies simultaneously—a much less stressful situation.

[10] For continuous frequencies greater than the end point of the curves shown in Figure A2, the protection circuit was not tripped.



39,000µF capacitors. At 28 VRMS, corresponding to 200W output into 4 Ohms, the impact of the protection circuit is minimal and only occurs at frequencies < 15 Hz.

A continuous square wave is much more stressing in terms of output current draw, as can be seen in **Figure A2**. For a 78 V peak-to-peak square wave (corresponding to 28 VRMS for a sine wave), the protection circuit is tripped for frequencies < 45 Hz, and the time before tripping is highly dependent on the frequency. For square waves > 45 Hz, there was

Figure A2

no impact on the protection circuit. When considering a full amplitude square wave the impact is even greater. The protection circuit will trip at frequencies up to 200 Hz; and, at
lower frequencies the protection circuit will trip within a few seconds as the current drain on the output-stage voltage regulators becomes excessive. The good news is that these results represent extreme cases and in actual use the *Amp I* will rarely—if ever—have the protection circuit trip during routine operation.

Since we have seen that most sine wave frequencies have little impact on the *Amp I*, we can use equation (8) to determine the maximum power, based on a sine wave with 100 volts peak-to-peak output voltage (35.4 VRMS). This gives

$$(35.4)^2 / 4 = 310 \text{ W}$$

as the maximum output power into a 4 Ohm load. However, using the DSA *Amp I* bias current values with equation (9), and a 4 Ohm load, we have

$$[(2 \bullet 3A)/1.414]^2 \bullet 4 = 72\ W$$

which represents the Class A output power limit into a 4 Ohm load. Thus, the DSA *Amp I* will switch to Class B operation for output powers greater than 72 W up to its maximum voltage limited power level of 310W into a 4 Ohm load in most cases.[11]

- **Using a 16 Ohm load**

As before, we need to look at the peak current that can be driven into the load, given by:

$$100 / (2 \bullet 16) = 3.125\ A$$

which corresponds to a required bias current of 1.56 A. Since this is less than the bias current of 3 A used in the *Amp I*, the *Amp I* will **always** drive a 16 Ohm load in Class A operation. And, since the peak current is not sufficient to force voltage limiting by the output-stage voltage regulators, the maximum *Amp I* power level is determined solely by the amount of peak voltage available when driving a 16 Ohm load. For this determination we only need equation (8) that gives

$$(35.4)^2 / 16 = 78\ W\ ,$$

which represents the *Amp I* **voltage limited** power into a 16 Ohm load.

A.5 QUO VADIS?

What is next, and what is the art of the possible? It is believed that the basic *Amp I* architecture can be readily expanded to power amplifiers having 200-500W of Class A power. The major challenge in this expansion is the cooling of the output stage. Since the *Amp I* is, and will remain, a mono-block design there exists plenty of room for heat sink expansion to handle the additional power requirements. The use of ultra-low noise fans will continue to be a design feature since it greatly enhances the cooling ability of the heat sinks. Custom made transformers to provide the necessary output stage voltages and currents are readily available. And the high power MOSFETs used in the *Amp I* can be found through several suppliers. The rail voltages for the amplifier and driver stages will need to be increased, but this is also a relatively simple task. The basic designs are not stressed in their current configurations and will easily support higher voltages. The only <u>real</u> question to be answered is how much power is sufficient? There must come a point where power amplifiers in the >1kW (or > 1 HP) category are not required for high quality audio reproduction, but instead are satisfying a basic need for “more is better” without a real audio purpose.

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[11] This represents an example of Class AB operation. The amplifier supports Class A operation to some power level and then transitions smoothly into Class B operation for the peak signal levels.

SPECIFICATIONS

Design Topology	Mono-block Power Amplifier	
Gain stages:	Balanced	
Output Stage:	Push-pull	
AC Voltage	120 VAC (240VAC option)	
Fuse Type and Rating	2 x Buss GMC (20 mm) 1.5 A 2 x Buss GMC (20 mm) 10 A	
Dimensions (with Critical Mass footers)	17” (W) x 14-1/2” (D) x 19” (H)	
Weight	82 lbs	
Connectors		
Input	1- XLR (Balanced), 1- RCA (Unbalanced)	
Output	2-pair binding posts for spade or banana connectors	
Input Impedance (Independent of input):	10k ohm	
Output Impedance (Measured at 1kHz)	0.2 ohms	
Throughput Gain	Unbalanced input: 25dB Balanced input: 25db, 31dB (user selectable)	
Frequency Response (-3dB response)	3Hz – 225kHz	
Output Phase Relative to Input	Non-inverted	
Output Noise (Shorted input)	2mV peak-to-peak (0.7mV RMS) -90dB re 1V RMS input	
Output Stage Compliment	4 x 2SK135 (N-channel MOSFET) 4 x 2SJ50 (P-channel MOSFET)	
Maximum Output Voltage	100 volts peak-to-peak (35.3V RMS)	
THD @ 1kHz	< 1% at max power output	
Maximum Power Output vs. Load (Ohms)	Class A Operation	Class AB Operation
4 Ohms	72 W (current limited)	310 W
8 Ohms	144W (design point)	155 W
16 Ohms	78 W (voltage limited)	N/A