

600W/1000W Full Bandwidth Class D Amplifier



The HCA600ACREF reference design delivers 600W RMS power into a 8Ω load and 1000W into a 4Ω load.

The design is part of the Intersil's Coolaudio™ program that supports customers to achieve a minimum time-to-market for audio end products. As part of this program, this design is offered after execution of a licensing agreement. At that time, Intersil provides to the licensee a documentation package containing: 1) a circuit description, 2) schematics, 3) test and manufacturing information, 4) A bill of materials with all vendors and vendor part numbers, 5) Intersil's engineering support contacts, 6) one evaluation unit.

For more information, visit our web page at <http://www.intersil.com>. For technical assistance, call Central Applications at 1-800-442-7747, or email us at centapp@intersil.com.

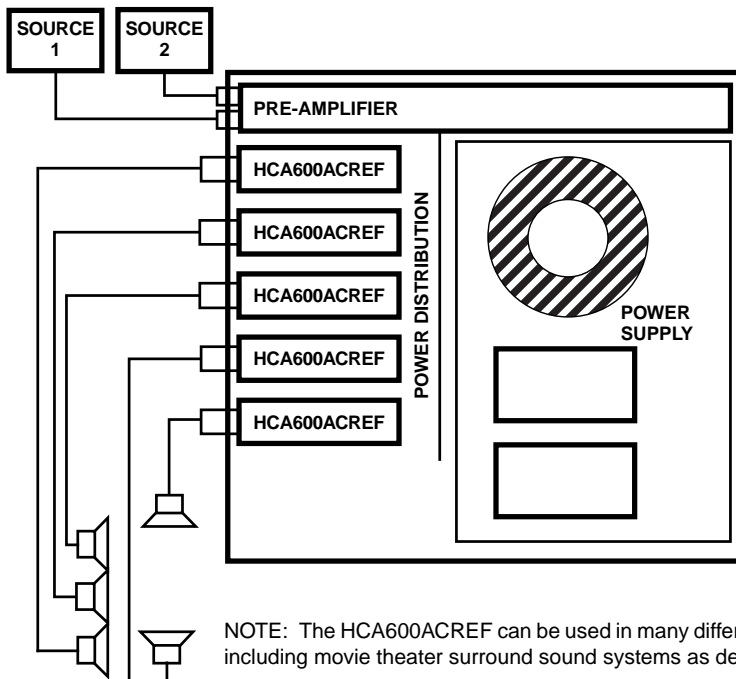
Licensing Information

Contacts for licensing details, reference design evaluation, and general questions are as follows:

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Reference Design Block Diagram



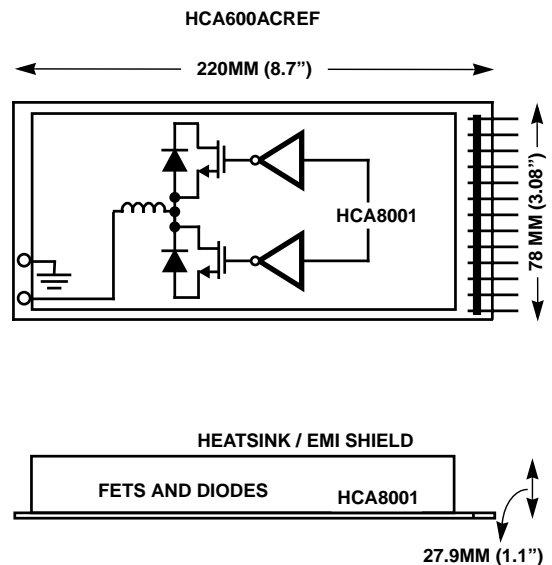
NOTE: The HCA600ACREF can be used in many different commercial and professional applications including movie theater surround sound systems as depicted in this reference design block diagram.

Features

- 600W RMS Power into 8Ω
- 1000W RMS Power into 4Ω
- THD <0.02% at 1kHz and 450W into 8Ω
- SNR >110dB Relative to Full Power
- Output Noise <200μV
- Constant Group Delay
- DC to 80kHz Small Signal Bandwidth
- Power Bandwidth 28kHz
- Slew Rate 18V/μs
- Efficiency >90% at 500W into 8Ω
- Meets FCC and EN55013 Requirements for EMC
- Based On the Intersil HCA8001, Audio Specific IC
- Differential or Single Ended Input
- Over-Current, Over-Voltage and Thermal Protection
- Soft Clipping
- Bridgeable up to 4000W

Applications

- Sound Reinforcement
- Professional and Commercial Sound Systems
- Powered Speakers
- Hi-Fi Stereo



HCA600ACREF

Absolute Maximum Ratings

Bus Voltage, V_{BUS}	$\pm 130V$ (Note 1)
+/-12V	+/-15V
12VFLT	-Bus +15V
Audio Inputs	12V Differential Peak to Peak Voltage

Operating Conditions

Bus Voltage, V_{BUS}	$\pm 110V$
+/-12V	+/-12V
12VFLT	-Bus +12V
Ambient Temperature Range	$0^{\circ}C$ to $50^{\circ}C$

NOTE:

- 1. WARNING: The voltages inside the shield, at the edge connector, and on the speaker cables are potentially deadly. Extreme caution is required.**

CAUTION: Stresses above those listed in "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress only rating and operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied.

Electrical Specifications $R_{LOAD} = 8\Omega$, $V_{BUS} = \pm 110V$, Supply Source Resistance $< 2.5\Omega$, Storage Capacitor $> 12,000\mu F$, 12VFLT = 12V, +/-12V = +/-12V

PARAMETER	SYMBOL	TEST CONDITIONS	$T_A = 25^{\circ}C$	
			TYP	UNITS
SUPPLY SPECIFICATION				
Minimum Bus Voltage	$V_{BUS\ MIN}$	600W into 8Ω	± 110	V
$\pm V_{BUS}$ RMS Current	$I_{V\ BUS}$	1kHz Sine Wave, Full Output Power (8Ω load)	3	A
$\pm V_{BUS}$ RMS Current	$I_{V\ BUS}$	1kHz Sine Wave, Full Output Power (4Ω load)	6	A
$\pm V_{BUS,Q}$ Average Current	$I_{V_{BUS}Q}$	Quiescent Current, No Signal	60	mA
12V Float Current	$I_{12VFLTBIAS}$	Current supplied to power output gate driver circuitry	400	mA
Minimum +/-12V	$V_{BIASmin}$	1kHz Sine Wave, Full Output Power (8Ω load)	11.5	V
$\pm 12V$ Max RMS Current	$I_{+/-15V}$	No input signal	40	mA
Rising Under Voltage Lock Out Voltage	$V_{UV\ Rising}$	Bus voltage that activates the amplifier	± 75	V
Falling Under Voltage Lock Out Voltage	$V_{UV\ Falling}$	Bus voltage that shuts down the amplifier	± 50	V
ENABLE Threshold Voltage	$V_{ENABLE1}$	Amplifier starts at this voltage, input amplifier muted	1	V
ENABLE Threshold Voltage	$V_{ENABLE2}$	Input amplifiers active and entire amplifier active	2	V
ENABLE Internal Source Current	I_{ENABLE}	Internal "Pull Up" Current	25	μA
OUTPUT POWER AND EFFICIENCY				
Maximum Output Power (Note 2)	$P_{MAX8\Omega}$	THD = 1%, 1kHz, $R_{LOAD} = 8\Omega$	600	W
Maximum Output Power (Note 2)	10% THD $_{8\Omega}$	THD = 10%, 1kHz, $R_{LOAD} = 8\Omega$	800	W
Maximum Output Power (Note 2)	$P_{MAX4\Omega}$	THD = 1%, 1kHz, $R_{LOAD} = 4\Omega$	1000	W
Maximum Output Power (Note 2)	10% THD $_{4\Omega}$	THD = 10%, 1kHz, $R_{LOAD} = 4\Omega$	1200	W
Efficiency	P_{MAXEFF}	$P_{OUT} = 200W, 8\Omega$	88	%
	P_{MAXEFF}	$P_{OUT} = 500W, 8\Omega$	95	%
	P_{MAXEFF}	$P_{OUT} = 400W, 4\Omega$	88	%
	P_{MAXEFF}	$P_{OUT} = 1000W, 4\Omega$	90	%
AMPLIFIER PERFORMANCE				
Total Harmonic Distortion + Noise	THD+N	$P_{OUT} = 400W, R_{LOAD} = 8\Omega, 1kHz$	0.015	%
Signal to Noise Ratio	V_{SNR}	Relative to full scale output, 600W into 8Ω	110	dB
Output Noise	V_N		200	μV
Intermodulation Distortion	IMD	SMPTE, 60Hz and 7kHz, 4:1, $R_{LOAD} = 8\Omega$ at 25W Output	0.02	%
PSRR ($\Delta V_{OUT}/\Delta V_{BUS}$)	PSRR	DC	300	$\mu V/V$

HCA600ACREF

Electrical Specifications $R_{LOAD} = 8\Omega$, $V_{BUS} = \pm 110V$, Supply Source Resistance $< 2.5\Omega$, Storage Capacitor $> 12,000\mu F$, $12V_{FLT} = 12V$, $\pm 12V = \pm 12V$ (Continued)

PARAMETER	SYMBOL	TEST CONDITIONS	$T_A = 25^\circ C$	
			TYP	UNITS
PSRR ($\Delta V_{OUT}/\Delta V_{BUS}$)	PSRRac	120Hz	-65	dB
Amplifier Output Offset Voltage	$ V_{OS} $	DC voltage across the speaker, load = 8Ω	2	mV
Amplifier Output Impedance	Z_{OUT}	Measured at 1kHz and 10W Output	16	$m\Omega$
Damping Factor	DF	Measured at 1kHz and 10W Output	500	
ADDITIONAL CHARACTERISTICS				
Cutoff Frequency, Referenced to 1kHz	F_{UPPER8}	-3dB, $R_{LOAD} = 8\Omega$ at 10W Output	80	kHz
Cutoff Frequency, Referenced to 1kHz	F_{UPPER4}	-3dB, $R_{LOAD} = 4\Omega$ at 10W Output	70	kHz
20kHz Response, Referenced to 1kHz	F_R at 20kHz	Output at 20kHz and 10W, $R_{LOAD} = 8\Omega$	-0.5	dB
Power Bandwidth	P_{BW}	Maximum Frequency for Full Power $R_{LOAD} = 8\Omega$	28	kHz
Slew Rate	SR	Maximum rate of change of the output voltage	18	V/ μs
Maximum Switching Ripple on Output	F_{PWM}	Full Output Power, $R_{LOAD} = 8\Omega$	12.0	V
Input Gain	A_V	Either Inverting or non inverting input. Unused input returned to analog ground	26	dB
Input Impedance, Inverting Input	R_{-INPUT}	Differential amplifier input, other input grounded	10	$k\Omega$
Input Impedance, Non Inverting Input	R_{+INPUT}	Differential amplifier input, other input grounded	5	$k\Omega$
Output Signal Phasing	Phasing	Positive going signal on non Inverting input results in negative going amplifier output	180	Degrees
Over Temperature Shut Down	OT_{SD}	Rising temperature to shutdown amplifier. Set by an external thermistor	110	$^\circ C$
Over Temperature Hysteresis	OT_H	Difference between rising and falling temperature shut down and start up points	10	$^\circ C$
Amplifier Output Current Limit	I_L	Absolute Value	25	A
Amplifier Output Current Limit Time (Note 3)	T_{IL}	Time the amplifier must be in current limiting before shutdown	50	ms

NOTES:

2. At this power level, the soft clipping circuitry is beginning to activate. It functions to "round off" peaks rather than hard limit as in most linear amplifiers. This helps to give this amplifier a pleasing sound during limiting. Moreover, this feature also makes the amplifier "sound louder".
3. This time allows the amplifier to reproduce large, sustained peaks without shutting down, yet is adequate to protect the amplifier output from shorted speaker lines.

HCA600ACREF Connector Pin Designations

PIN	DESIGNATION	FUNCTION	WIRE COLOR	SPECIFICATIONS AND COMMENTS
1	Analog Ground	Input Ground	Black (22 Gauge)	Connect to ground of pre-amp or connect to pin 18.
2	Non-Inv Input	Audio Input	Phono	Audio applied to pin 2 does not invert the phase of the signal. Input impedance is 5kΩ.
3	Inv Input	Audio Input	Phono	Pin 3 and 4 are differential inputs. Audio applied to pin 3 inverts the phase of the signal. Input impedance is 10kΩ.
4	Analog Ground	Input Ground	Black (22 Gauge)	
5	Enable	Enable	Green (22 Gauge)	Add capacitance to delay startup or pull low to disable amp.
6	Fan	Controls fan or drives LED indicating over temperature shutdown	Brown (22 Gauge)	Optional
7	CL_OUT	Drives LED to indicate onset of current limit	Grey (22 Gauge)	Optional
8	SFCL_OUT	Drives LED to indicate soft clipping is activated	Blue (22 Gauge)	Optional
9	-12V	- Bias Supply	Purple (22 Gauge)	50mA, -12V ±10%
10	+12V	+ Bias Supply	Orange (22 Gauge)	50mA, +12V ±10%
11	PGND	Power Ground	Black (16 Gauge)	Connect to Star Ground
12	+BUS	Positive Supply	Red (16 Gauge)	For best results use at least 12,000µF, 160V electrolytic capacitor. Limit Bus under no load conditions to 130V.
13	+BUS	Positive Supply	Red (16 Gauge)	
14	PGND	Power Ground	Black (16 Gauge)	
15	-BUS	Negative Supply	White (16 Gauge)	For best results use at least 12,000µF, 160V electrolytic capacitor. Limit Bus under no load conditions to 130V.
16	-BUS	Negative Supply	White (16 Gauge)	
17	+12VFLT	Floating 12V supply (referenced to -Bus)	Yellow (20 Gauge)	500mA, +12V ±10% This signal is referenced to the negative rail (-Bus).
18	PGND	Power Ground	Black (16 Gauge)	

Molex Part Numbers: Header - 26-60-5180, Connector - 09-50-8183, Pins - 08-52-0113

WARNING: Insulate wires. Accidental shorts between +/- Bus and bias supplies will damage the amplifier.

Typical Performance Curves

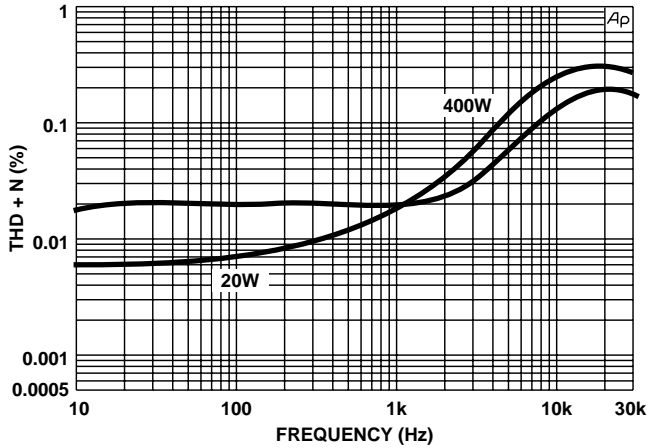


FIGURE 1. THD + N (%) vs FREQUENCY LOAD = 8Ω

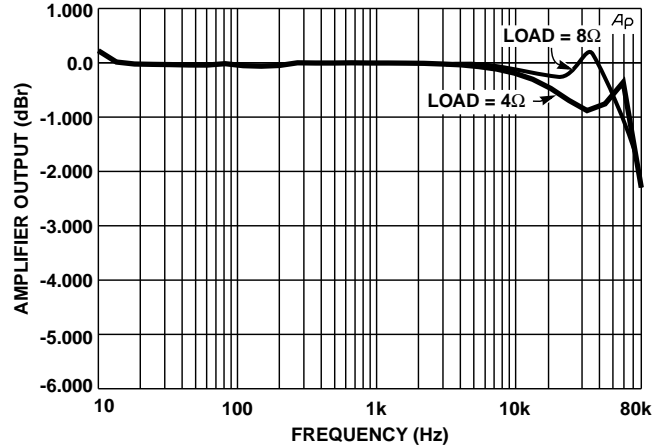


FIGURE 2. AMPLIFIER FREQUENCY RESPONSE
10W - LOAD = 8Ω

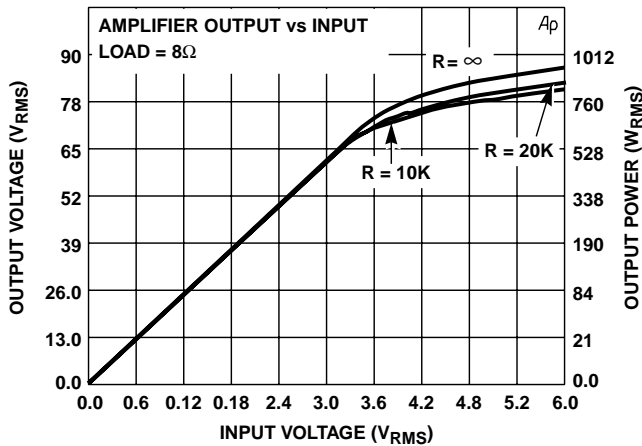


FIGURE 3. AMPLIFIER TRANSFER CHARACTERISTIC WITH
VARIOUS SETTINGS OF SOFT CLIPPING
RESISTOR

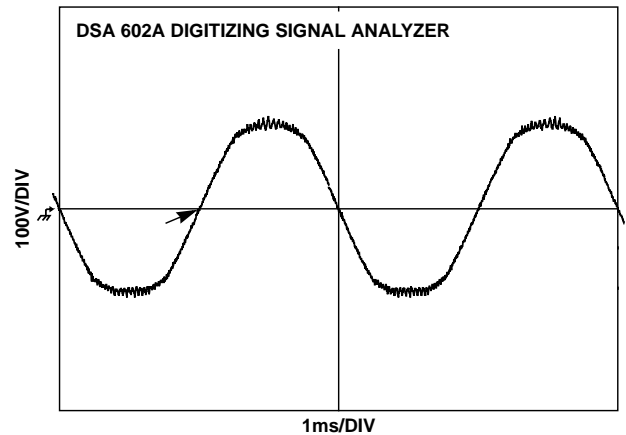


FIGURE 4. OSCILLOSCOPE DISPLAY OF AMPLIFIER
OUTPUT WITH SOFT CLIPPING CIRCUIT
ENABLED

Soft Clipping

Figures 3, 4 and 5 show the effects of the soft clipping circuitry within the amplifier. Figure 3 shows the transfer characteristic of the amplifier for various values of the soft clipping programming resistor. An important aspect of soft clipping is the apparent increase in sound level. As soft clipping is reached, the upper and lower envelop of the sinewave is gradually reduced. This “soft” rounding reduces the higher harmonics that would result if hard clipping as shown in Figure 5 was enabled. Soft clipping also results in an amplifier with a more pleasing sound. Figure 4 shows the rounding of the output with soft clipping, while Figure 5 shows the ampler output without soft clipping.

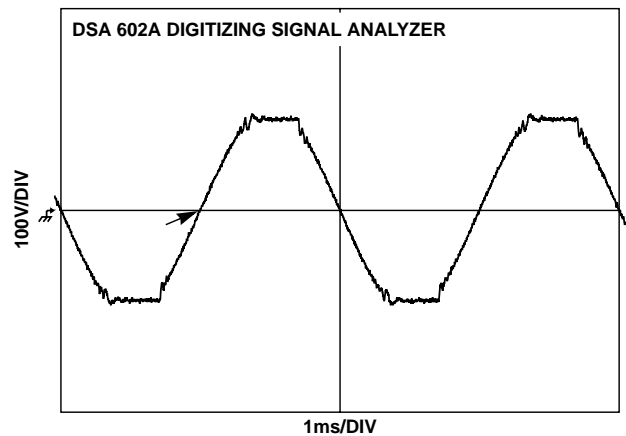
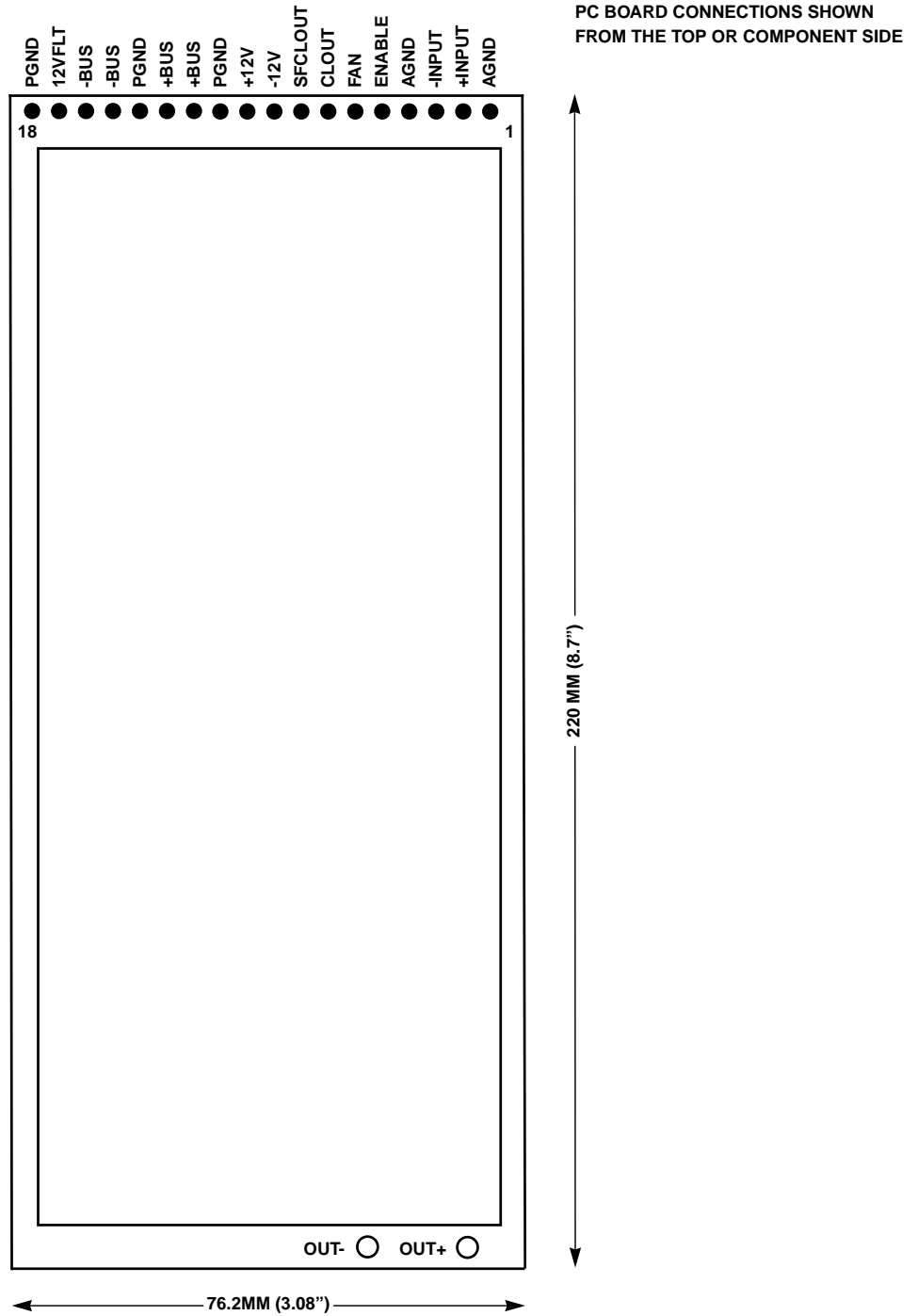


FIGURE 5. OSCILLOSCOPE DISPLAY OF AMPLIFIER
OUTPUT WITH SOFT CLIPPING CIRCUIT
DISABLED

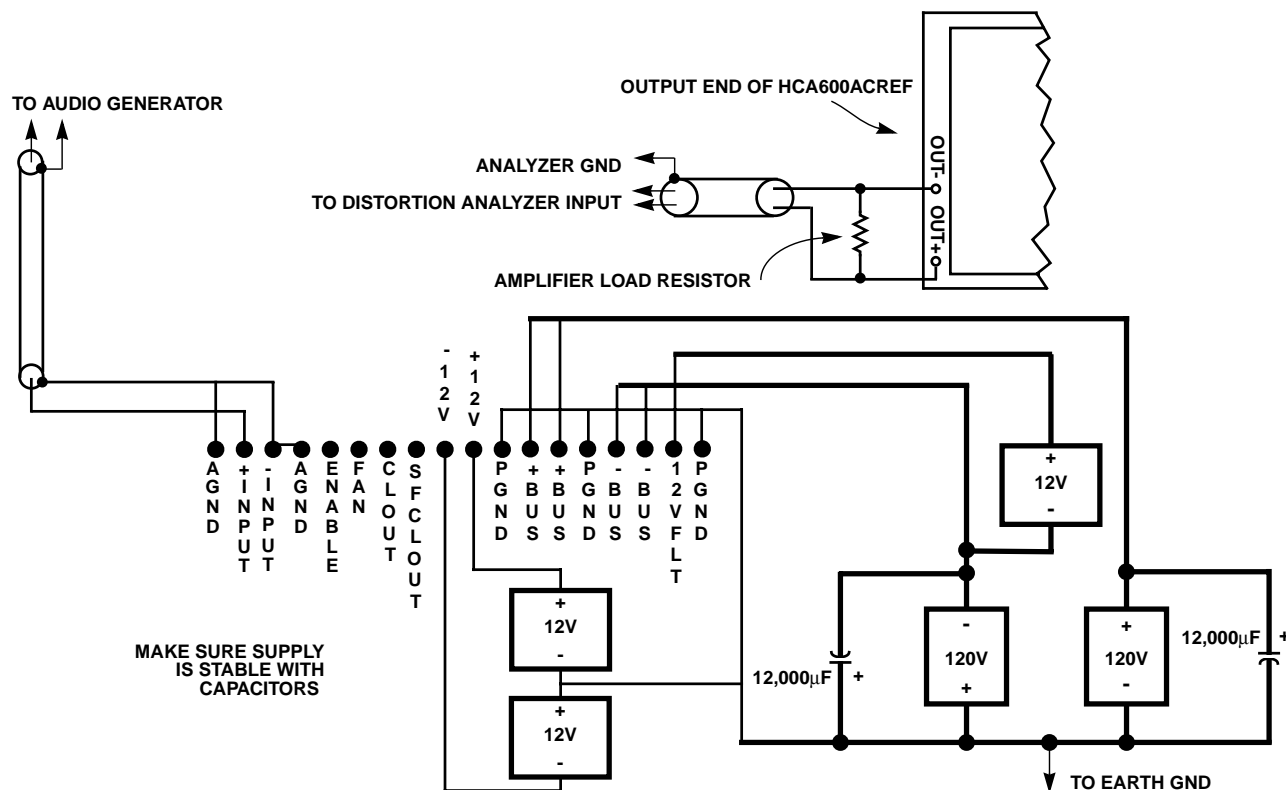
HCA600ACREF

Full Size Outline of HCA600ACREF Board

HCA600ACREFC
TOP VIEW



Schematic Diagram of HCA600ACREF Board Test Setup



CAUTION: Remove all power when inserting or removing the amplifier board. Make sure power supply capacitors are discharged or damage to the amplifier may result.

Board Test Equipment and Test Procedure for Intersil HCA600ACREF Amplifier

Equipment required for evaluation of the Intersil HCA600ACREF Amplifier is as follows:

1. Few bench supplies can deliver the rated voltage and current for this amplifier. Furthermore, most linear bench supplies cannot sink current. If at all possible a 1KVA transformer (92V-0-92V) and rectifier should be used to supply main power. See Figure 6. Bench supplies can be used to provide bias as shown on the next page.
2. Three 12V, 500mA Power Supplies (if transformer with the required secondary windings is not available).
3. Distortion Analyzer such as the Audio Precision System One or System Two or equivalent.
4. Load resistors, 8Ω, 500W and 4Ω, 1000W and a fan.
5. Associated connectors and cables.
6. HCA600ACREF Amplifier Board.

Test Procedure for Evaluation of HCA600ACREF

1. The power supply sequencing is not critical with one exception. The -12V must be applied at the same time or before the +12V. If not, the amp may not start.

Frequency sweeps should be limited between 3Hz and 80kHz at high powers. Amplitude vs. frequency sweeps at full power will not damage the amplifier. Nevertheless, high frequency (>10kHz) high power continuous sine wave testing may result in

a thermal shutdown and in extreme cases failure, so this should be avoided. Music does not contain high frequency high power signals so this is not a concern in real applications.

WARNING: This amp is DC coupled. Do not apply DC to the input. In applications, a DC blocking cap is required in the preamp or between the preamp and the amplifier. For example, a 2.2µF film capacitor between the preamp and the -input will roll the frequency response off at 7Hz (10K input impedance).

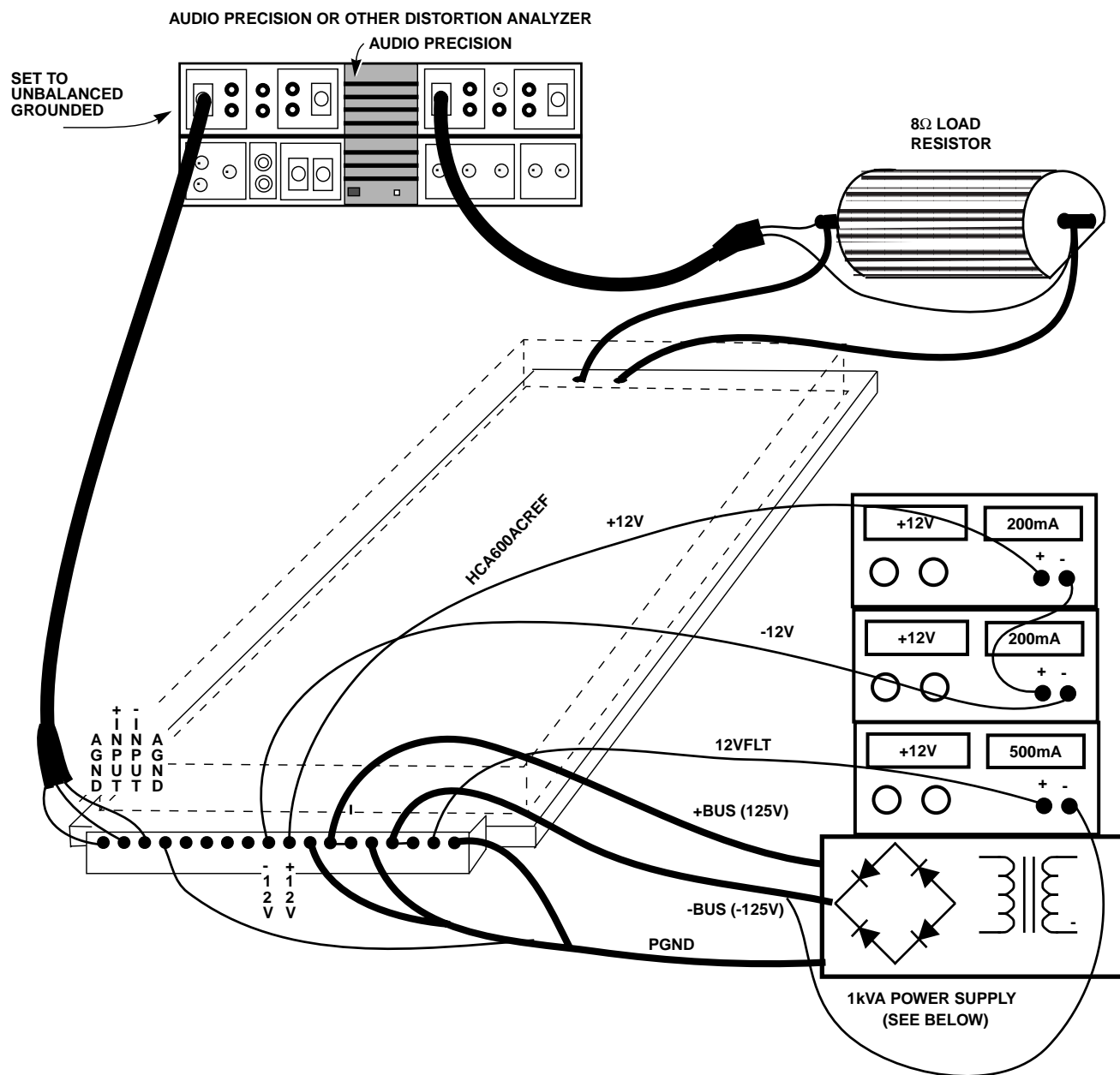
2. THD measurements are not valid if the AP filters are not used. The AP interprets the carrier of a class D amplifier as noise. Filters must be used to remove the carrier. Always make sure that either the 22, 30 or 80kHz filters in the AP are selected. The 80kHz filter does not attenuate the carrier completely, and if it is selected an external 80kHz RC filter should also be used. This filter must use a high quality cap so that it does not contribute to THD. A 10K metal film resistor with a 180pF polypropylene cap does the job well.

If the carrier is visible with a scope on the reading output of the AP, then the AP is including the switching frequency in its THD+ Noise calculations. The number is not valid.

Selecting the 80kHz filter and using a single pole external 80kHz low pass filter allows the 2nd, 3rd and 4th harmonics of a 20kHz signal to be observed.

The external RC filter should also be used when measuring IMD and CCIF.

Block Diagram of HCA600ACREF Test Setup

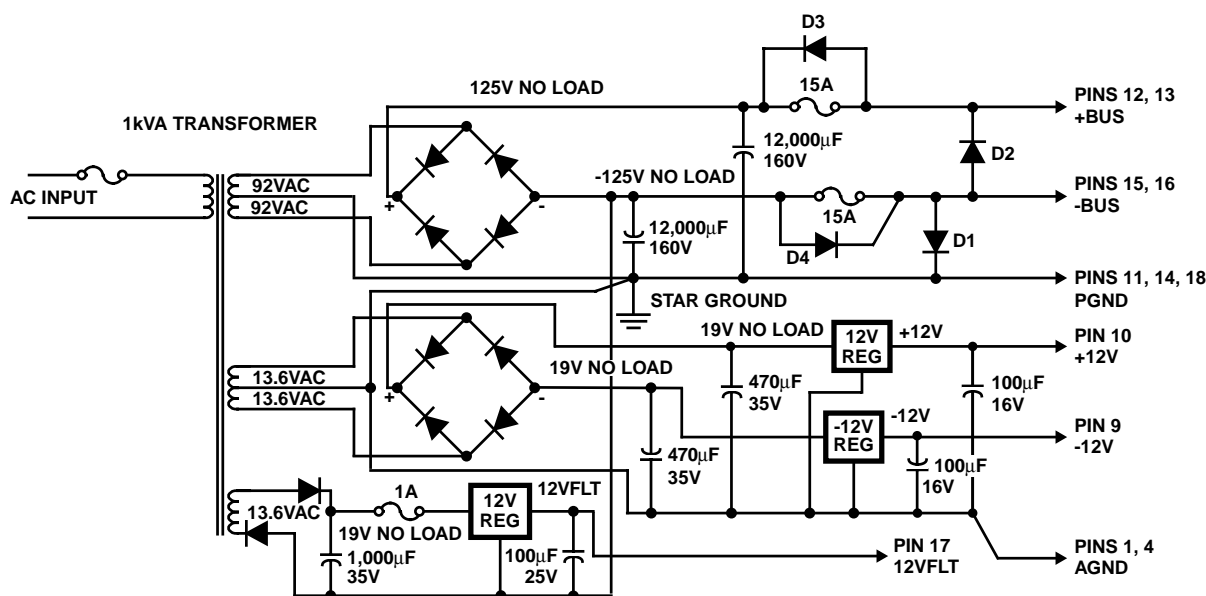


CAUTION: Remove power and discharge capacitors before removing or inserting the amplifier. Failure to do so may damage the module.

NOTES:

4. Differential input. input signal to - INPUT and + INPUT returned to analog ground.
5. When using + INPUT, return - INPUT to analog ground.
6. Enable may be left open since a 25μA pull up current will enable the IC. The fan, CL and SFCL all may also be left open.

Power Supply For the HCA600ACREF



WARNING: High voltage secondary.

NOTES:

7. D1, D2 are 200V, 3A diodes. These will blow both fuses if either MOSFET in the power amplifier fails short.
8. D3, D4 are 200V, 1A diodes that return energy to the supply if a fuse blows.

FIGURE 6.

Power Supply Specifications

+Bus and -Bus

The voltage necessary to achieve full power is $\pm 110V$. In an unregulated supply, the no load voltage will be significantly higher. The MOSFETs used in the amplifier support the differential voltage between the buses. That is if the +/-Bus are 125V, then each MOSFET has to support 250V. The breakdown of the MOSFETS is 275V. Care must be taken to ensure that under no load, high line conditions this breakdown voltage is not exceeded. Doing so may damage the amplifier.

This limitation makes it difficult to achieve full power from an unregulated power supply. The output impedance of the transformer has to be very low and the size of the bulk capacitance must be large. A better solution is to use a switching power supply. This allows the amplifier to be used to its full potential. With an unregulated power supply, 500W is the maximum power. The amplifier will still be able to provide 600W transient RMS power.

While not shown in the power supply diagram, high frequency ceramic caps (0.1µF) should be placed in parallel with the electrolytic capacitors for the +/-12V bias and 12VFLT. This additional filtering will improve the performance of the amplifier.

+12V and -12V

Each supply draws approximately 40mA. Regulation is required. For best results make sure that the rectified secondary voltage at minimum line voltage is greater than the dropout voltage of the regulator. Any 100mA, 12V, linear regulator can be used.

12VFLT

This voltage is needed to drive the gates of the MOSFETs. The current required is on the order of 400mA. This voltage should also be regulated. The current is high enough that a 1A regulator with heatsinking is required. This supply is referenced to -Bus. **Do not reference this supply to ground as the amp will be damaged.**

NOTE: In applications that use multiple modules, power supplies can be shared as long as the currents of each supply is scaled accordingly.

The voltages on +/-Bus are dangerous. Be careful. Do not touch the components inside the shield when power is applied. Make sure the bulk capacitance in the power supply is discharged before disconnecting or connecting the edge connector. Don't touch uninsulated speaker wires when the amp is running at high powers. Diodes D1- D4 are required for safety. Use them.

Heat Sinking

The HCA600ACREF heat sink must be supplemented to achieve full power. The amount of additional heatsinking depends on the airflow.

For bench testing, a small fan set up within inches of the board blowing across the shield is sufficient for full power testing. The resistors used to test the board will also likely require a fan.

In applications, the internal thermal transfer plate should be bolted to the chassis. This can be accomplished by either placing the board horizontally so that the shield is in thermal contact with the bottom or side of the chassis or by using an L bracket which mounts to both the chassis and the thermal plate. The shield will not make good thermal contact with the thermal transfer plate unless a stiff piece of aluminum is bolted to the transfer plate from the outside of the shield. The reference design uses 125 mil aluminum bars for this purpose. The chassis and L bracket can also serve the same purpose, allowing the aluminum bars to be discarded. The aluminum shield is necessary for EMC compliance. Do not remove it.

To ensure a long and reliable life, the heatsinking should be designed so that the module typically runs at 70°C or less. Higher operating temperatures will reduce the lifetime of the module.

It is also important to use high temperature fiber washers when mounting the FETs to the transfer plate. Teflon™ and plastic washers will flow at high temperatures causing the FETs to loose contact with the transfer plate and fail.

At one third power into 4Ω (333W) the efficiency is 85%. The amplifier shuts down when the heat sink temperature is 100°C. Allowing for a temperature rise of 50 degrees above ambient, the thermal resistance of the heat sink must be approximately 1°C per watt. A fan is highly recommended. With a small fan, the existing heat sink bolted to the chassis is more than adequate.

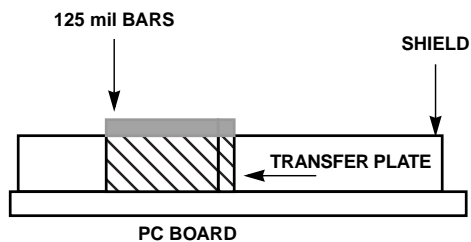


FIGURE 7.

Assembly

Make sure the FETs are secure, and use thermal grease on both sides of the aluminum oxide spacers. Glue the inductors down and ensure that the coils of the output choke do not run against the shield. This, may cause a short. The

large inductor should be glued to the shield and the board, so that it is anchored securely. Thermal grease between the transfer plate and shield is required. Place small washers under the heatsink to lift it up off the board. The washer next to R3 requires thermal grease on both sides so that the thermistor used to sense the temperature of the thermal transfer plate will be in thermal contact.

GROUNDING

As in all audio amplifiers, grounding is important. The module has two ground planes, power and analog. These are connected on the board by a zero ohm jumper, R31. *In most applications, this jumper should be removed, and analog ground should make one and only one connection with power ground, (star ground) - see Figure 6 for power supply transformer.*

AUTOMATIC RESTART INTO SHORT

The amplifier is capable of distinguishing a low impedance load from a dead short. If the output is shorted with a low impedance, the amp will deliver 30A for 50ms and then shut down. If the impedance is very low (a short), the amplifier will deliver 50A for a short burst and then shut down. In either case, power must be cycled by the user to restart the amplifier. The amp will not shut down if the impedance of the loudspeaker dips, or if the speakers are momentarily shorted. In this case, the amplifier limits the current supplied to the loudspeaker. The amplifier is designed for use with 4Ω and 8Ω speakers. It is stable into 2Ω and 1Ω loads, but the magnetics and heatsinking are not designed for low impedance speakers or multiple speakers in parallel.

If auto restart into a dead short is absolutely required, then populate R59 with a 10Ω 805 resistor, and change C11 to a 0.1μF, 10V, 1206 capacitor. The current limit time out will now be 5ms, and the amplifier will always try to restart after a dead short one or more times. For safety and reliability issues, if the current ramps to more than 50A on any start up attempt, the amplifier will shut down and power will need to be cycled. In this mode, unless the short is removed quickly the fuses in the power supply will blow. After the short is removed and the fuses replaced the amp will restart. Most users should not use auto restart, as it is easier for the customer to cycle power than replace a fuse.

EMC COMPLIANCE AND POWER SUPPLY WIRING

As with all Harris reference designs the amplifier meets both FCC and CE requirements when placed in a suitable chassis with appropriate use of by-pass capacitance. The audio input requires a 1000pF NPO capacitor to chassis, and the +speaker cable requires a 0.047μF 200V NPO or X7R capacitor. The negative audio input and speaker return should be grounded to the chassis. A power line filter is also required to meet conducted emission specifications.

Power supply wiring is important. The wires for the +/-Bus must be kept close to their return (power ground). Twisting the cables is recommended. The bias supplies should also be kept close to their returns (AGND). Twisting is recommended. The return for the 12VFLT is the -Bus. The primary wires for the transformer should be twisted as should the secondary wires to the rectifiers. When twisting is not possible, use tie wraps. Low frequency EMI issues are usually due to radiation from the bridge rectifiers as the board itself is compliant.

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