20W Amplifier Module

Mark Stuart

A low-cost, single chip, 20 Watt wide-band low distortion Mono/Stereo amplifier module

THIS single chip stereo amplifier module delivers a maximum power of 11 Watts per channel into 2 ohms, or 20 Watts into 4 ohms in mono full-bridge mode. It will also drive all higher impedance (such as 8 ohm) loads at reduced power levels.

Using the STA7360 Stereo/Bridge amplifier i.c. and using very few external components, this easy-build project should fall well within most constructors' budgets. A general run-down on this low-distortion, wide frequency range chip is outlined in the Specification panel.

The circuit board has been designed to allow operation in stereo or mono (bridge) mode – selectable by a wire link. Operating voltage can be between 8V and 18V so the circuit is perfect for use in car systems. The power output ratings are *continuous average power* and assume a suitable heatsink is fitted.

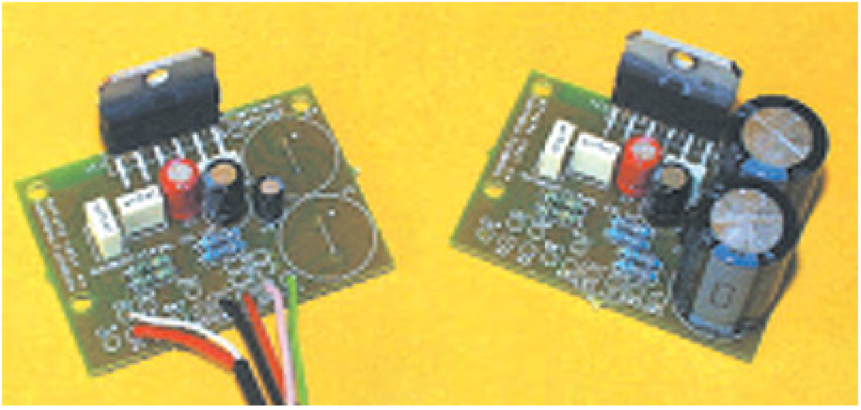
Circuit Details

The internal structure of the STA7360 20W Bridge/Stereo Amplifier i.c. and its pinout information is shown in Fig.1. The full circuit diagram of the amplifier module in stereo configuration is shown in Fig.2, and in mono "bridge" mode in Fig.3.

In stereo mode (Fig.2) all components are required and pins 4 and 8 of IC1 *must* be linked together. Loudspeakers LS1 and LS2 are connected between output terminals OP1 and PW-GND1 (Channel 1) and OP2 and PW-GND2 (Channel 2).

The power supply connections ***must*** be made to the +V and 0V terminals. Although there are several connection points to the circuit "ground" (0V) it is important that the negative supply and the speaker PW-GND1 and PW-GND2 connections are made as shown. The peak currents in the speaker and power lines can exceed 4A and the voltage drop across even short lengths of printed circuit board (p.c.b.) copper track can be enough to cause distortion and instability.

The chip has independent signal (S-GND) and power (PW-GND) ground pins so that the high power circuit currents are separated from the input circuits. It seems a contradiction to add a connection between S-GND and PW-GND on the circuit diagram – but the p.c.b. track layout is arranged very carefully with a gap in the ground area so that the high current only flows in and out of PW-GND and is separated from the small input signal currents flowing into S-GND.



Two versions of the STA7360 audio amplifier; mono bridge (left) and stereo (right)

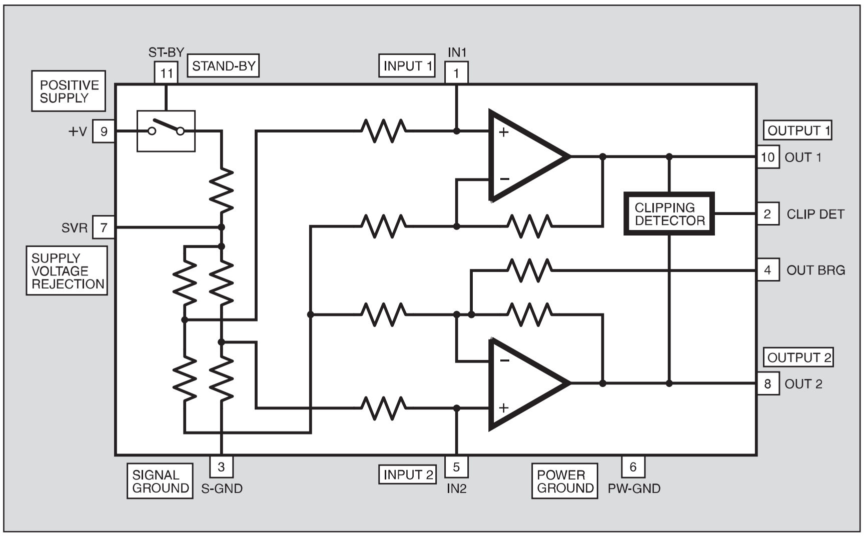
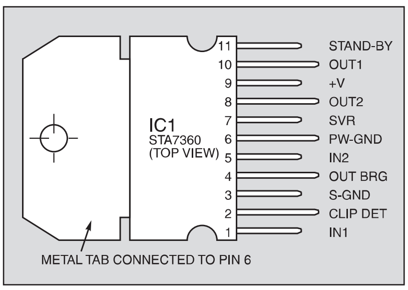


Fig.1. Basic internal structure of the STA7360 stereo/bridge amplifier. The i.c. pinout details are shown below.



Stereo Mode

In Stereo mode (Fig.2) the two amplifiers within the chip operate independently as standard single-ended push-pull amplifiers. Without an input signal each output sits at mid-rail (half of the supply voltage) and swings up towards the positive supply

Specification . . .

Frequency Response:	From 10Hz to well over 100kHz
Distortion:	Less than 0·03% at 1kHz.
Output:	11W per channel stereo into 2 ohms, 20W into 4 ohms mono full-bridge – see text
Loudspeaker Protection:	Both outputs shut off in any overload condition
Clipping Detector:	Output shows if either channel is overdriven
Standby:	Switch off function – very low standby current
Chip Overheat:	Shut down protection

Plus: Output a.c. and d.c. short circuit protection – to ground and to supply voltage; wide output voltage swing makes maximum use of the available supply; delayed turn-on mute circuit eliminates switch on/off noises (pops); high supply ripple rejection.

simply by a single-pole switch. It has the disadvantage that there will be around 1mA flowing via resistor R6 in standby mode, more than ten times the chip current! To avoid this disconnect R6 and connect ST-BY to the positive supply line (+V) for normal operation, and to 0V for standby. Capacitor C3 provides a short time delay to hold the circuit in standby mode when power is applied. It helps prevent turn-on "pops".

Capacitor C7 decouples the internal bias circuits so that the circuit is insensitive to supply noise and ripple. It also controls the switch-on "pop" prevention delay.

Stereo input signals are connected to inputs IN1 and IN2, via capacitors C1 and C2, and the corresponding ground (0V) connections must be made to points S-GND1 and S-GND2. The input coupling capacitors C1 and C2 are necessary because IC1 input pins have a d.c. bias and so are not at 0V.

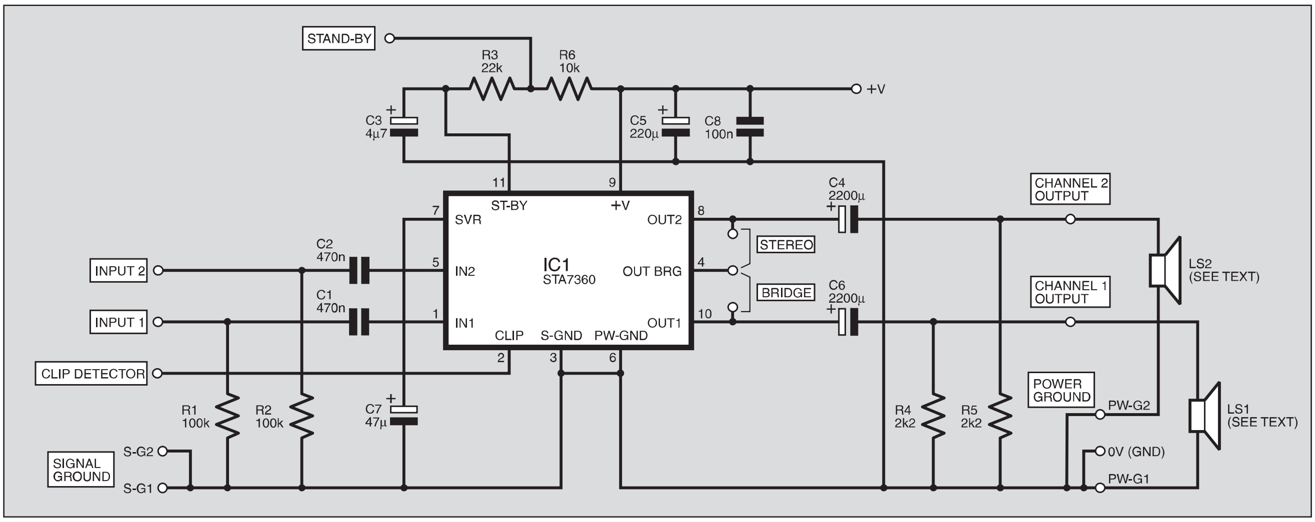


Fig.2. Full circuit diagram for the Amplifier Module in stereo configuration

and down towards 0V when driven by an input signal. The output swing is limited by the supply voltage and by the voltage drop across the internal output transistors.

In previous i.c.s, the difficulty of making good *pnp* power devices meant that more complicated asymmetrical circuits using *npn* devices had to be used, often dropping 2V or more. However, the STA7360 uses new technology which make it possible to include fast, high gain *pnp* output transistors. These allow a fully symmetrical output configuration enabling the output voltage to swing within 0 3V of both the positive and negative rails.

This additional output voltage swing is significant because output power is proportional to the square of the voltage. So, for example, with a 10V supply and 2V dropped from each rail the power is proportional to 6×6 = 36. If the drop is just 0 3V from each rail, the swing is 9 4V so the power is proportional to 9 4×9 4 = 88 – almost 2 5 times the power!

Output coupling capacitors C4 and C6 block the mid-rail d.c. voltage but have very low impedance at signal frequencies above a few tens of Hertz. Resistors R4 and R5 provide a charge path for C6 and C4 in case loudspeakers LS1 and LS2 are not connected, ensuring that the d.c. voltage at outputs OP1 and OP2 is held to zero.

They can be omitted if speakers are wired permanently to the circuit board.

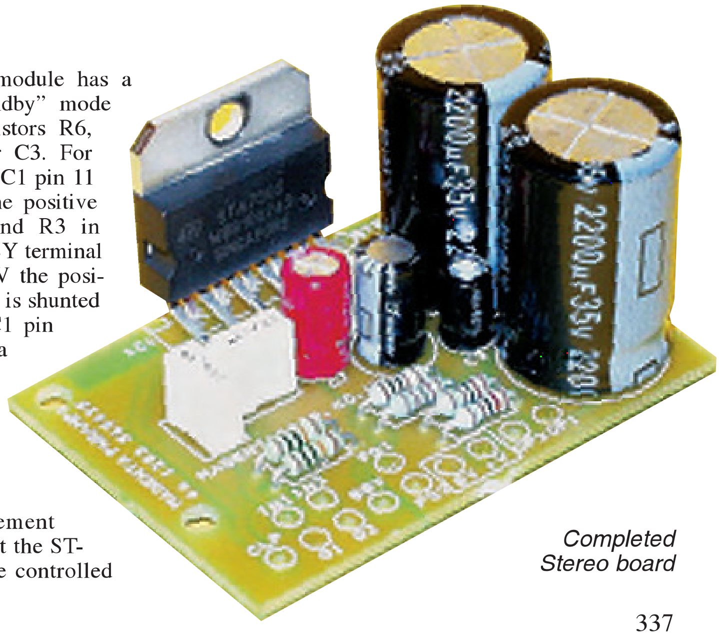
Capacitors C5 and C8 decouple the power supply providing a low impedance even if long supply leads are used. Film type capacitor C8 is added in parallel with the electrolytic C5 to make sure that the decoupling is effective at high frequencies where electrolytic capacitors are not so good.

On Standby

The amplifier module has a low current "Standby" mode controlled by resistors R6, R3, and capacitor C3. For normal operation IC1 pin 11 is connected to the positive supply via R6 and R3 in series. If the ST-BY terminal is connected to 0V the positive current via R6 is shunted to ground, and IC1 pin 11 is grounded via R3, shutting off the circuit and reducing the supply current to 100μA.

This arrangement was chosen so that the ST-BY point could be controlled

Resistors R1 and R2 provide charge paths for C1 and C2 to keep the input terminals at 0V even when input circuits are not connected. If they are omitted there will be unavoidable clicks and pops when inputs leads are plugged in. It is surprising how many commercial designs don't bother with this simple precaution.



Completed Stereo board

The input impedance of each amplifier is 50k (kilohms). It will be reduced slightly by the parallel effect of resistors R1 or R2, but in most cases this will be unimportant. If the full 50k is needed R1 and R2 can be taken out of circuit.

Bridge Mode

In Bridge mode (Fig.3) the two independent stereo amplifiers are combined to drive a single loudspeaker LS1. The loudspeaker is connected between one amplifier output (OP1) and the other (OP2) as shown in Fig. 3.

As the two amplifier outputs are at the same mid-rail voltage there is no d.c. voltage difference and so there is no need for output coupling capacitors C4 and C6, used in the stereo version. Resistors R4 and R5 are also redundant.

If the two amplifier inputs were driven with the same signal, the outputs would also be the same, driving both terminals of loudspeaker LS1 up and down together so that the voltages would cancel each other and there would be no voltage difference across the speaker – and no sound!

For bridge mode the output of one amplifier is inverted so that instead of cancelling each other the voltage across the speaker is doubled. This is achieved in IC1 by removing the link between pin 8 and pin 4 (Stereo mode), and instead linking pins 10 and 4 (Bridge mode).

The output voltage swing in bridge mode is doubled compared with the single-ended stereo mode because the speaker can be driven almost to the full supply voltage in one direction when output OP1 (pin 10) is high and OP2 (pin 8) is low, and similarly in the opposite direction when output OP2 is high and OP1 low. This results in a much higher output especially at lower supply voltages.

Only one input (IN1) needs to be connected to the input signal, whilst the other input (IN2) can be connected to its input ground (S-G2), via its coupling capacitor C2. If the other input is not grounded, it works as an inverting input, and can be used to cancel some types of interference and noise.

Reverse Polarity

The circuit has no protection from a reverse polarity power supply connection. The i.c. is able to withstand 10A of reverse current for what the data sheet describes as "as long as it takes to blow a 2A fuse".

Using a series protection diode would reduce the output swing by about 1V, and possibly introduce output distortion, so putting a fuse in the power line is efficient, practical and effective, and is strongly recommended.

Clip Detector

An internal open collector *npn* transistor turns on if the circuit is driven into clipping. The output current from the transistor is 70μA for approximately 1% distortion, and rises at higher levels.

If the circuit supplying the input signal has some type of d.c. volume control, it could be connected so that the output is automatically reduced to avoid overload distortion. Alternatively the current could be amplified to drive an l.e.d.

Construction

The Amplifier Module uses only a few components, and is built on a small single- sided printed circuit board (p.c.b.). The topside component layout and full-size underside copper track master are shown in Fig.4. This board is available from the *EPE PCB Service*, code 500.

The track layout is critical for good performance, because of the high power ground and output currents. It is, therefore, recommended that the layout is followed closely – especially the routing of the "ground plane" area. This is *not* a "stripboard" project!

Several of the capacitors are polarised, so take care to connect them the right way round. Most electrolytics have a broad white band with "-" minus signs printed on them adjacent to the negative lead.

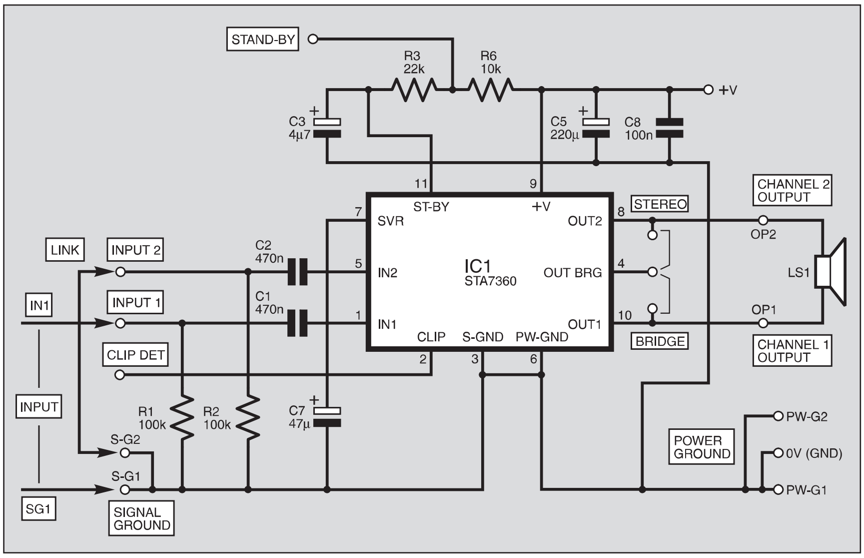


Fig.3. Complete circuit diagram for the Bridge mode Amplifier Module

COMPONENTS

Resistors

R1, R2	100k (2 off)
R3	22k
R4, R5	2k2 (2 off)
R6	10k

All 0.25W 5% metal film

See SHOP TALK page

Capacitors

C1,C2	470n box polyester 63V (2 off)
C3	4μ7 min. radial elect. 25V
C5	220μ min. radial elect. 25V
C4,C6	2,200μ radial elect. (2 off)
C7	47μ min. radial elect. 25V
C8	100n box polyester 63V

Semiconductors

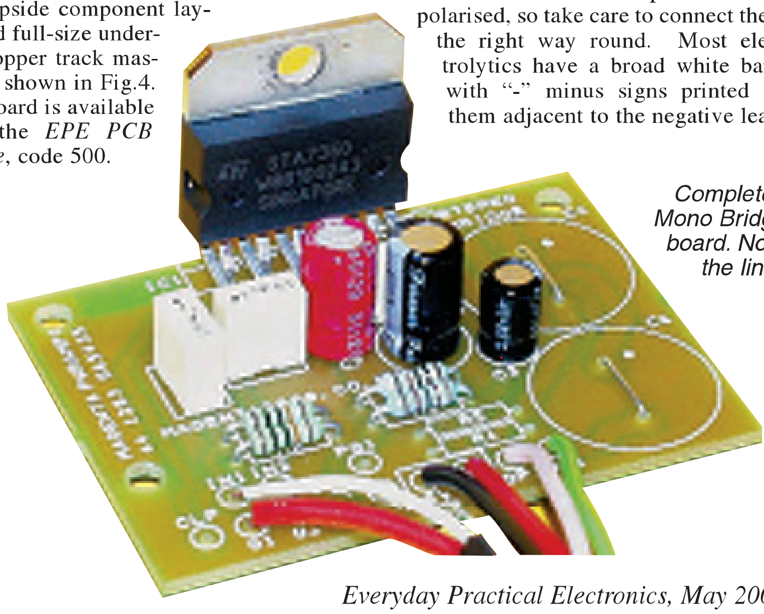
IC1	STA7360 20W bridge/stereo audio amplifier

Miscellaneous

LS1,LS2	2Ω to 8Ω loudspeaker, see text (2 off)

Printed circuit board available from the *EPE PCB Service*, code 500; finned heatsink, see text; single-core link wire; multistrand connecting wire; solder; etc.

Approx. Cost Guidance Only **£12** *excl speaker & power supply*



Completed Mono Bridge board. Note the links

Link Up

A single wire link selects Stereo or Bridge mode. In Bridge mode capacitors C4 and C6 are omitted and wire links fitted instead. Amplifier module IC1 is fitted on the p.c.b. with its metal tab parallel to the edge of the board so that it, together with the p.c.b., can be mounted onto a flat metal heatsink plate just by the heatsink screw. Three other mounting holes are provided in the board for more conventional mounting arrangements.

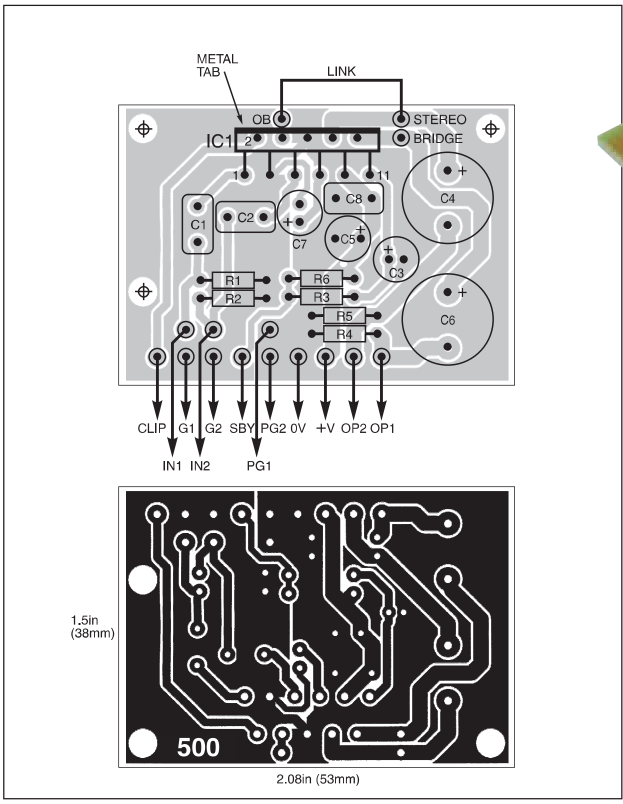


Fig.4. Printed circuit board component layout and full-size copper foil master for the Amplifier Module in Stereo mode. For Bridge mode capacitors C4 and C6 are omitted and replaced with wire links – see photos.

Many different types of heatsink can be used, and the over-temperature protection will soon start complaining if the output is too big or the heatsink too small! The heatsink tab is connected internally to the chip power ground 0V pin (6) so might not need insulating in some applications. It is certainly not advisable to power the chip via the metal tab, as there is a danger of instability or distortion due to possible ground loops.

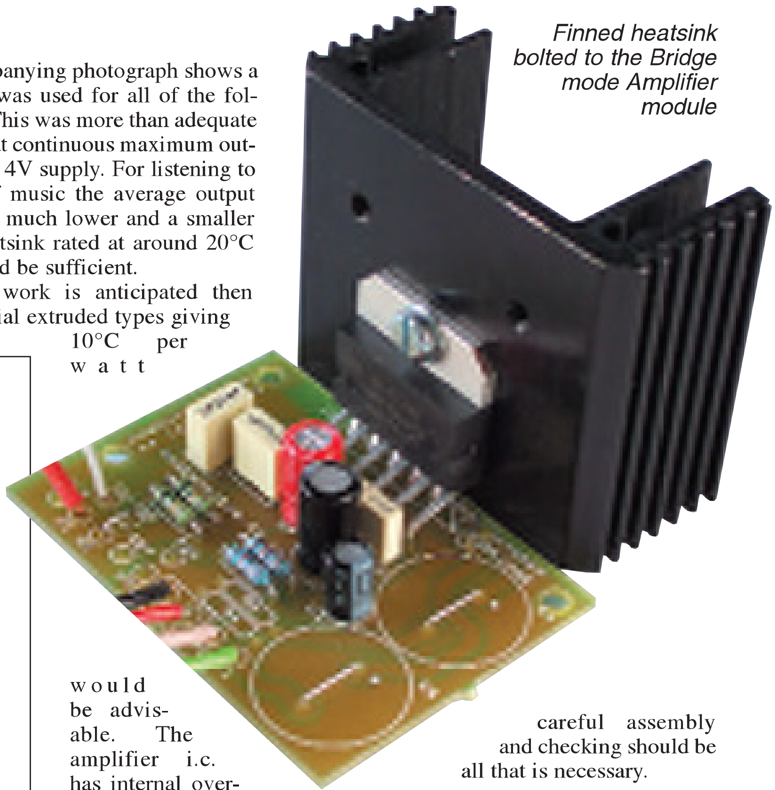
The holes in the p.c.b. for mounting IC1 are quite tight so a little care might be necessary to jiggle them into position. The pins need to be about 1mm proud of the copper side of the board to be soldered correctly. It is not necessary to force them through any further. The chip has ESD (electrostatic discharge) protection, so there should be no need for special handling.

The wire link selecting Bridge/Stereo operation runs between IC1 pins and the edge of the board. Use a straight bare wire link and bend it just at the end if Bridge mode is to be used. Make sure that it does not short to any of other the pins, and that it cannot contact the heatsink.

Heatsink

The accompanying photograph shows a heatsink that was used for all of the following tests. This was more than adequate for operation at continuous maximum output using a 14 4V supply. For listening to most kinds of music the average output power will be much lower and a smaller or thinner heatsink rated at around 20°C per watt should be sufficient.

If heavier work is anticipated then more substantial extruded types giving 10°C per watt would be advisable. The amplifier i.c. has internal over-temperature protection and so "thermal runaway" is not possible. If the chip's temperature rises too far the output is limited by the protection circuits and shows itself as very harsh distortion.



Finned heatsink bolted to the Bridge mode Amplifier module

Testing

As always, start the testing procedure by inspecting the board for dry joints, solder bridges and for any reverse polarity of components. Also, before connecting loudspeakers, make sure that the wire "bridging" link is in place to select the required Stereo or Bridge mode of operation.

Next, apply the power supply to the 0V and +V terminals of the board (making sure it is connected the right way round!) via some sort of current limiting device. An ideal current limiting device is a car tail lamp bulb – it both limits the current, and lights up dimly or brightly depending on the overload!

Once power is connected successfully, check across the loudspeaker terminals to make sure there is no d.c. voltage present. In Stereo mode the d.c. voltage will decay to zero in a few seconds as the output capacitors C4 and C6 charge through resistors R4 and R5. In Bridge mode the two outputs will be at half of the supply voltage, but the voltage between them will be small. A few hundred millivolts of "d.c. offset" is possible and acceptable.

Connect the loudspeaker(s), and then apply a suitable input signal at a low level (using a 10kΩ log. potentiometer if necessary). As there are so few components, careful assembly and checking should be all that is necessary.

Power Supplies

The amplifier operates correctly at between 8V and 18V. At 14 4V in Bridge mode and at full power into 4 ohms, a supply capable of delivering 3A is required. In Stereo mode using 8 ohm speakers the supply needs are more modest and a 1 5A supply is sufficient.

The circuit is ideally suited to operation from a car battery, and also has good supply ripple rejection so that it can work satisfactorily from an unregulated mains transformer with a bridge rectifier and smoothing capacitor. Make sure that the unloaded supply voltage does not exceed 20V. A transformer delivering 12V a.c. with a bridge rectifier and a 4,700μF 25V electrolytic smoothing capacitor should be acceptable, but check the "off load" voltage.

Computer power supplies often have suitable 12V or 15V outputs and provide enough power to run two separate circuits in bridge mode to give 40W stereo output.

Performance Matters

As stated earlier, the operating supply voltage range is 8V to 18V. Quiescent current (with no input signal) is between 65mA and 120mA which is quite high, and the STA7360 i.c. is certainly not intended for operation from batteries, (except car batteries of course) however in applications such as loudhailers, where there is a "push-to-talk" switch, the Standby pin (11) can be used effectively, and the standby current is less than 100μA.

Most of the manufacturer's performance curves are shown at 14 4V, the nominal voltage of a car battery. Higher power can be obtained with the maximum 18V supply, but make sure the power supply is ***regulated*** because the "absolute maximum" supply is only 20 volts so there is not much room for errors.

The distortion at 1kHz with a 14 4V supply in Bridge mode, at medium power levels, is less than 0·03%, rising to 0 1% at 13W output. The frequency response is considered remarkable because the circuit

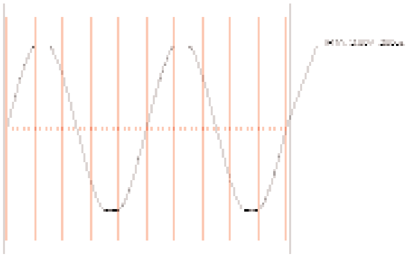


Fig.5. Stereo mode 12V no load

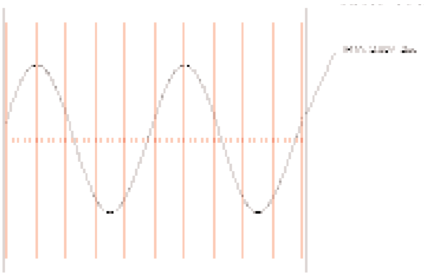


Fig.6. Stereo mode 12V 100kHz 4Ω load

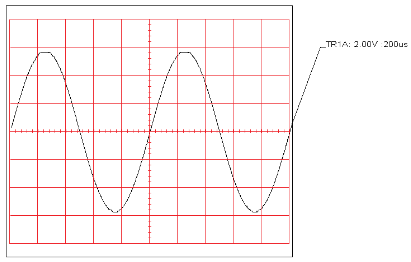


Fig.7. Bridge mode 14·4V 1kHz 4Ω load. Supply current 2A. OP1 shown, 11·5V p-p (4·1V r.m.s.), input is 600mV p-p

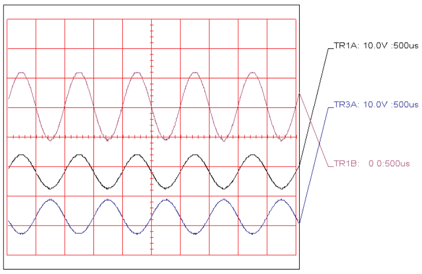


Fig.8. Bridge mode lower trace OP1, middle trace OP2, upper trace OP1-OP2

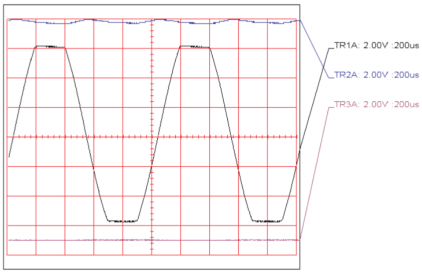


Fig.9. Bridge mode 14·4V 1kHz 4Ω. Overdriven to show OP1 max output. Lower trace 0V, upper +14·4V supply

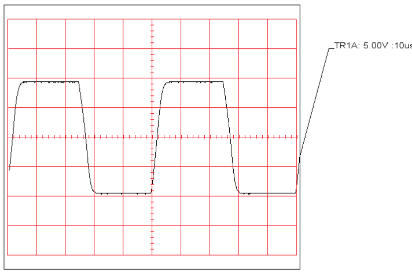


Fig.10. Bridge mode 14·4V 20kHz square wave response 4Ω load. 20 Watts output, 2μs rise and fall time

uses "local" feedback in the output stage, and so has a low overall open loop gain (just like a valve amplifier in fact!). The result is that external compensation components are not needed, and at medium signal levels the response is flat to 200kHz.

Low frequency response is determined by the input and output coupling capacitors. The values shown give a low frequency −3dB point of 18Hz in Stereo mode. In Bridge mode the speaker is d.c. coupled so only the input capacitors have any effect and the low frequency response extends well below 10Hz.

The amplifier voltage gain is 20dB or 10:1 in Stereo mode and 26dB or 20:1 in Bridge mode. This means that the normal Auxiliary signal levels – most audio sources including Digital TV tuners, Computer sound cards, DVD and CD players – will be able to drive the output up to clipping levels.

A Measured Performance

The measured performance of the circuit in Stereo and Bridge mode is illustrated by the oscilloscope plots shown in Fig.5 to Fig.10. These were recorded by a fast DSO (Digital Sampling Oscilloscope).

The output of one channel with a 12V supply and no load is shown in Fig.5. The vertical scale is 2V/cm, and it can be seen that the output voltage swings very close to the positive and negative rails which are three divisions above and below the mid line. With a 4 ohm load the output still swings within 0 6V of the supply rails – when delivering a peak current approaching 1 4 amps!

Still in Stereo mode, with the input turned down to just below the clipping point at 1kHz and the frequency increased, Fig.6 gives an indication of the frequency response into 4 ohms. At 100kHz the amplitude is almost unchanged. There is just a tiny amount of crossover distortion visible at the centre of the screen where the waveform passes through zero.

On the Bridge

The result from one of the amplifier's outputs, OP1, when connected in bridge mode, at 14 4 volts and 4 ohms load, is shown in Fig.7. The other output OP2 is producing the same waveform but with the opposite polarity.

The positive peak output voltage from OP1 is approximately 5 75V, so the corresponding negative output from OP2 is −5 75V giving a peak voltage across the 4 ohm load of 11 5V and so the peak output current is 11 5/4 or just under 3A. The output power is 17 Watts.

At this current level the output voltage swings to within 1 4V of each supply rail – which is still an impressive performance.

The output voltage across the load – obtained by subtracting the OP2 trace from the OP1 trace – is shown in Fig.8. The Vertical scale has been reduced to 10V per division.

The maximum output swing of OP1 is shown more clearly in Fig.9. Here the output has been overdriven, to give flat tops and bottoms, and two traces have been added showing the 0V rail and the +14 4V supply.

The trace shows that the voltage reaches within 1 4V of each rail, and also shows how the positive supply voltage drops as the circuit draws high current at the peaks of each waveform. This voltage drop is surprising because the amplifier is being powered from a regulated supply via just 40cm of 16/0·2 connecting wire. It shows a voltage drop of 300mV or so during the peaks when the output current is 3A and corresponds to an effective supply resistance of 0·3/3 or 0 1 ohms.

This illustrates the need to provide good power connections (and more importantly ground connections). Note that the ground line shows no voltage drop but that is because the 0V reference point was taken where the wire connects to the board. If the reference point had been the power supply terminal, the 0V line would also show the same voltage drop as the positive rail.

To demonstrate the frequency response it is useful to see the amplifier's performance with a square wave input. The resulting waveform in Fig.10 shows the square wave performance at 20kHz. Note that the amplifier is not being overdriven, so the flat top is due to the input signal and not to any clipping effects. The output power is 20 Watts. The circuit shows perfect symmetry of the rising and falling edges which have a 2 microsecond rise and fall time.

Summing-Up

The board has separate connecting points for loudspeaker, power, and input ground connections. ***Do not*** be tempted to economise by combining any of these – even though they all "go to the same place"! Ground loops can cause instability, and introduce distortion that the chip designers have worked hard to eliminate! If the i.c. metal tab is being connected to a chassis heatsink, don't rely on the connection to provide the power, and ideally use an insulation kit.

The specification and measured performance of the circuit are impressive, it uses very few components and provides an effective power amplifier for many audio applications. The short-circuit protection, clipping indicator, shut down mode, and switch on/off "pop" reduction features make this circuit very versatile.

Real Power!

The power output of these modules is real continuous "average power" (sometimes incorrectly called r.m.s. power) which heats up the load resistors! It should not be confused with things like "80 Watt" computer speakers – powered from a wall transformer rated at 6 Watts!!

The author doesn't have "golden ears" and has deliberately avoided making any subjective observations, The specification speaks for itself, and we look forward to hearing from readers who have built, tested, and listened. □