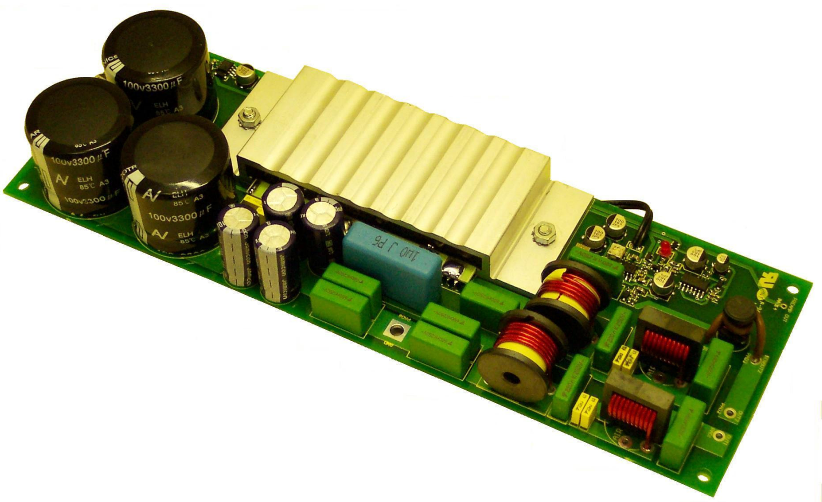
SDV1015

CLASS D AUDIO AMPLIFIER MODULE APPLICATION NOTE 1.3

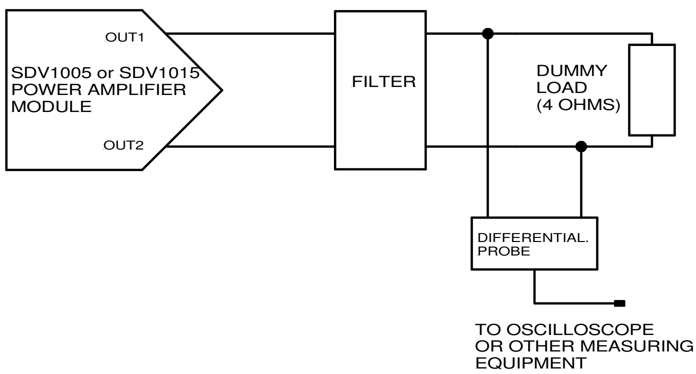
INTRODUCTION



The SDV1015-600 is a class D amplifier module. To operate the amplifier module a suitable power supply and interface circuitry is required. This document describes simple power supply requirements and optional interface circuitry. The complexity of the interface circuitry depends upon the application and the performance required from the amplifier module. A typical interface scenario is shown opposite. In this application the associated circuitry contains short-circuit protection, thermal protection, decoupling of power supplies and output filter. Details of the circuitry are described later in this application note.

MEASUREMENT OF OUTPUT POWER

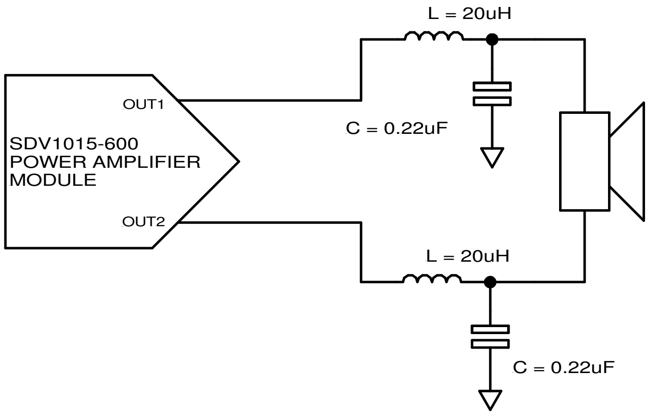
The output power from the SDV1015 class D amplifier modules must be measured differentially across both of the amplifier outputs. Failure to measure differentially will produce erroneous power level readings. A typical measurement scenario is shown opposite.



Best results are achieved using a battery powered differential probe, which can then be connected directly to an oscilloscope. A single ended probe connected to one output and the earth lead connected to the other output will destroy the amplifier module. Connecting a probe to one output and the earth lead to the amplifier ground will give erroneous readings, such that the measured power will be 25% of the actual power. The load shown in the measurements is a resistive 4-Ohm load rated at the power level for the amplifier. Magnatec can supply 600W, fan cooled, resistive dummy loads that can be wired for 4Ω, 8Ω, 16Ω and 32Ω.

OUTPUT FILTER

For testing and demonstration purposes the amplifier module can be used without an output filter. In the latter case, the two amplifier output terminals are connected directly to the loudspeaker. The speaker will absorb the higher frequency signals produced by the amplifier module. To alleviate the dissipation in the speaker a simple LC output filter configuration can be used. The simplest possible scenario is depicted opposite. In this example, the inductor value should be less than 20uH (ideally use air core inductors and at least 1mm diameter copper wire) and the capacitor value should be less than 220nF. Using these values will give a cut-off frequency of approximately 25KHz. The simple filter has a number of deficiencies. In particular:



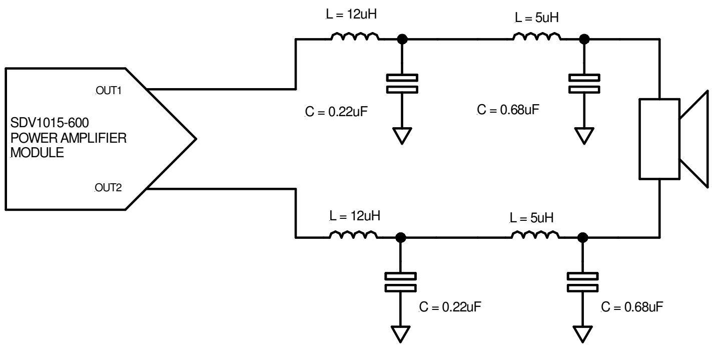
Attenuation of the switching signals is at best 25dB

- The filter response is influenced by variations in the load impedance.

- The filter provides minimal blocking between the amplifier and load.

Not withstanding the above, the simple filter has the advantage of small size and lowest cost.

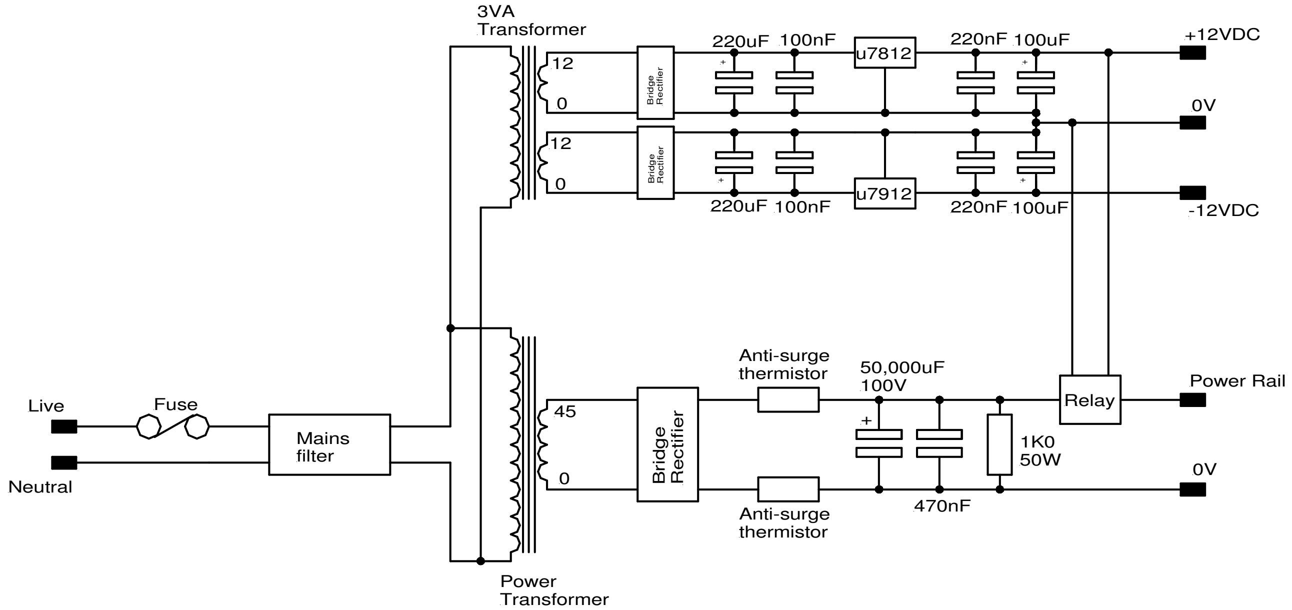
If the performance of the simple filter is insufficient a two-stage LC filter can be employed. The performance of a two-stage filter will improve the attenuation of the switching signals. The configuration is illustrated opposite. With this configuration the attenuation of the switching signal for the SDV1015 module will be approximately 32dB, with a 3dB down point of 20KHz and 85% to 90% of the rated power coupled into the speaker (excluding cable losses). Semelab plc. have patented a filter combination for class D amplifiers that will produce greater than 40dB attenuation of the switching signals (SDV1015) whilst effectively blocking the amplifier from the load when there is no audio signal. The custom filter topography also minimises the affect of speaker load variations. For more details of this type of filter contact Magnatec.



When designing an amplifier layout with an output filter it is important to consider the thermal management of the filter components. In a class D amplifier system, the filter will typically operate at a higher temperature than the amplifier. A correctly designed output filter will both block the amplifier from the load and absorb high frequency signals produced by the amplifier. In such cases a small amount of airflow across the filter is beneficial.

POWER SUPPLIES

The class D amplifier modules have been powered by linear, switch-mode and battery supplies. For testing purposes the simplest approach is to build a simple linear power supply with regulated control voltages and unregulated power rail. A block diagram of a simple linear power supply is shown below.

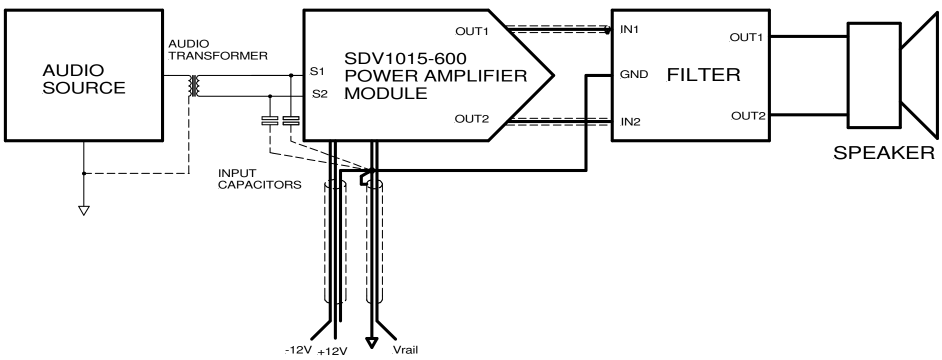


For details of battery or switch-mode power supply operation please contact Magnatec Ltd.

NOISE REDUCTION AND DISTORTION

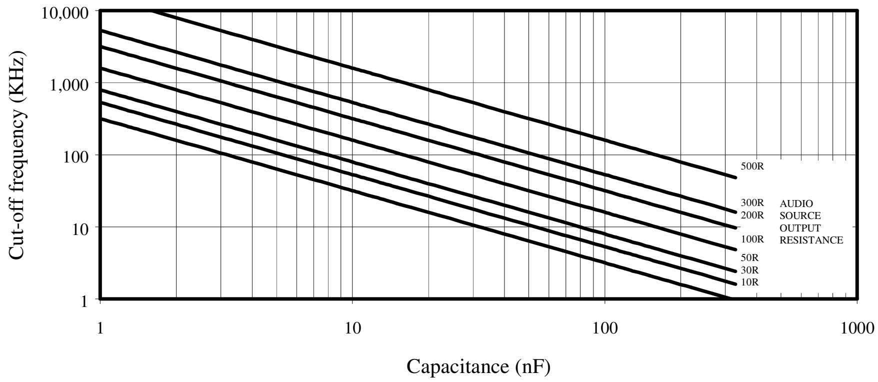
The layout and connections to the amplifier are critical to achieve the best performance from the module. In particular, general low noise and screening procedures should be adopted where possible. The critical points to consider when making connections to the amplifier are:

- Keep all cableforms as short as practical.
- Use screened low noise cable for the audio input.
- Keep the audio signal and low power connections away from mains cables and components.
- Use multicore, screened cables for the output and power connections.
- Use substantial gauge wire for all power connections to and from the amplifier (ideal >1.5mm^2).
- Connect all signal grounds to one point using a 'star ground' methodology with the ground point at the amplifier module GND connection.
- Layout the amplifier and filter such that the input audio input signal is as far opposed from the amplifier outputs and filter as practical.
- Use an audio input transformer if possible (contact Magnatec for suitable devices), particularly when attempting to run two units from a common power supply.
- Use solder connections wherever possible.



A typical wiring layout is shown above which includes the screening layout. Note the use of the input capacitors on the amplifier input. These serve to reduce any stray rf interference in the local environment. The output resistance of the audio source and the chosen upper cut-off frequency for the amplifier determines the value for the capacitors. For more details of the capacitor selection, see the chart below which describes the relationship between the audio source output resistance, amplifier upper cut-off frequency and capacitance value. In addition, a simple audio input transformer is used to isolate the ground paths of the audio source and the amplifier and power supplies. Magnatec are able to supply these components and a suitable transformer is the SDV5032-3K audio input transformer. The transformer should be mounted as close to the amplifier inputs as possible. In the example above, the filter depicted is the Magnatec proprietary design (SDV1017-30). If a simpler filter is used the ground point shown could be redundant. If interference problems persist or if unsure about ground and screening layout please contact Magnatec for more assistance.

Cut-off frequency versus capacitance

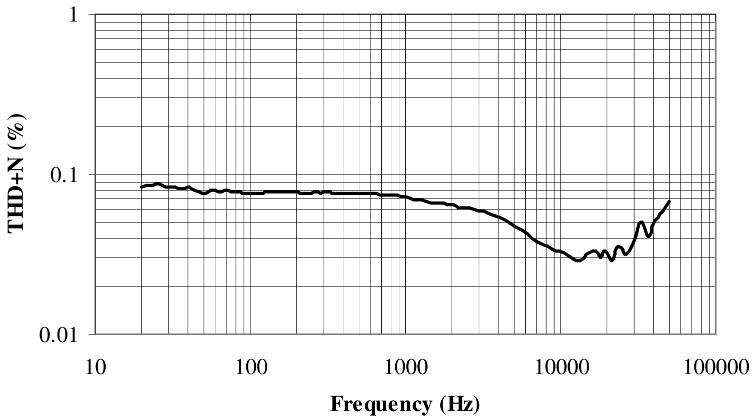


The distortion measurements for the amplifier modules are heavily influenced by the test conditions. The distortion of a class D amplifier is fundamentally different from a linear amplifier. With a linear amplifier the open loop distortion is generally poor and feedback is employed to reduce the inherent distortion. The distortion figures for a linear amplifier are a measure of how well the feedback corrects for this feature. Measures of total harmonic distortion for linear amplifiers with figures less than 0.1% are commonplace.

For a class D amplifier module the basic amplifier and open loop gain are highly linear and the inherent distortion is much lower than an equivalent linear amplifier. However, the total harmonic distortion readings for the class D amplifiers are influenced by the residual switching signal passed by the output filter and general switching noise. This noise is outside the audio band at 450KHz and above, but it can have a dramatic effect on reading of total harmonic distortion (THD+N). In addition, the distortion of a class D amplifier will increase with increasing modulation factor as the irregular effects of the switching characteristics of the class D power output stage become more predominant. However, most of these effects are irrelevant when using the class D amplifier to amplify signals in the audio band.

The chart opposite shows the measurement of total harmonic distortion for an SDV1015-600 amplifier with test scenario optimised for low distortion. The readings were taken at the average power level for an audio amplifier and the power supplies to the amplifier were regulated and filtered. In addition, localised decoupling of 500uF (low ESR capacitors) was placed on the main rail voltage terminal of the amplifier.

SDV1015-600 Distortion Measurements

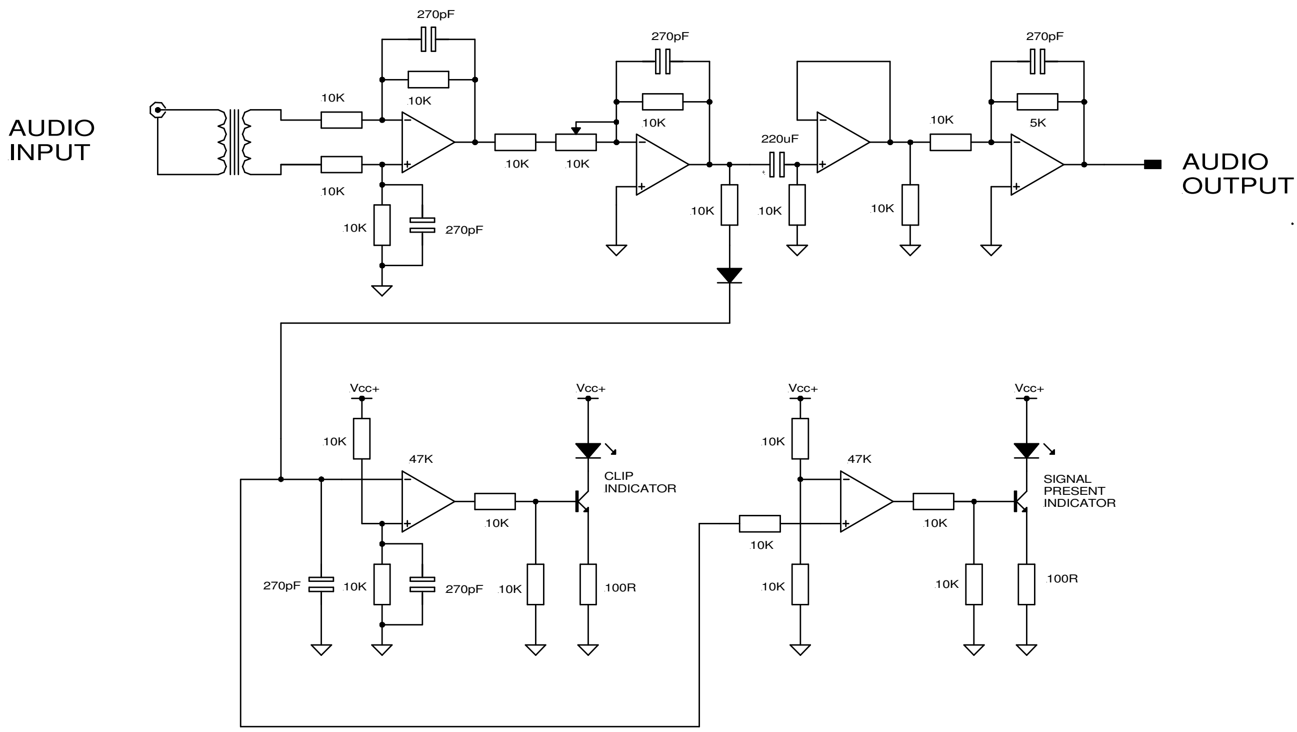


INPUT CONDITIONING

The input configuration of the basic amplifier module is designed to take single-ended or differential (balanced) inputs. The input signal level is pre-set for an absolute maximum value of 2.2V peak-to peak (p-p). Input signal levels greater than the levels specified above should be avoided. These will not damage the amplifier but will introduce distortion into the audio signal.

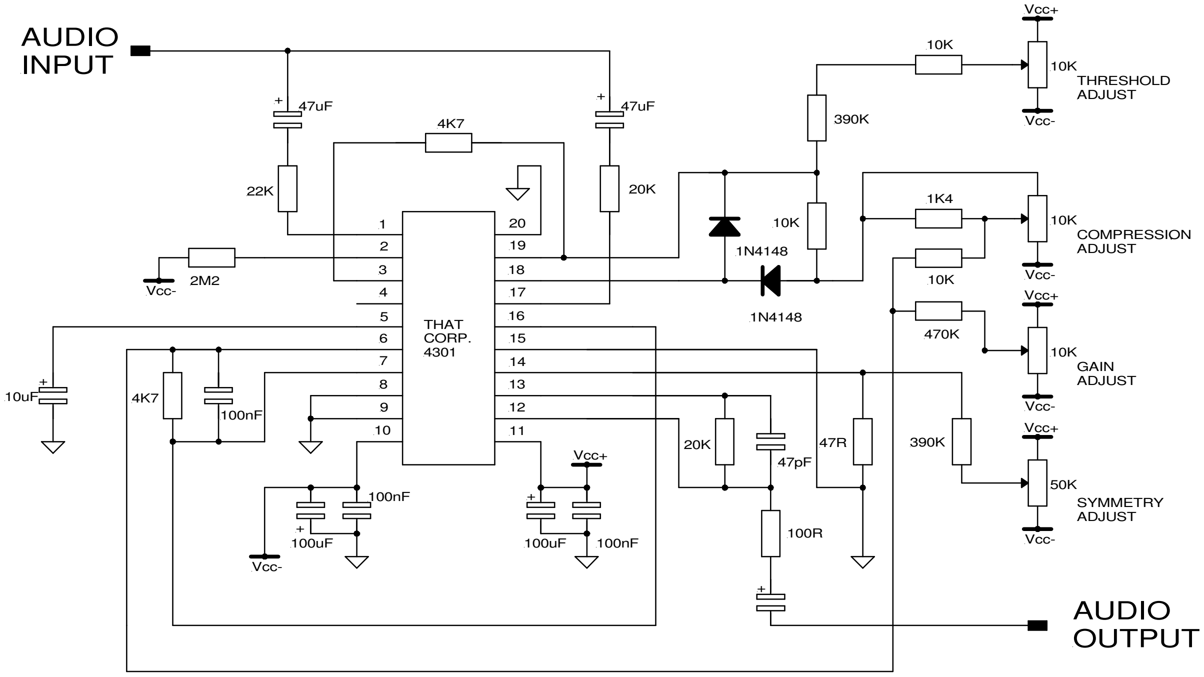
However, it is not always possible to avoid excessive input levels and in these instances an input conditioning circuit is recommended. For customers requiring in excess of 1,000 modules per annum the input conditioning circuits depicted below (excluding indicators) can be incorporated into the amplifier module. Notwithstanding this, it is usually more cost effective for the user to produce these circuits external to the amplifier. The circuits below are illustrative and the list is by no means exhaustive. If special input requirements exist that are not catered for below, please contact Magnatec for a discussion of the application.

The first example circuit is a simple clip limiter that clips the input signal amplitude just below the maximum signal level. The circuit has a fast speed of response and clips cleanly across the top of the input signal peak. The amplifiers shown are MC3304 and swing to the supply rails. The input amplifier is configured to accept single-ended or differential (balanced) inputs.



In addition to the basic anti-clip shown above more elaborate schemes have been developed. One such scheme uses the THAT Corporation 4301 analogue processor. The circuit shown below includes anti-clip, compression and gain control. The circuit functions different to the previous circuit as it minimises distortion on the audio signal. The previous simple anti-clip flattens the peaks of the input signal above the input threshold. This latter scheme monitors the rms level of the input signal and if a signal is detected above the input limit it automatically reduces the signal gain to prevent any clipping of the audio signal. The circuit is shown with adjustments for the clip threshold, compression, gain and symmetry. In practise, once set for a particular application the potentiometers can be replaced by resistor networks.

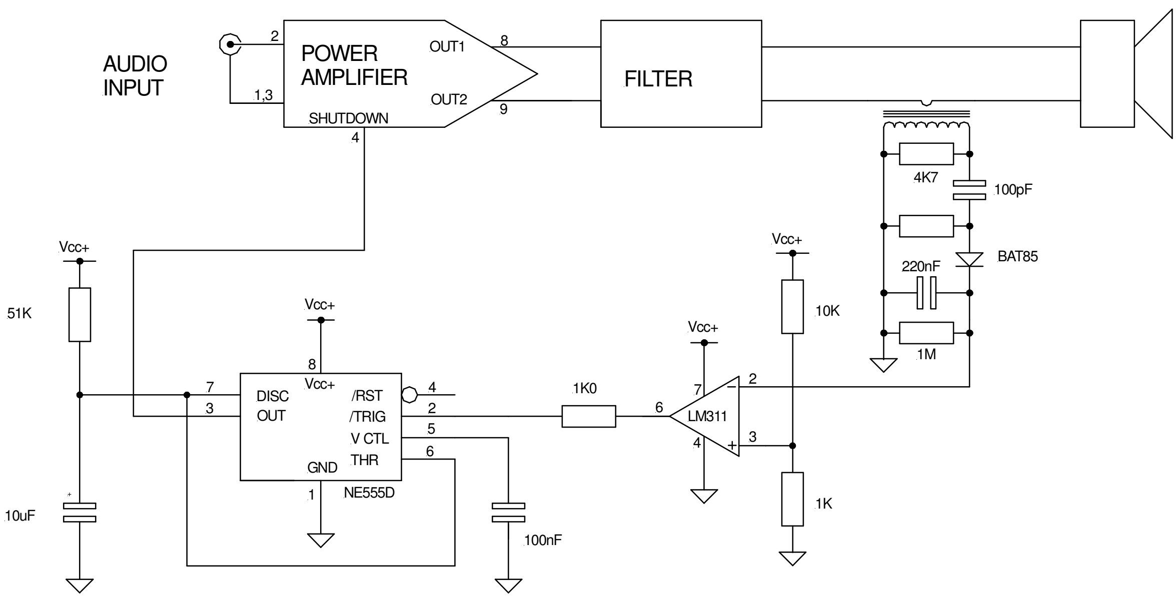
MAGNA TEC



For details of other input conditioning options, please contact Magnatec.

SHORT CIRCUIT PROTECTION

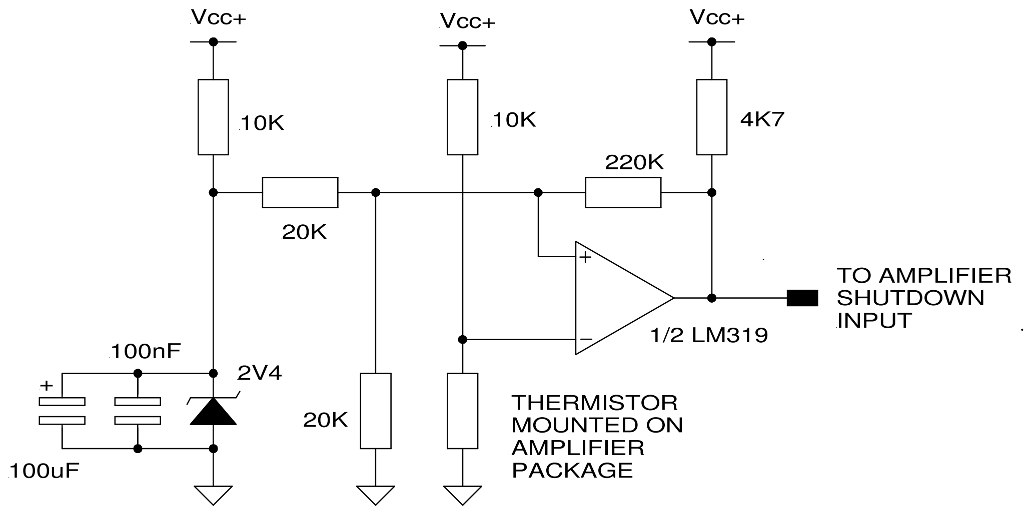
The basic amplifier module does not have short circuit protection fitted as standard. It is a simple matter to fit the circuitry external to the module. The scheme that has been adopted is to wind one of the output leads from the filter around a current transformer that detects the current due to the residual switching frequency. The transformer current is filtered and compared to a threshold voltage by a comparator. The comparator output triggers a monostable which sends out a 1 second pulse which when connected to the amplifier shutdown connection will switch of the output stage of the unit. After 1 second normal operation is resumed and if the short is still present the above scenario repeats. With this scheme it is possible to directly short the output of the amplifier whilst applying maximum input signal with full protection of the amplifier module and the speaker.



The above scheme has the following advantages:

- It is non-invasive in the signal path.
- The protection is effectively instantaneous.
- The circuit effectively monitors the output impedance, it does not rely and is unaffected by the audio signal
- The circuitry is compact and inexpensive.

In addition to the basic short circuit protection, another simple protection scheme is a thermal trip that monitors the temperature of the module heatsink. This scheme is useful in applications where the amplifier module might be operated outside the normal conditions for short periods of time i.e. into a low impedance load. The sensor is a thermistor (negative temperature coefficient) that is fixed onto the amplifier housing (typically using one of the fixing holes). In the circuit shown below the sensor is connected to the input of a comparator. The comparator output is low whilst the sensed temperature is less than 55°C. Once the temperature exceeds 55°C the output of the comparator goes high and the output will not change until the measured temperature is less than 45°C. If the circuitry is run on a +5V power supply the comparator output can be connected directly to the amplifier shutdown input.



The thermistor used in the above examples has a resistance at 25°C of 10KΩ. It has a beta value of 3920. Other thermistors with different parameters can be used but the component values in the circuit will need to be modified. Magnatec can supply a simple spreadsheet program to facilitate this operation.

GLOSSARY

Active speaker	Integrated loudspeaker and amplifier.
Audio passband	Audio spectrum from 20Hz to 20KHz.
Anti-clip	Circuit to correct for excessive input signals.
Class D	Amplifier using pulse width modulated output stage.
Decibel	Measure of relative power dB = 10logP1/P2
EMC	Electro magnetic compatibility
ESR	Equivalent series resistance
Filter attenuation	Performance of a filter at a specific frequency or band of frequencies.
Harmonic	Higher multiple of a frequency
(K)Hz	(Kilo) Hertz, frequency measure
Inherent efficiency	Measure of the efficiency of the amplifier module alone.
Input impedance	Impedance looking into the amplifier.
Latency	Description of the dynamic range of music
Modulation Factor	Ratio of input signal amplitude to maximum permissible signal amplitude.
Noise floor	Residual noise level of the amplifier expressed in dB.
Output impedance	Source impedance seen looking into the amplifier output.
PCB	Printed circuit board
PFC	Power factor corrected
p-p	Peak to peak measurement
PSU	Power supply unit
PWM	Pulse width modulation
Quiescent current	Current consumed by amplifier with no audio signal input.
Rms	Root mean square = $V_{p-p}/(2\sqrt{2})$
Slave module	Additional power output stage driven from an optional master unit.
SNR	Signal to noise ratio
Switching frequency	Sample frequency of PWM.
THD	Total harmonic distortion - measure of the accuracy with which an amplifier replicates an input sine wave.
Theoretical output power	Maximum output power of amplifier module, alone assuming 100% efficiency.
Thermal resistance	Measure of heatsink efficiency
Total coupled power	Actual power coupled from amplifier to load (loudspeaker)
UPS	Uninterruptable power supply