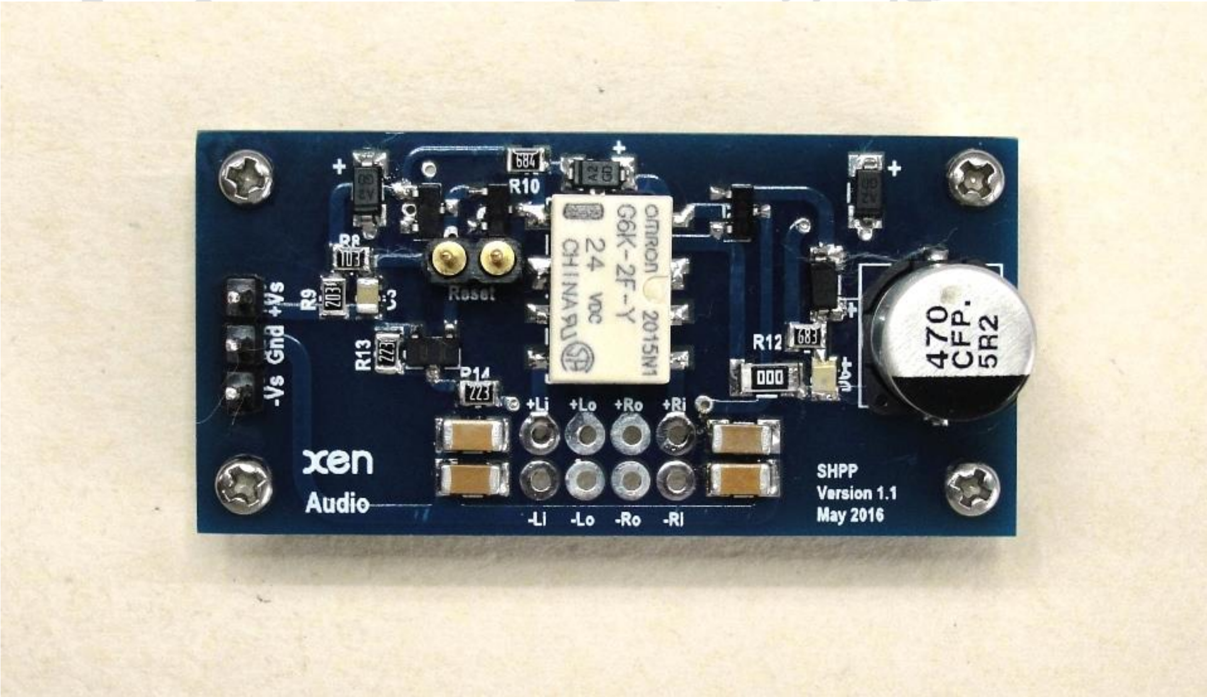
XEN SHPP Headphone Protection Circuit

XEN Audio
June 2016



Motivation

There are not many circuits, commercial or otherwise for headphone protection. I guess partly because headphones are quite robust, but also because they are also nowhere near as expensive as full size speakers. Having said that, there are now some real expensive headphones on the market, and the amps are also getting very powerful. In case of a component failure at the amplifier, the danger of damage is not negligible.

State of the Art

Some of the low-cost solutions available are based on the now obsolete uPC1237 IC. These have a DC trigger value which cannot be changed at will. Moreover, the negative and positive DC trigger levels are different. Then there are circuits, like that from Douglas Self [1], or our own XEN SSP [2], which are essentially meant for loudspeaker protection, and has a trigger voltage at around 2V, which can be already too high for some sensitive headphones.

Another well-known example of such a protection circuit is the Epsilon 12 [3]. It is supposed to trigger at as low as 80mV DC offset, both for singled ended or balanced output. This circuit works by summing all 4 outputs of the stereo amplifier with a TL082 and then running them through an inverting low pass filter. If any of the outputs have more than ±80mV DC present this will cause Opamp and the following detection circuit to switch off the output relay, thus disconnecting the headphone drivers. Once the DC level goes below ±80mV again, the opamp's output will return to ground, and the headphones are reconnected. It also includes a slow start circuit which will disconnect the drivers for a few seconds during power up, so that the amplifier has time to reach its proper operating level.

Sounds all we need, right ?

Let's look at a few cases in detail.

Suppose you have a single ended amp, and both outputs have an offset of 40mV. You probably do not want the protection circuit to trip as yet. But the summing opamp cannot distinguish this from a single channel offset of 80mV, and the circuit will trip. Not quite as intended.

Now suppose we have a fully balanced amplifier, and both the positive and the negative phase has a DC offset of 40mV. This is actually common mode DC, so it will not be seen by the headphone driver. But it will be seen as a 80mV offset by the protection circuit, which will then trip, when it should not.

Suppose again for a balanced amplifier with a +40mV offset on one phase, and a -40mV on the other phase. Now the headphone driver will see this as 80mV differential DC, but the protection circuit will see 0mV averaged offset, and hence will not trip, when it should.

You can argue that the chance of the above happening is small. But perhaps the chance of needing protection is also small. So one can choose between no protection, partial protection, or fully protection. All a matter of choice.

If the small DC offset is being superimposed by a large AC signal at low frequencies (say 30Hz), there is a good chance that the low pass filter is not filtering all of the AC voltage, and the protection circuit could be toggling between ON and OFF at the same frequency. We think it is better to have a latch, so that even when the offset has disappeared after a few seconds, the protection circuit is still latched in its faulty state, to make sure the owner is aware that a faulty condition has occurred. You can find such a latch in the XEN SSP, which uses the positive pole of the relay to provide the latching action.

Unfortunately, if the amplifier output has a temporary 100mV output DC during the slow start (relay off), the latch will also be engaged, and the relay will not turn back on even if the DC drops back to zero after the slow start. So a means has to be found to disable the DC detection trigger during the slow start phase.

Working Principle

To do all this in simple analogue circuitry without MCUs or logic chips was not so straight forward. Here is an example showing how this could be done, using a +/-6V supply (for 12V relay). The inputs should survive +/-12V coming from the headphone amplifier. You can easily adapt this to work with +/-12V (for 24V relay) without problems.

We first looked at our own SSP circuit to see how much of that could be adapted for this application. The JFET differential pair used in the SSP just will not have enough gain in itself to provide the protection trigger at 80mV. So a separate DC-offset amplifying stage as in the Epsilon 12 cannot be avoided. The OPA2192 that we choose has much lower input offset, as well as built-in input protection. It is also rail-to-rail, and functions on a wide range of supply voltage. To avoid the problems with the summing opamp as mentioned above, two separate differential opamps are used, one for each channel. This functions equally well with single ended or balanced inputs. The DC triggering circuit uses the BE junction voltage of two NPN BJT for positive and negative offset detection as described by Self (Fig. 4) [1].

The relay driving circuit is more similar to the XEN SSP and has already been described in detail there. As in the SSP, we do not want to exclude the latching option (selectable with a simple SPST switch or jumper). So we choose to perform the triggering and the slow start functions by two separate BJT switches in series with the protection relay. The NPN slow-start switch (Q5) is also used to temporary disable the protection trigger during the start-up phase. This is necessary to avoid the unwanted latch-up as already described above. Here a N-JFET is used instead of a NPN BJT because during the start-up phase, the gate and the source will then be both at +Vs, whereas in case of a NPN, the emitter is 600mV lower, thus not switching off the triggering circuit 100%. Once C4 is charged up to about 1.2V, Q5 will conduct, switching on the relay and switching off the N-JFET to enable the protection triggering circuit around Q3.

The circuit as shown has a triggering point at 80mV differential. It is also capable of filtering a sine wave of 2.5Vrms at 100Hz without changing the triggering point by more than a few mV. The start-up delay is about 3s; and the trigger delay of a 80mV DC step is about 2.5s.

Customising

Once the working principle is understood, it is relatively easy to customise the circuit to your own needs. The opamp sets the limit of the power supply to +/-18V maximum. The resistors R7, R10 to R14 would have to be adjusted accordingly to give the same operating current. Of course, when using a summed rail voltage other than that of the relay, a resistor needs to be added in series to provide the appropriate voltage drop so as not to overload the relay.

The start-up delay time can also be varied by adjusting the value of C4. And by changing the values of R2, R4 simultaneously, you can change the gain of the input differential amplifier, and hence the DC trigger level.

PCB layout

The PCB is shrunk to a minute size of 45mm x 22mm, so that it can easily fit onto any desktop headamp front panel, close to the headphone socket. SMD components are used extensively. The Omron G6K relay is fully sealed, rated at 1A and has silver gold alloy contacts. More importantly it only requires 10µA to ensure proper contact. The amplifier outputs can either be single ended or balanced, but only the positive connection is switched by the relay. The negative connection is connected to the headphone permanently. For those who prefer no latching, just leave out R10 (open circuit).

Power supply should be taken from one channel of the amplifier, to which the Gnd of the protection circuit should be connected. Current consumption is less than 15mA, plus that for the relay (4mA for 24V version).

Setup

No adjustment is required. To test the PCB, it is best to use a regulated dual supply with 50mA current limit. For better visualisation, it is worth considering soldering an LED temporarily in series with a 10k resistor in parallel to the relay coil during testing.

Short all the inputs to 0V before start up. The relay should engage after about 3s. Then connect each of the 4 inputs to a DC offset of +/-100mV (provided by a 10k potentiometer and one polarity of the power supply or a 9V battery). The DC detection circuit should trigger in about 3s, and the relay should be switched off. With the latching option, the relay should remain switched off even after the offset should be returned to 0V. Shorting the reset pins should bring the circuit back to normal operation.

Then connect each of the input to a sine wave of 1Vrms 100Hz with no DC offset (the remaining 3 inputs at 0V). The DC detection circuit should not trigger.

The protection circuit is now fully tested and ready for deployment.

References

1. D. Self Relay Muting, Electronics World, 1999
2. http://www.diyaudio.com/forums/pass-labs/244157-simple-speaker-protection-power-amplifier-balanced-outputs.html
3. http://www.amb.org/audio/epsilon12/

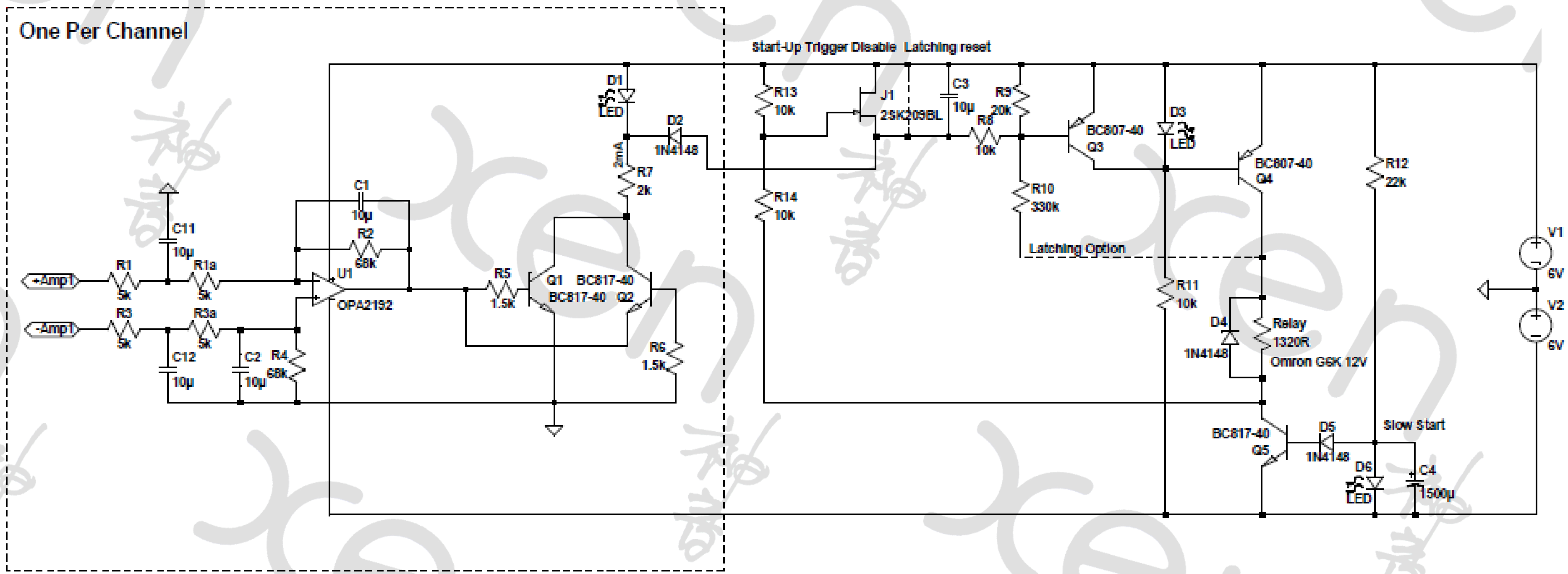


Fig. 1 XEN Simple Headphone Protection Version 1.0 Schematics