Audio Amplifier PCB
for LM3875 Overture IC

Attached schematics show the inverting and non-inverting amplifier configurations as implemented in the ADL Sperry LM3875 PCB. These are the schematics obtained by populating the components as detailed on the next page. Ci is 22uF/50V, negative towards ground. The volume control potentiometer is optional and not wired on the PCB, but located externally. A volume control could equally be added to the inverting amp, and its presence in the schematic is simply arbitrary.

Please review the following manufacturer documents to familiarize yourself with the IC amplifier capabilities and topologies.

http://www.national.com/ds/LM/LM3875.pdf
https://www.national.com/an/AN/AN-1192.pdf
https://www.national.com/an/AN/AN-898.pdf
http://www.veriscorp.com/eb/overture2.pdf

It is highly suggested you save all the above files on your computer, since manufacturers have been known to often remove documentation material without notice. (this is the case for the last document in the list)

Soldering Notes:

if you have not previously soldered components to a double-sided PCB, you will notice some differences from single-sided PCBs.

First, more heat is required. Not necessarily a hotter iron, but a longer heat-up time, before solder begins to flow. Instead of heating up just one PCB pad, as in the case of single sided PCB's, you are now heating up two solder pads, (top and bottom) plus the metal channel lining the hole.

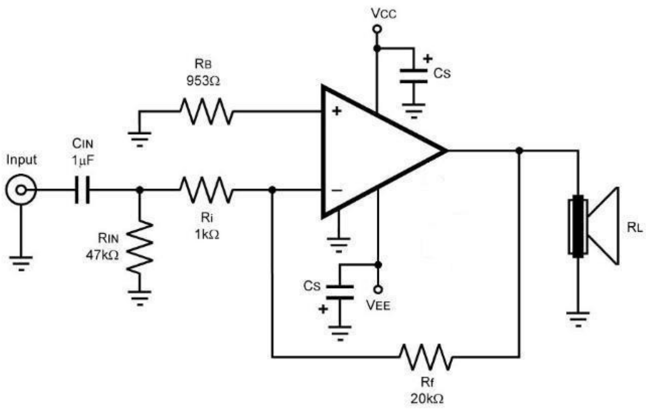
The same precaution applies regarding too much heat applied to a copper pad, with the resulting risk of lifting off of the pad. So get in, heat up, flow the solder, then get out, as quickly as you can. A 30W soldering iron should be used, while units of less than 25W may be insufficient.

Second, more solder is required. Instead of building one cone of solder between the component lead and the PCB pad, you are building two such cones (both sides of the board), plus filling the entire hole space with solder. This uses up roughly 3 times more solder than what you may have been used to.
It also requires more heat, to melt 3 times more solder.

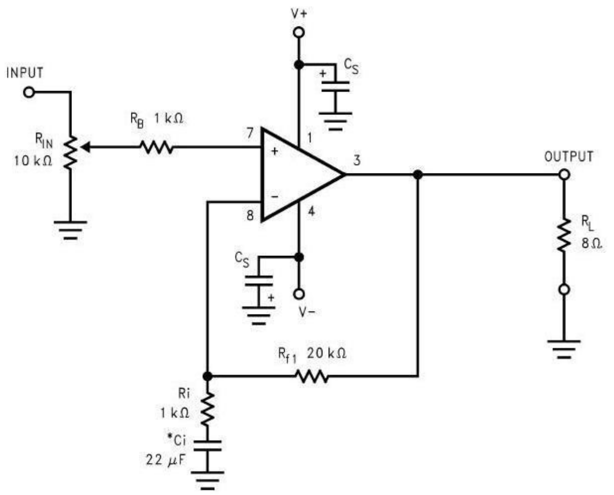
You need to inspect both sides of the board, since you may be more likely to create cold solder joints, by applying insufficient heat or solder.

A nice, perfect-looking solder cone around a component leg, can quickly become a cold joint after you remove the soldering iron, if the hole plating heats up latently, then sucks down the solder cone, leaving a rough, crystallized mass.

Takes some practice to work with double sided boards.



Inverting Amplifier Application Circuit



Noninverting Amplifier Application Circuit

Also note that if you intend to install some components on a temporary basis, with the intention for later removal, de-soldering from a double-sided board is likewise more difficult than from a single sided one. It requires more heat and more time. It is highly recommended that you take a 2-step approach

1. heat up the joint, and suck up solder briskly with a solder sucker.

2. re-heat joint well, and remove component. Reworking a double sided board carries greater risk of lifting a copper pad. Inexperienced workers tend to pull a component away with pliers, before the component-side solder has had a chance to melt completely, thus pulling the pad together with the part.

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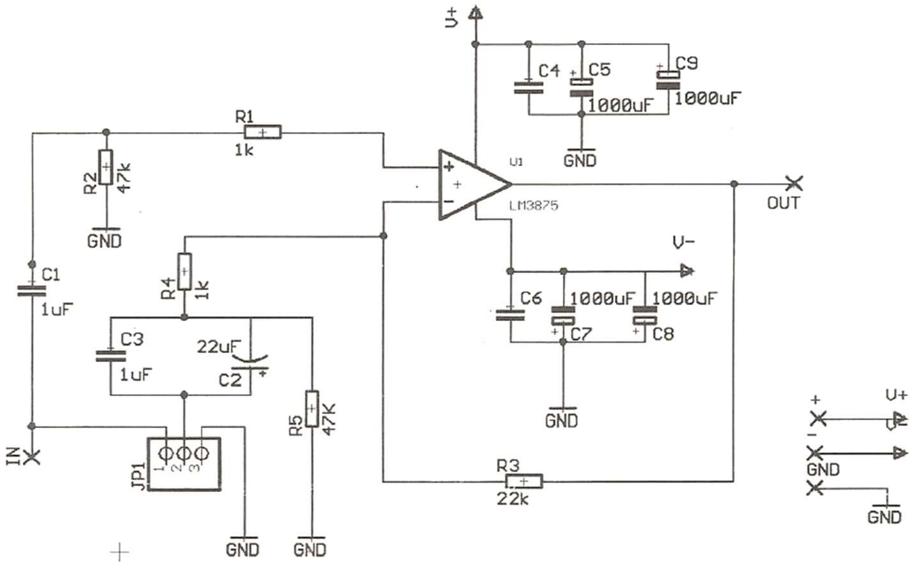
Building the noninverting amplifier

Populate R1, R2, R3, R4, C1, C2 on the PC board.

Populate a 0.1-inch jumper between positions 2-3 of the jumper block.

C3 and R5 remain open circuit.

A potentiometer can be used as volume control at the input (10K) and would be located off-board. Capacitor C1 may be any value from 0.47 to 5uF at 50V, as long as its pin spacing conforms to PCB hole positions. Values larger than 1uF do not offer any benefit. C1 can also be replaced by a short, to obtain a DC-coupled amplifier.
R2 value is also non-critical, and can be from 33K to over 200K, or can even be left out (open circuit). It presents a set input impedance to the source, and forms a high pass filter with C1, at about 20Hz with the values given. This filters out potential low frequency noise such as vinyl record undulations and DC drift.



For the inverting amplifier

Populate RI, R3, R4, R5, C3 on the PC board.

populate a 0.1-inch jumper between positions 1-2 of the jumper block
C1, C2 remain open-circuit.
R2 becomes a wire jumper, to connect R1 to ground.
C3 plays the same role as C1 in the non-inverting version, and can be shorted for a DC-coupled amplifier.

C2 and C3 occupy same position. You use one OR the other, depending on inverting/noninverting choice.

For both amplifier configurations:

Populate C5, C7, and optionally, C4 and C6. C5, C7 should be 50-63V 1000uF electrolytics. Low-ESR types would be best. Values higher than 1000uF can be used, but not lower than 500uF. Pin spacing and board area limit size of these caps. C4, C6 can be 0.1uF -1uF mylar (ok) or monolithic ceramic (best) rated for at least 50V.
These are not supply filtering capacitors, but bypass capacitors. Capacitor positions C8 and C9 are provided for those who are overly concerned about supply bypassing, but are generally not required.

Fasteners and grounding

Board is ideally secured with nylon snap-in stand-offs, not metal screws. Fasteners should not make ground connections. PCB ground should connect to chassis ground at a single point.

Capacitor C2 affects DC gain and its value is not critical. 22uF or higher, at 50V should be adequate. We sometimes see attempts by hobbyists at improving amplifier quality, by replacing electrolytic capacitors with film types. A 22uF 50V film capacitor would be extremely large, almost the size of a ping-pong ball. Using such a capacitor actually degrades performance by violating rule No.1 of good layout: keep all leads short and keep the signal confined to a small space. A very large mylar capacitor will put the signal through a huge ball of metallic foil, effectively creating very long leads, and exposing the audio signal to stray noise pickup.

ABOUT BYPASS CAPACITORS

Capacitors C4 through C9 electrically connect across each power supply rail, and need to be very close to the IC body.

They are bypass capacitors. They are not supply filtering capacitors, although they may appear to be. Filter capacitors are still required, and are expected to exist as part of the power supply. Bypass capacitors provide a storehouse of nearby energy to the IC, so that when the music signal demands a sudden current peak at high amplitude, the energy can be taken from this capacitor. This prevents dipping of the power supply voltage, and improves transient response (the ICs ability to deliver sudden current demands to the load). In automotive sound systems, the bypass capacitor would be called a "bass stiffening" capacitor, and is often seen with values of 1 Farad or more. Since there is no filtering required in an automotive application (the source is pure DC from the battery), this is clearly not a filtering cap.

The power supply filtering capacitors would not be able to meet this transient response need. Their required capacitance (3,000 - 10,000uF per channel) would cause them to be of such a size as to be impossible to locate near the IC body. It is important that the audio circuit components making up the amplifier be as close to the IC, to minimize lead length, and reduce noise and distortion. This therefore precludes filter capacitors from taking up this space. The presence of a large heat sink, requiring good ventilation, also constrains the space usage around the IC.

The bypass capacitors should be rated for a voltage at least 5 volts higher than the power supply voltage (per branch) that you plan to use, and have a capacitance value as large as possible for the space and pin distance available.

Overrating the voltage of these capacitors does not provide any benefits.

Electrolytic capacitors are rated for "Working Voltage", meaning that is the voltage at which the capacitor is designed to work. If your power supply delivers 45 volts per side, using capacitors rated for more than 50V or 63V, only wastes money and space, and does not improve the performance or lifetime of the part.

The bypass capacitors must be physically located as close to the body of the IC as possible. The larger the cap, the farther away it will be kept from the IC (by its own size) So there is a practical limitation to how much capacitance you can add at this position.

The usefulness of any capacitor in delivering sudden bursts of current depends almost entirely on its internal resistance, and internal inductance. These are termed ESR (Effective Series Resistance) and ESL (Effective Series Inductance), and are parasitic (unwanted) consequences of electrolytic capacitor construction. Resistance can range from a few hundred milliohms to a few ohms, and inductance can range from a few hundred nano-Henrys to a few micro-Henrys. Although these values would be negligible in most other applications of the capacitor, they become huge hurdles to the instantaneous delivery of a big charge in a transient response situation.

Using a capacitor with the lowest possible ESR would be a big plus. Most electrolytics do not have ESR specifications. Those that do are expensive and difficult to find. ESR is furthermore very variable from one part to another in the same lot.

It is even quite possible to find an ordinary electrolytic that has lower ESR than a "Low ESR" rated cap, by measuring the ESR of a heap of random electrolytics.

If you wanted to become seriously involved in minimizing ESR, there are simple jigs a hobbyist can put together to measure the ESR of a capacitor. An Internet search would reveal a number of useful circuits. They do however, require a signal generator and an oscilloscope.

Mask-free lands are provided on the PCB bottom, for soldering SMT ceramic capacitors between the supply rails. Several can be used in parallel, and values as high as 4.7uF/50V are available commercially.

More about ESR and ESL.

ESR and ESL are inherently higher in electrolytic caps than any other capacitor construction, simply because of their internal structure, and their sheer size. ESR further increases with age, limiting the practical lifetime of an electrolytic. Here again, there is great variability between same lot parts. We have tested capacitors from TV sets made in the 1950's with lower ESR than very recent units. The slow evaporation and drying of the electrolyte inside a capacitor is responsible for capacitor ageing, and the ESR increase that results. A more airtight rubber seal prevents electrolyte evaporation. Some capacitors have better rubber seals than others, however. In fact, some seem to have very, very good ones. So there is ultimately a measure of luck and surprise involved in measuring capacitor ESR.

Some quick facts about capacitor ESR

Tall and skinny electrolytics tend to have lower ESR than short fat ones.

Paralleled capacitors offer better overall ESR by paralleling, and thus reducing, the series resistance.

Non-electrolytic capacitors can also have significant ESR, by virtue of their geometries. Polymer film (mylar, polystyrene, etc..) capacitors have a wound construction, where metal foil and plastic film are wound together in a long spiral. For large values of capacitance, this curled foil becomes very, very long, resulting in ESR and ESL. Lowest possible ESR and ESL is obtained with modern ceramic capacitors. These have an interdigitated, rather than a rolled construction, which minimizes parasitics. The leadless, surface mount MI-CC (multi-layer ceramic capacitor) is probably the closest you'll ever get to ERS and ESL perfection. Their small size also allows them to be positioned close to where they're needed, reducing lead length by a factor of 10 or more over a large electrolytic.
Ml-CCs with values of 5uF at 50V are in existence today, and paralleling a few of these alongside an electrolytic can usually improve performance in a measurable way.

INVERTING OR NON-INVERTING?

Both inverting and non-inverting amplifier topologies have their strengths and weaknesses, and there is no reason to exert bias one way or the other except for reasons of technical merit.

Inverting op-amp configurations have traditionally been known to be more stable than noninverting ones. National Semiconductor actually admits (on page 19 of the LM4780 data sheet) that the inverting amplifier can have better THD+N performance than the noninverting one.

That said, the non-inverting amp has higher input impedance, and will thus be able to accept high impedance sources without loading. In contrast, the input impedance of the inverting amp is essentially equal to the series resistor going into the inverting input. The inverting input pin is a virtual ground, so it looks like a zero impedance to ground. The series input resistor acts as if it were going to ground. And you cannot make this resistor too high, because you degrade gain. On the other hand, the non-inverting input has inherently high resistance, of the order of many megohms, typically more than you ever need.

Even so, we must note that high impedance signal sources, which abounded in the 1950's and 60's, have nearly disappeared (crystal and ceramic phono cartridges, crystal microphones, vacuum tube output stages, etc.)

So the characteristics of inverting and non-inverting amplifier configurations ARE different. It means you have a good reason to choose wisely. Just don't choose for the WRONG reason (the noninverting amp is "natural", inversion is "artificial")

Keep in mind that the non-inverting amplifier's input impedance is equal to the series resistor going into the inverting input. Increasing this resistor decreases gain, since gain is roughly proportional to the ratio of R(feedback) to R(in-). So you must also increase Rf to maintain gain. Now you're using higher value resistors, and you are potentially adding more noise to the circuit. Thermal noise, one of the noise elements contributed by resistors, is proportional to the resistor's ohmic value. The higher the resistance, the more noise it adds. Trying to keep all resistors below about 20Kohms can minimize added thermal noise.

Star Ground
The PCB uses a star grounding layout (brings input, output, power supply, and other signal grounds through separate paths to a common grounding point.
The white "star" mark on the top side of the PCB indicates the location of the star ground point. The ground plane also connects to other ground leads at this point

Using premium components.

A knowledgeable mechanic can go inside a car's engine, and make real modifications which can improve the car's performance. An unknowledgeable car owner, may not be able to touch the engine, but may nevertheless replace the spark plugs, door handles, and bumpers trim with gold-plated equivalents, in an effort to feel that he has done something to improve the quality of his vehicle.

And so it is, with Chip amplifier builders. Many builders promote a true fanaticism in seeking out the absolute most expensive parts to use in their amplifier. It is the only way to justify a high price tag. The truth is that virtually all the elements that matter in amplifier quality, have already been incorporated inside the IC by the astute design of people who actually know what they are doing. In fact, it is considered poor design to allow a circuit's performance to depend on individual component characteristics. Circuit topology itself must factor out component variability to guarantee performance. Although this seems like an idealistic goal in analogue circuits, it is attained to a surprising degree in good circuit design.

What's left for you to do is:
Keep all leads short.
Use a star grounding technique.
Use the components with the most appropriate construction for the job Use
good power supply filtering (1000uF for every 10W, for each channel)
Use good power supply shielding to avoid EMI.
Avoid low impedance loads. 4 and 2 ohm loads require excessive currents, which bring out the imperfections in connections, and cause faster degradation of these connections.

What does work:
Resistors are noisy. they produce several types of noise, notably shot noise, and Brownian or thermal noise. Thermal noise is proportional to temperature, and also proportional to a resistor's ohmic value. Keep all resistors under 50K or so, and preferably under 10K, and you will minimize this noise. Carbon composition resistors are the noisiest. Carbon film and metal oxide film follow. Metal film resistors have the lowest noise of all. Temperature coefficient is irrelevant in audio, so paying more for this feature does not add quality.
Using wire-wound resistors does not offer any improvement over metal film types. They do add a parasitic inductive component, which is unintended in the schematic.

Some well audited information exists, which indicates electrolytic capacitors may have slight non-linearities in their voltage-current relationship. This would translate into distortion if the capacitor appears in the signal path. The amount of distortion is of the order of 0.005 to 0.015%, by all measures inaudible to the human ear. Vacuum tubes have non-linearities much higher than this figure, resulting in audible levels of 3-rd harmonic distortion, which does not appear to bother many audiophiles. Major Hi-Fi equipment manufacturers routinely use electrolytic capacitors in their power amplifier signal path, an indication that doing so is not heresy. If you do, however wish to replace electrolytic caps with better alternatives, you would need polymer-foil types of equal capacitance and voltage rating.
The problem is that values like 22uF at 50V, would result in an excessively large film capacitor, about the size of a ping-pong ball. This would not only cause a problem with component placement, but would violate the short-lead rule. Putting the audio signal through such a large ball of metal foil effectively creates very long leads, (the foil wound up in the capacitor qualifies as a lead) and exposes the signal to noise in a significant way. The signal path begins to look increasingly more like an antenna.

Committing additional funds to expensive monster cables may not necessarily improve sound quality. A columnist engineer once wrote an article about how he demonstrated a sound system to a group of audiophiles. He alternately used both expensive cables, and chicken fence wire to connect the speakers to the amplifier, without the audiophiles knowing which he was using. The audiophiles could not identify which connections were producing the better sound, and fiercely disagreed among themselves on that point. When the editor told them they were listening to chicken fence wire (while in reality, it was the expensive cables that were connected) all audiophiles suddenly agreed that they could clearly hear a very poor quality sound. They could hear the coarse, scratchy, gritty, granular, metallic, brittle sound of the metal molecules not being smoothly bonded to each other. Wow, what a nasty scorecard for cables costing over $1000!
What does matter, however are the connectors at the ends of the cables. Removable connectors are a weak point for deterioration to occur, and should be gold-plated (gold-plated hardware is not particularly expensive, however).

Expensive may not be better.
Keep in mind that the most expensive part may not be the best for an audio application. An $18 resistor may have special reliability specifications for military applications. Withstanding temperature extremes present in a military aircraft, or vibrations in a battle tank, may cause a part to be manufactured in ways not optimal for Hi-Fi audio. A transistor costing $1 may have a version costing $16.
which may be nothing more than a specially selected part. A human tests a heap of transistors, and chooses only the ones with life narrowly located between 120 and 130. That transistor receives some "X" suffix designation and costs many times more. The military has uses for things like that. Does that part help you more in audio? Not a chance.