56W Audio Amplifier

Attached schematic show the inverting and non-inverting amplifier configurations as implemented on the LM3875 Kit 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:

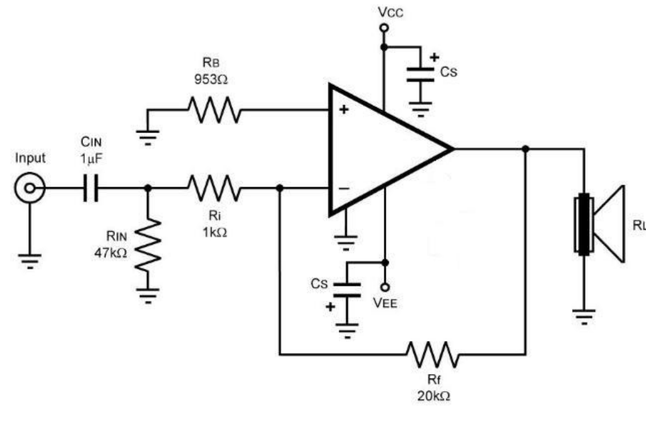
If you have not previously soldered components to a double-sided PCB, you will notice some differences from single-sided PCBs.

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+bottom) plus the metal channel lining the hole.
A precaution still 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.

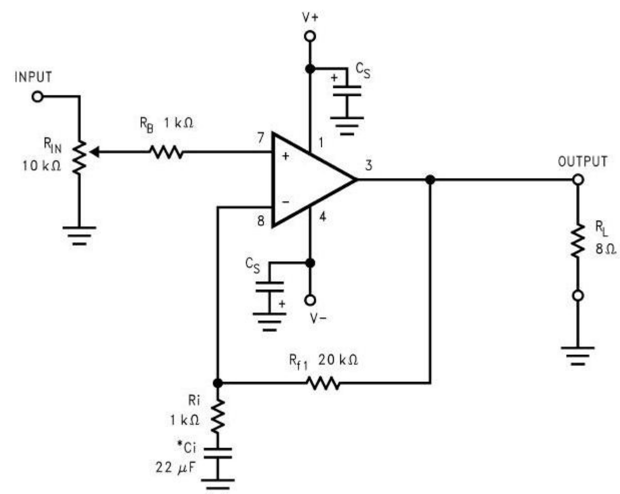
Second, more solder is required.
Instead of building one cone of solder between the component lead and the PCB pad, you are building two such cones (both sides of the board), plus filling the entire hole space with solder. This uses up roughly 3 times more solder than what you may have been used to.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



Inverting Amplifier Application Circuit



Noninverting Amplifier Application Circuit

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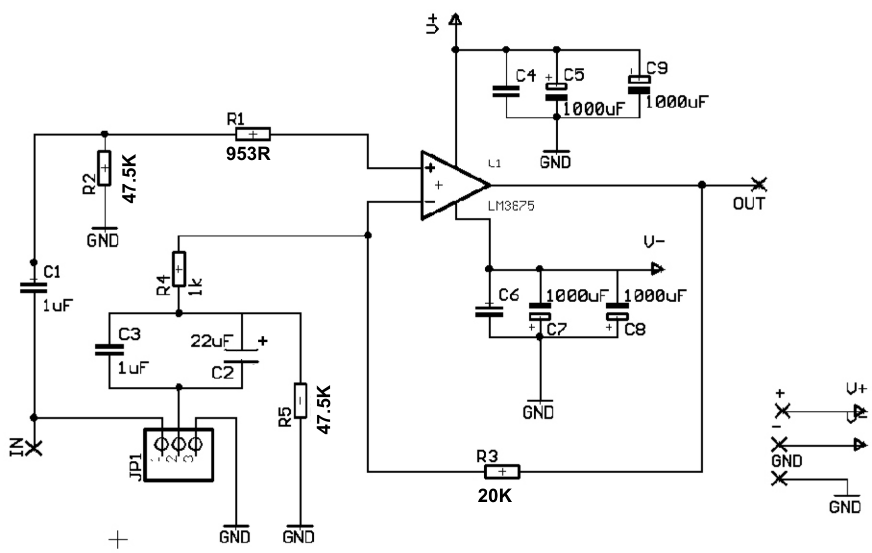
Also note that if you intend to install some components on a temporary basis, with the intention for later removal, de-soldering from a double-sided board is likewise more difficult than from a single sided one. It requires more heat and more time. It is highly recommended that you take a 2-step approach.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

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 R1, 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 ac C1 in the non-inverting version, and can be shorted for a DC-coupled amplifier.

For both amplifier configurations:
Populate C5, C7, and optionally, C4 and C6. C5, C7 are 50V 1000uF electrolytics, low-ESR types. Values higher than 1000uF can be used, if desired. Pin spacing and board area limit size of these caps. C4, C6 are 0.1uF -1uF Epcos BlueCap film caps rated for 50V.
These are not supply filtering capacitors, but bypass capacitors. Capacitor positions C8 and C9 are provided for audiophiles who are overly concerned about supply bypassing, but are generally not required.
If SMT bypass capacitors are provided, they can be soldered either between the legs of C5 and C7, or between the mask-free lands provided next to the IC body. Determine which lands go to Ground, V+ and V-, and solder one each SMD ceramic cap between GND and V+ and between GND and V-.

Fasteners and grounding
PCB fasteners should not make ground connections to chassis. PCB ground should connect to chassis ground at a single point.

Capacitor C2 affects DC gain and it's 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 may actually degrade performance by violating rule Nr 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 large ball of metallic foil, effectively looking like an antenna, and exposing the audio signal to stray noise pickup.

ABOUT BYPASS CAPACITORS

Capacitorss 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 IC's 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 - 10,000 uF per channel) would cause them to be of such a size as to be difficult 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.

Overrating the voltage of electrolytic 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.

INVERTING OR NON-INVERTING?

Both inverting and non-inverting amplifier topologies have their strengths and weaknesses. Inverting op-amp configurations have long 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.
However, the input impedance of the inverting amp is essentially equal to the series resistor going into the inveting 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. It will be able to accept high impedance sources without loading.
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")
The non-inverting amplifier's input impedance is equal to the series resistor going into the inverting input. But 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 as low in value as practical 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 gounding point.
The white "star" mark on the top side of the PCB indicates the location of the star ground poiont. The ground plane also connects to other ground leads at this point

Zobel Network

Rz and Cz are component positions provided for an optional Zobel network. A Zobel network my be required in rare cases when the speaker loading causes oscillations in the amplifier. This may happen notably when paralleling two or more amplifiers for greater current output. Zobel component values must be determined experimentally, and are dependent on speaker voice coil, resonance, cable length and parasitics, and crossover network component values. An incorrectly sized Zobel network may be worse than no Zobel at all, and majority of commercial amplifier designs do not use a Zobel network. The kit as designed does not provide components for a Zobel network, and the component locations are provided only for users who are going further in their experimentation than the scope of the kit. A zobel network is used to solve a problem. It's need must be confirmed with an oscilloscope and component values determined experimentally. If paralleling amplifiers, a resistor/inductor network in series with each output will be required as well (off-board).

Using premium components.

Some vendors in the hobby amplifier arena promote a true fanaticism in seeking out the absolute most expensive parts to use in an amplifier. Actually, one of the basic rules of electronic design states that overall circuit performance must not be made dependent on the exact value and type of individual components, but on the arrangement of those components (layout, topology, design, call it what you will). Although using good quality components is always a wise approach, dwelling excessively on exotically expensive parts indicates both a lack of knowledge of electronic design, and a preoccupation with maximizing profits by creating a false science around expensive components. 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.

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 those 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 resistor values low to 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. Wire-wound resistors do not offer any improvement over metal film types, and they add a parasitic inductive component, unintended in the schematic.

Some information exists, indicating 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 higher than this figure, resulting in audible levels of 3-rd harmonic distortion, which does not appear to bother many audiophiles. HiFi 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 other 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, perhaps 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. The signal path begins to look increasingly more like an antenna.

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Kit Contents:

Capacitor, Electrolytic, 2200uF, 50V (4)
Capacitor, Electrolytic, 22uF, 50V (1)

Resistor, Metal Film 0.25W 1% 1K [Brown-Black-Black-Brown-Brown] (2)
Resistor, Metal Film 0.25W 1% 20K [Red-Black-Black-Red-Brown] (1)
Resistor, Metal Film 0.25W 1% 47.5K [Yellow-Purple-Green-Red-Brown] (2)
Resistor, Metal Film 0.25W 1% 953R [White-Green-Orange-Black-Brown] (1)
Capacitor, Epcos Polyester Film 1uF 63V (1)
Capacitor, Panasonic Polyester Film 0.33uF 63V (2)
Capacitor, Wima, Ceramic Surface Mount, 2.2uF, 100V (2)
LM3875TF Amplifier IC (1)
Printed Circuit Board (1)

Solder components starting with lowest profile parts (resistors) first.

The 1uF SMT capacitors should be soldered on the bottom of the PCB, between the legs of C5 and C7, after C5 and C7 are already in place. Wait at least 30 seconds after soldering one side of the cap, before soldering the other terminal, to avoid the electrolytic capacitor coming loose in the process. Handle the SMT capacitors gently, with tweezers, not with bare hands, and note that they are brittle. Do not flex the PCB and do not tighten it excessively so as to warp it when mounting.
Depending on the PCB, additional lands for soldering additional (optional) SMT capacitors may be provided between the supply rails. If SMT lands are provided for this purpose, then solder these capacitors to the lands between V+ and GND and between V- and GND. Also note that you will populate C2 OR C3 but not both (depending on inverting/noninverting choice)

Caution: the 1uF 100V SMT ceramic capacitors are fragile and brittle. Do not apply excessive heat to them.
Handle them with care. Never flex the PCB once these capacitors are installed. If damaged, they are difficult to replace, being easily the most expensive component in the entire kit.

A rectified and filtered power supply is needed, providing a minimum (+28V) - (0) - (-28V), maximum of (+42V) - (0) - (-42V).

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

Using premium components.

A knowledeable 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 with gold-plated equivalents, in an effort to feel that he has done ***someting*** 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. 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.

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 amout of distortion is of the order of 0.005 to 0.015%, by all measures inaudible to the human ear. Vaccuum 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 HiFi 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 does 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. Removeable 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 from a tank, may cause a part to be manufactured in ways not optimal for HiFi 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 hfe 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.

Kit Contents:

Capacitor, Electrolytic, 1000uF, 50V (4)
Capacitor, Electrolytic, 22uF, 50V (1)

Resistor, Metal Film 0.25W 1% 1K [Brown-Black-Black-Brown-Brown] (2)
Resistor, Metal Film 0.25W 1% 20K [Red-Black-Black-Red-Brown] (1)
Resistor, Metal Film 0.25W 1% 47.5K [Yellow-Purple-Green-Red-Brown] (2)
Resistor, Metal Film 0.25W 1% 953R [White-Green-Orange-Black-Brown] (1)
Capacitor, Epcos Polyester Film 1uF 63V (1)
Capacitor, Epcos Polyester Film 0.47uF 63V (2)
Capacitor, Wima, Ceramic Surface Mount, 1uF, 100V (2)
LM3875T or LM3875TF Amplifier IC (1)
Printed Circuit Board (1)

Solder components starting with lowest profile parts (resistors) first.

The 1uF SMT capacitors should be soldered on the bottom of the PCB, between the legs of C5 and C7, after C5 and C7 are already in place.
Wait at least 30 seconds after soldering one side of the cap, before soldering the remaining terminal, to avoid the electrolytic capacitor coming loose in the process. Handle the SMT capacitors gently, with tweezers, not with bare hands, and note that they are brittle.
Depending on the PCB, additional lands for soldering SMT capacitors may be provided between the supply rails. If SMT lands are provided for this purpose, then solder these capacitors to the lands between V+ and GND and between V- and GND.

Caution: the 1uF 100V SMT ceramic capacitors are fragile and brittle. Do not apply excessive heat to them. Handle them with care. Never flex the PCB once these capacitors are installed. If damaged, they are difficult to replace, being easily the most expensive component in the entire kit.

A rectified and filtered power supply will be required, providing a minimum of (+28V) - (0) - (-28V), and a maximum of (+42V) - (0) - (-42V).