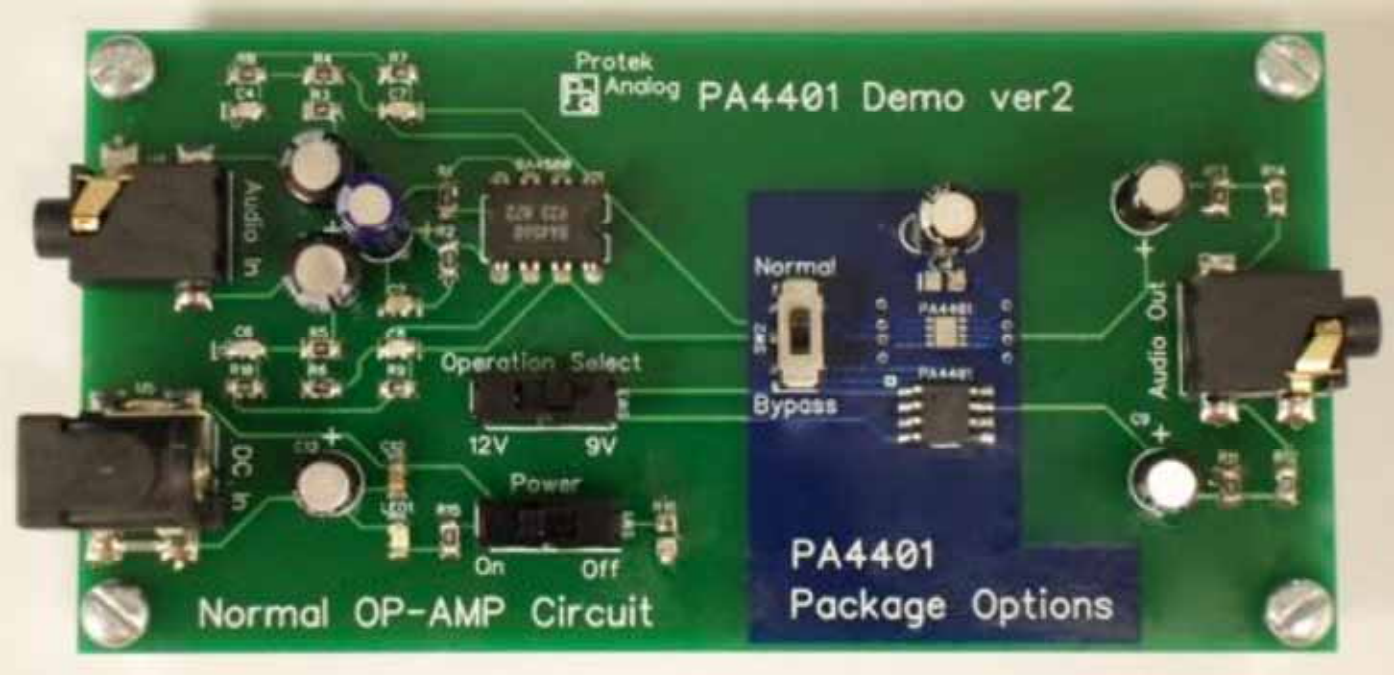
## Preamble

This document is a user's guide for operating the PA4401EB as well as providing documentation for using Protek Analog's PA4401 Series POP noise solution.




(Assembled board)

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## Product Description

The PA4401EB is a PCB that demonstrates the working of the PA4401 IC. The PA4401 provides click-pop suppression for devices that lack a POP noise startup or shutdown noise solution. The device is placed between the codec and/or amplifier and the output coupling capacitor. The click-pop noise is generated at the coupling capacitors while the device is starting up as well as shutting down.

The PA4401 controls the ramping of the DC voltage into the coupling capacitors thus reducing the click-pop noise generated during the startup and shutdown sequences. The start time can be controlled or changed using an external capacitor.

The evaluation board also contains an on-board a Dual Hi Voltage Operational Amplifier IC and two 3.5mm headphone jacks. This evaluation board is styled along the lines of a normal audio output stage following a CODEC in a set top box or equivalent unit.

The evaluation board has been designed to operate at a $V_{CC}$ of 9V or 12V DC. The PA4401EB has a slide switch that switches between “Normal” and ”Bypass” modes to enable the demonstration of the PA4401.

ESD protection circuits are provided at the inputs and outputs of the device. The PA4401 consumes less than 5mA of current and provides a THD of less than 1% for a load of 600 ohms.

The PA4401EB comes with either an 8L-SOIC or DFN-8 Package on the board.

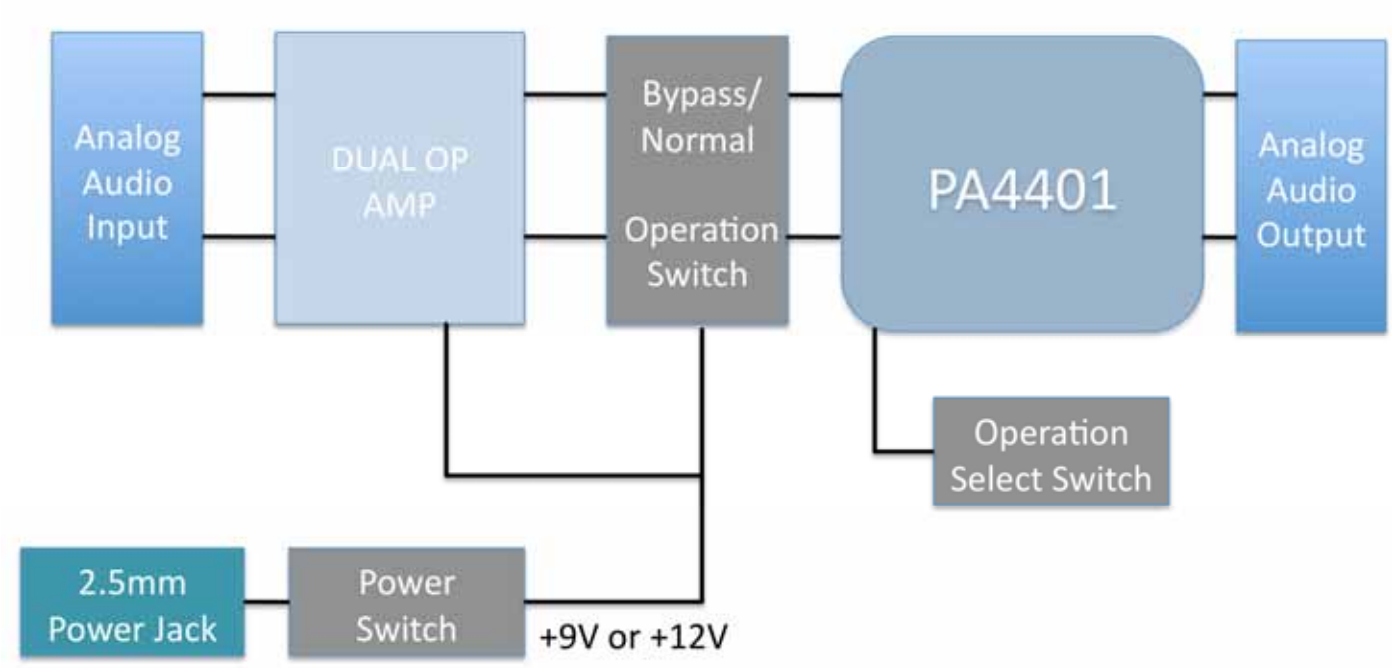


Figure 1: Block Diagram of the PA4401 Evaluation Board

## Features

The PA4401 evaluation board has the following features:

- +9V or +12V Operation
- Dual OP AMP (BA4560) on board
- 3.5mm headphone jack inputs and outputs
- Power Switch (provide power to the circuit)
- Operation Select switch (for +9V or +12V operation)
- Bypass Switch (demonstrate audio POP noise and muting audio POP noise)
- Greater than 3Vrms signal capability on the series switch lines with a 600Ω load
- Evaluates 4401DN (DFN-8) and 4401DQ (SOIC-8) packages

The PA4401EB replicates the analog output stage in the following, but not limited to, applications:

- Set-top boxes (STB)
- DVD players/Recorders
- Notebook Audio
- PC speakers
- Digital Video Recorders (DVR)
- LCD TVs
- Home Theater systems
- Projectors

## Operation Setup

Upon opening the PA4401EB, the following should be included on the board:

- All components listed on the Bill of Materials
- Either a PA4401DN or PA4401DQ on board

The user of the PA4401EB needs to provide the following to use the board:

- +9V/+12V Power supply (2.5mm ID, 5.5mm OD Power jack is provided on board)
- 3.5mm stereo plug for Analog audio input (ex: MP3 player can be used for audio input)
- 3.5mm stereo plug for Analog audio output (600Ω min load required)

Analog Audio Setup:

For Analog audio input, connect the analog input source with a 3.5mm stereo audio plug to audio jack labeled “Audio In” adjacent to the Power Jack connector.

For Analog audio output, connect the analog output source with a 3.5mm stereo audio plug to audio jack labeled “Audio Out” on the opposite end of “Audio In.”

Power supply setup:

The PA4401 is designed to operate at two voltages +9V and +12V. These are the ideal voltages to use on the PA4401EB. A different voltage supply may cause damage to the components on the board and/or external components used or may cause the board to not function properly. The preferred Power supply setup uses +9V or +12V, and current limit of 100mA.

Power supply Switch (SW1):

Using SW1 to provide power to the circuit ensures the proper rise and time for optimal performance of the PA4401. If this switch is not used during turn on/off of the board the PA4401 may not mute POP noise properly. Further information on this will be provided later in the documentation.

Operation Select Switch (SW3):

Using SW3 connects the PA4401 SEL pin to either GND or $V_{CC}$. This ensures proper operation of the PA4401. Use the following table to make the proper connection for optimal operation of the PA4401.

| PIN | POWER SUPPLY VOLTS | CONNECTION |
|---|---|---|
| Select (Pin 4) | +12V | $V_{CC}$ |
| Select (Pin 4) | +9V | GND |

Figure 2: Operation Select Switch connections table

## Component Selection

Power-Supply Decoupling Capacitors:

To ensure proper operation of the PA4401 proper values for decoupling capacitors should be used in order minimize any audio distortion during operation. PA4401EB uses a 10µF (C13) and a 0.1µF (C12) capacitor to ensure proper operation when using SW1 as the power supply to the circuitry.

$C_{EXT}$ Capacitor:
The $C_{EXT}$ pin has an external capacitor used to control the rate of the internal POP noise control circuitry. A larger capacitor value of $C_{EXT}$ has a direct relationship with the power supply turn-on time: a larger capacitor value will have a longer turn-on time and vice versa.

Conversely the power supply turn-off time will have an effect on the turn-off time for the voltage on the $C_{EXT}$ Capacitor. An optimal value should be used to establish a proper operation sequence. A large enough capacitor should be used in order to reduce the POP noise during the power supply turn-on sequence yet not have too large of a value that the PA4401 cannot discharge the voltage in time during the power supply turn-off time.

For example, a 4.7uF capacitor may be used to eliminate the POP noise of a system during turn on, but the PA4401 would not be able to discharge the capacitor if the circuit has a 50mS turn-off time. On the next power supply turn-on sequence there will be POP noise. Therefore a smaller capacitor value, like 2.2uF, should be the maximum capacitance value placed on the $C_{EXT}$ pin. (Note: a user can also change the system by configuring the circuit to have a longer turn-off time, allowing for an increase capacitor value)

| **Power Supply Turn-Off Time (mS)** | | **50** | **75** | **150** | **300** | **500** | **1000** |
|---|---|---|---|---|---|---|---|
| | **$C_{EXT}$ Values** | **$C_{EXT}$ Discharge Times (mS)** | | | | | |
| | **0.1µF** | 1.3 | 1.7 | 2.3 | 3.5 | 4 | 7 |
| | **1.0 µF** | 4.8 | 4.8 | 4.6 | 4.5 | 13.7 | 20.2 |
| | **1.5 µF** | 7.3 | 7.7 | 7.8 | 8 | 14.6 | 25.6 |
| | **2.2 µF** | 11.7 | 10.2 | 9.7 | 12 | 16.3 | 28 |
| | **4.7 µF** | N/A | 23.2 | 18.7 | 18 | 20.5 | 31 |
| | **10 µF** | N/A | N/A | 62.5 | 45 | 45 | 48 |
| | **22 µF** | N/A | N/A | N/A | 105 | 89 | 82 |

Figure 3: Turn-off Times for $C_{EXT}$ Capacitor

PA4401EB features a thru hole capacitor (C11) and surface mount (0805 package, C14) to use for $C_{EXT}$.

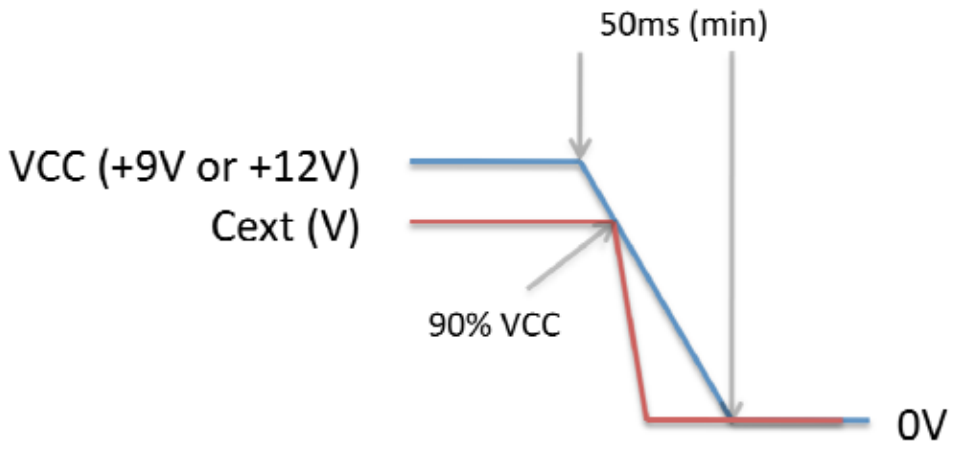


Figure 4: Linear Power Turn-Off Sequence

Figure 4 shows an ideal $V_{CC}$ turn-off sequence. The $C_{EXT}$ capacitor voltage is triggered at 90% of $V_{CC}$ and the PA4401 begins to turn-off muting any POP noise coming after $C_{EXT}$ reaches 0V.

There are also system designs where the Power turn-off is not a linear sequence as seen in Figure 5.

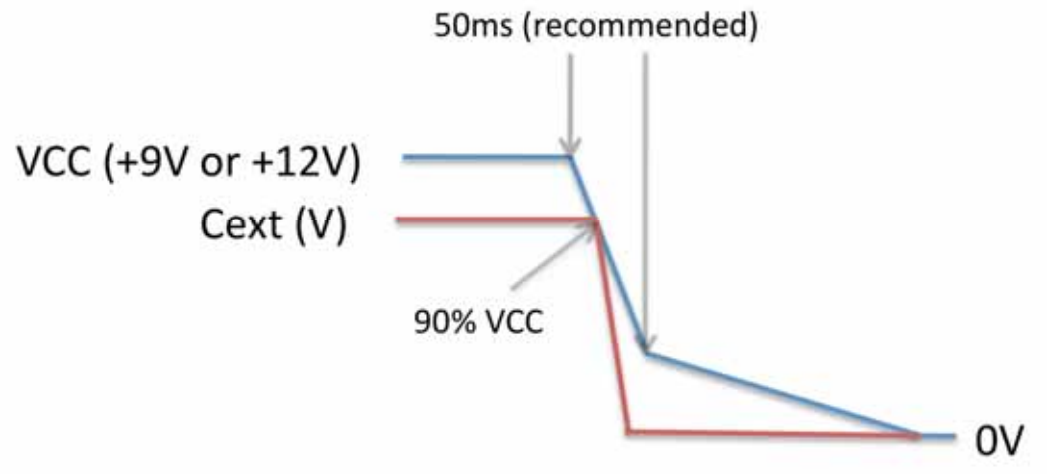


Figure 5: Non-linear Power Turn-Off Sequence

Figure 5 demonstrates an example for a non-linear power turn-off sequence that shows two different rates of discharge for $V_{CC}$. This shows that while although the Power turn-off time may be longer it would have a negative impact on the discharge of the $C_{EXT}$ capacitor.
At the point where the $V_{CC}$ changes the turn-off rate (from a faster rate to a slower rate) a POP noise may occur on the audio line, so it is recommended that the small enough capacitor should be used on the $C_{EXT}$ pin in order to ensure the POP noise during turn-off can be reduced. (Note: there are many different variations of what the $V_{CC}$ signal could look like for a turn-off sequence and not all of them are represented in this document)

## Performance

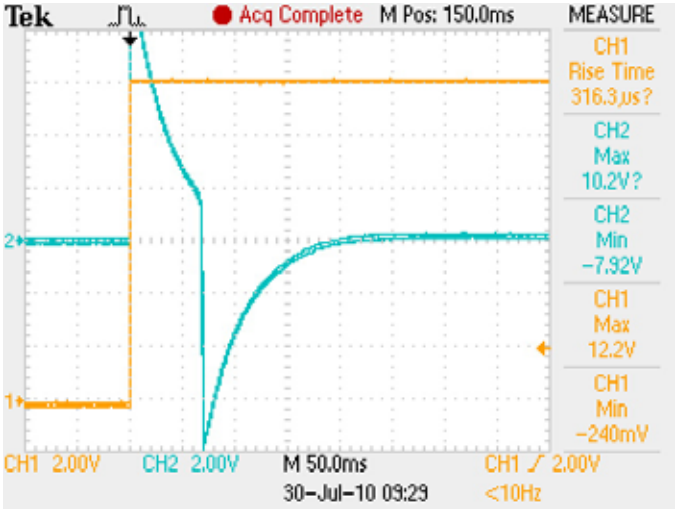


Figure 6: $V_{CC}$ vs. Audio Out (BYPASS)

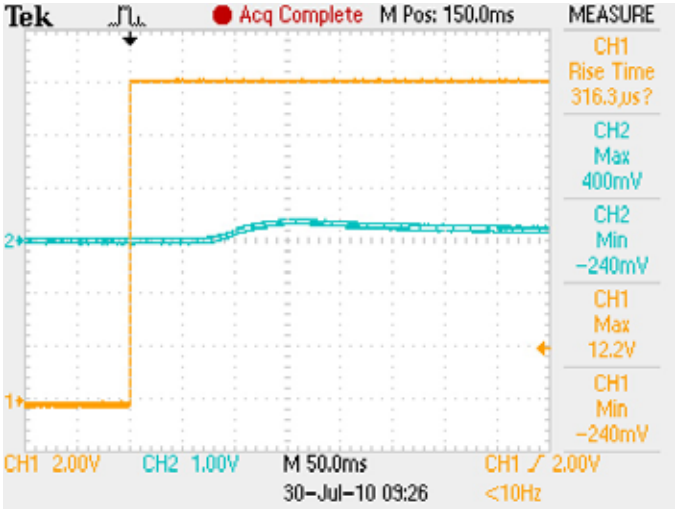


Figure 7: $V_{CC}$ vs. Audio Out (NORMAL)

As shown in the waveforms (Figure 6 and 7), the Startup waveforms demonstrate that in NORMAL mode the PA4401 reduces the audible level in the POP noise waveform (blue waveform) when compared to $V_{CC}$ (yellow waveform).

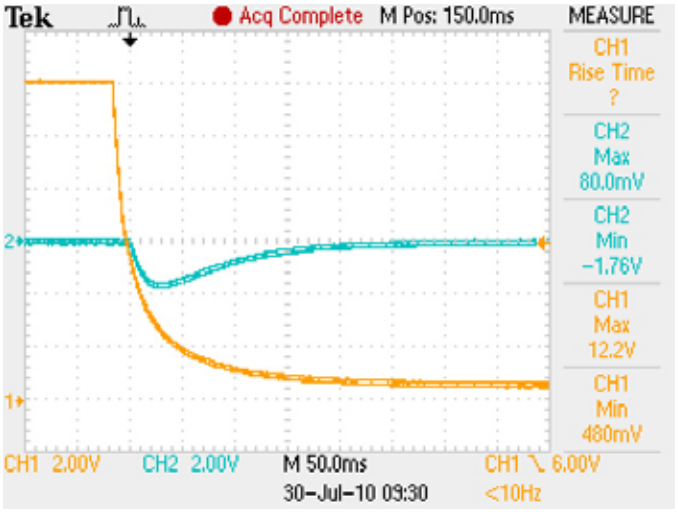


Figure 8: $V_{CC}$ vs. Audio Out (BYPASS)

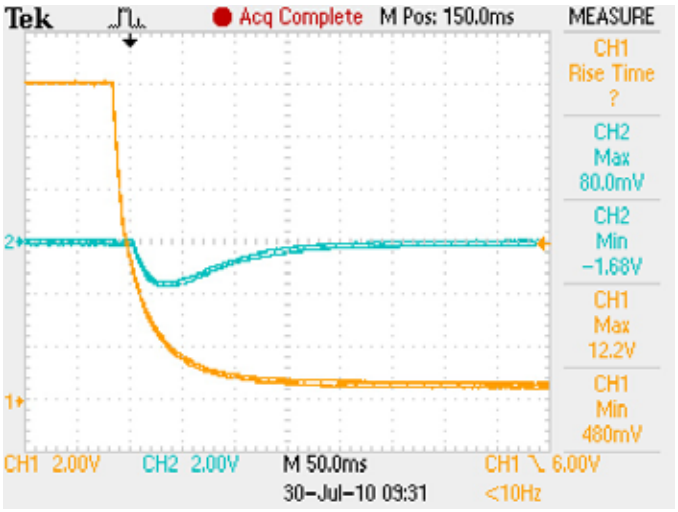


Figure 9: $V_{CC}$ vs. Audio Out (NORMAL)

As shown in the waveforms (Figure 8 and 9), the Audio Out signal (blue waveform) is unchanged. This is because the circuit is not producing on POP noise during shutdown of the power supply. The circuit is designed not to produce a POP noise during shutdown.

Note: Figures 4-7 were taken while using the Power Switch on board to the PA4401EB.

## Schematic(s)

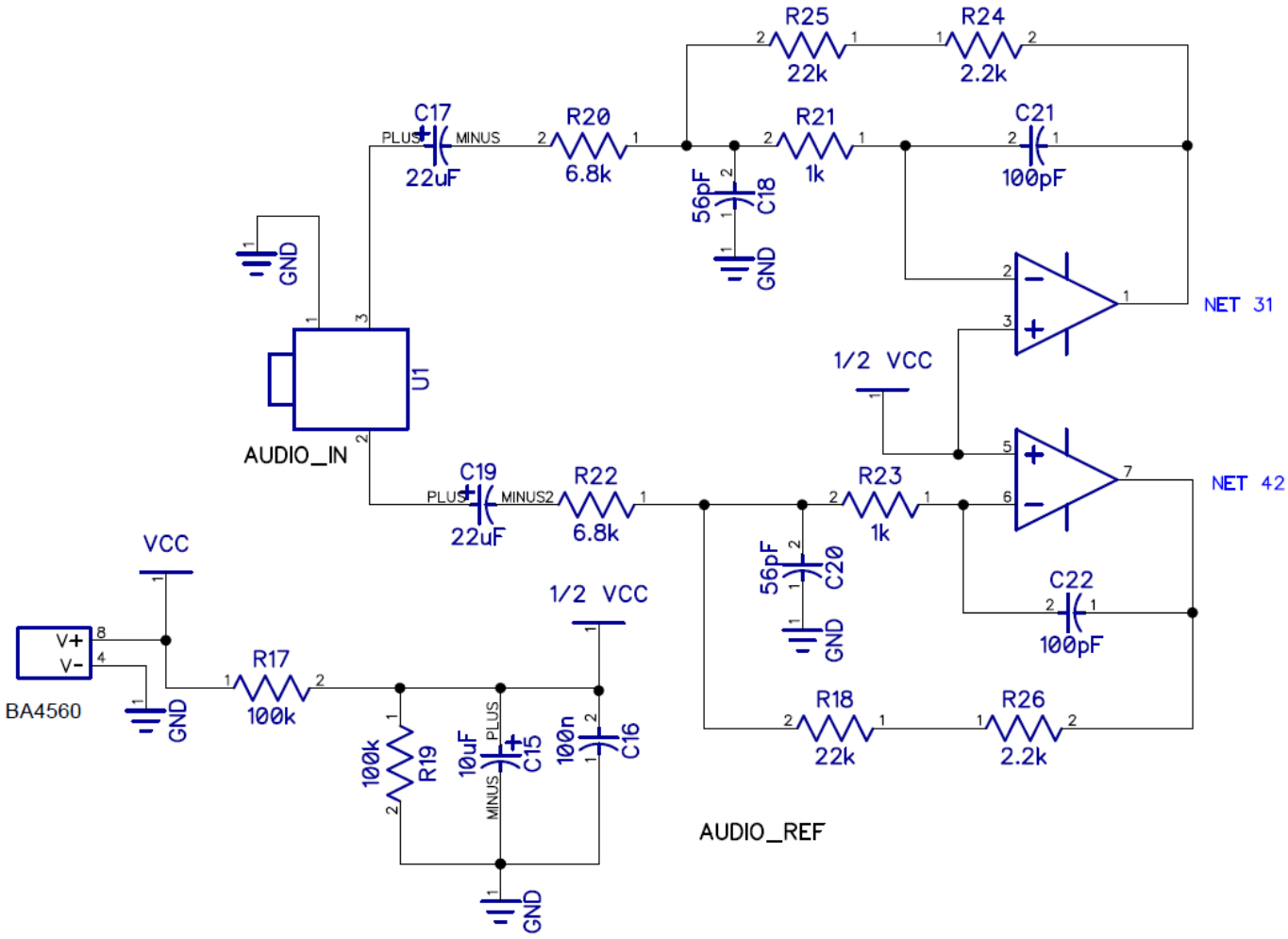


Figure 10: Dual OP Amp Schematic

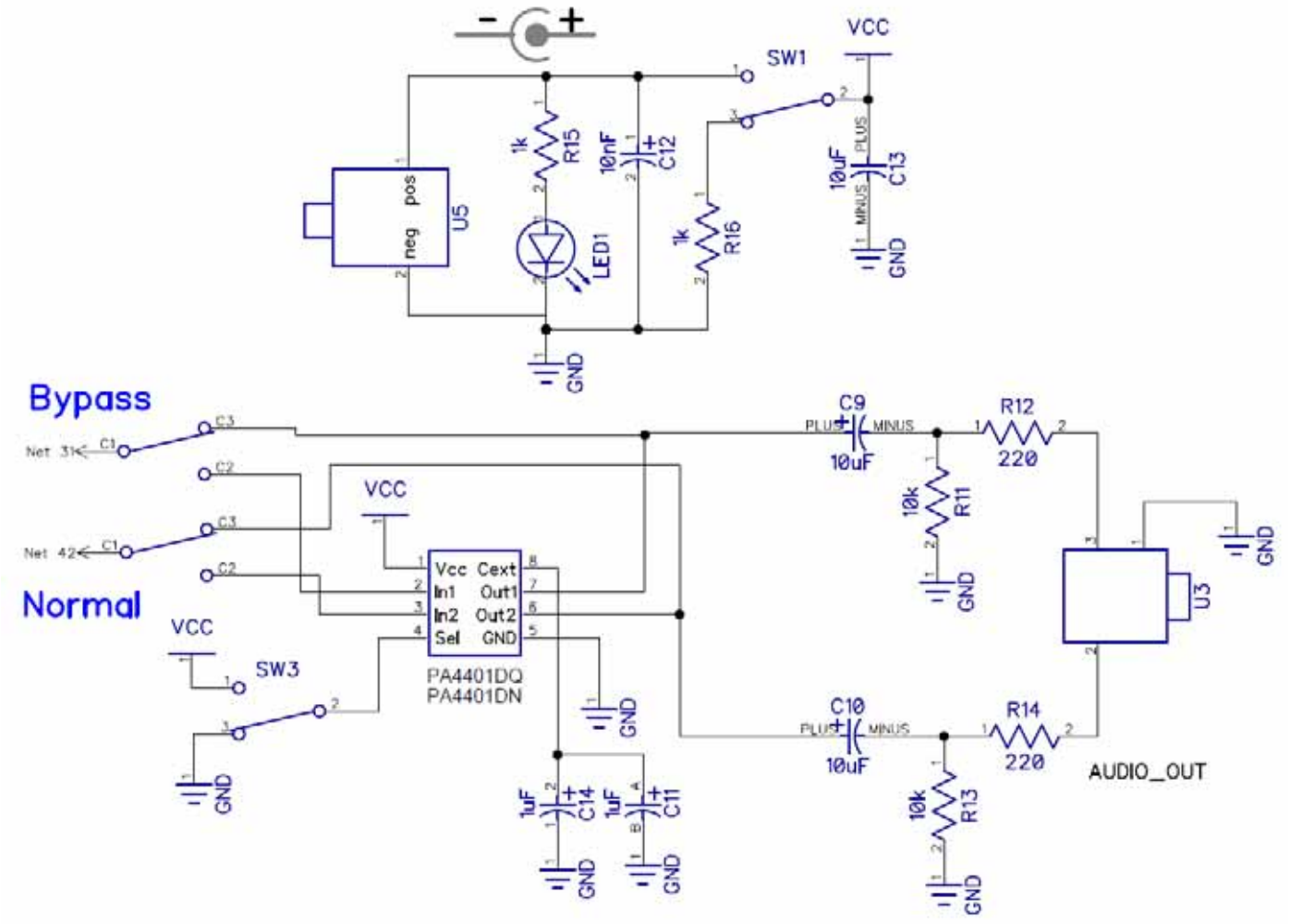


Figure 11: PA4401 and Power Connection Schematic

## Bill of Materials

| Part Reference | Package | Value |
|---|---|---|
| C1 | Through Hole | 10uF |
| C2 | SMT 0805 | .1uF |
| C3 | Through Hole | 22uF |
| C4 | SMT 0805 | 56pF |
| C5 | Through Hole | 22uF |
| C6 | SMT 0805 | 56pF |
| C7 | SMT 0805 | 100pF |
| C8 | SMT 0805 | 100pF |
| C9 | Through Hole | 10uF |
| C10 | Through Hole | 10uF |
| C12 | SMT 0805 | 10nF |
| C13 | Through Hole | 10uF |
| K1 | Through Hole | SPDT |
| K2 | Through Hole | DPDT |
| LED1 | SMT 0805 | Green LED |
| R1 | SMT 0805 | 100k |
| R2 | SMT 0805 | 100k |
| R3 | SMT 0805 | 6.8k |
| R4 | SMT 0805 | 1k |
| R5 | SMT 0805 | 6.8k |
| R6 | SMT 0805 | 1k |
| R7 | SMT 0805 | 2.2k |
| R8 | SMT 0805 | 22k |
| R9 | SMT 0805 | 2.2k |
| R10 | SMT 0805 | 22k |
| R11 | SMT 0805 | 10k |
| R12 | SMT 0805 | 220 |
| R13 | SMT 0805 | 10k |
| R14 | SMT 0805 | 220 |
| R15 | SMT 0805 | 1k |
| BA4560 | 8-DIP | Dual OP Amp |
| U2 | SMT | 3.5mm Stereo Jack |
| U3 | SMT | 3.5mm Stereo Jack |
| U5 | SMT | 2.5mm ID, 5.5mm OD |
| U6 | Through Hole | SPDT |
| PA4401 | 8-DFN or 8-SOIC | PA4401 |

Figure 12: Bill of Materials List

## Board Layout(s)

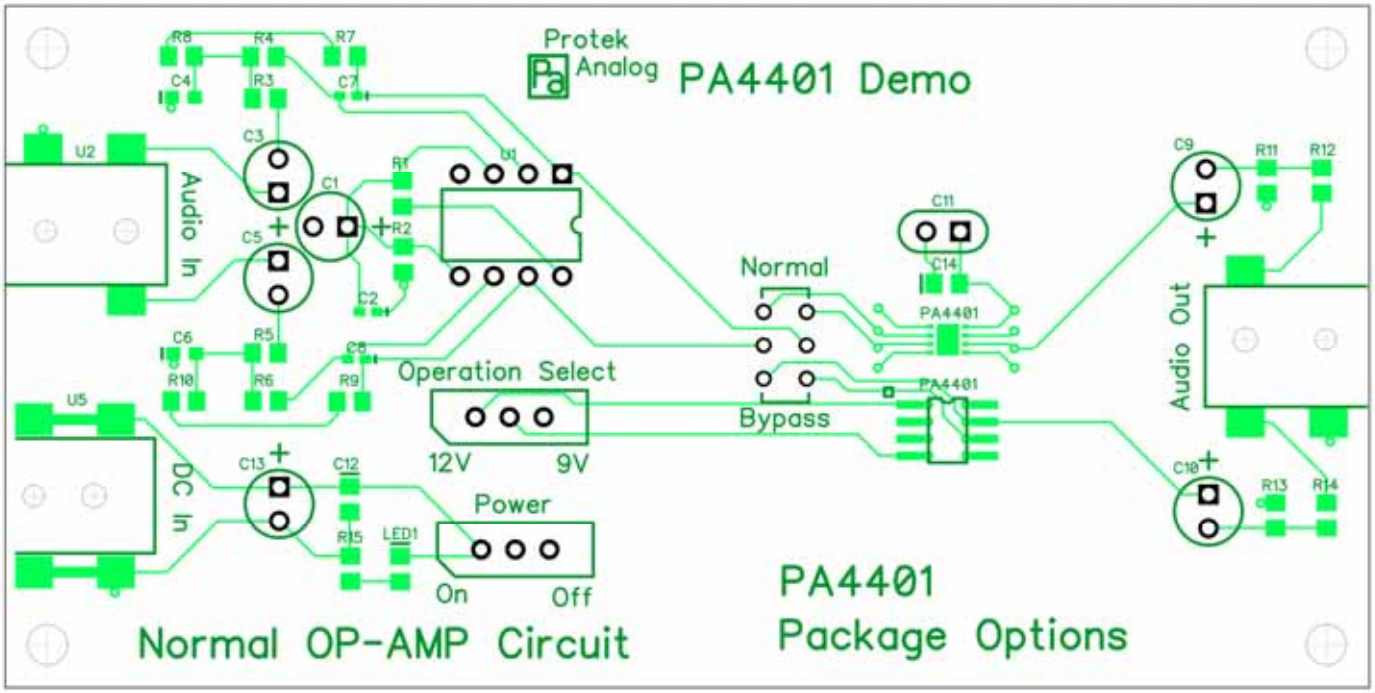


Figure 13: Top Side PCB Layout

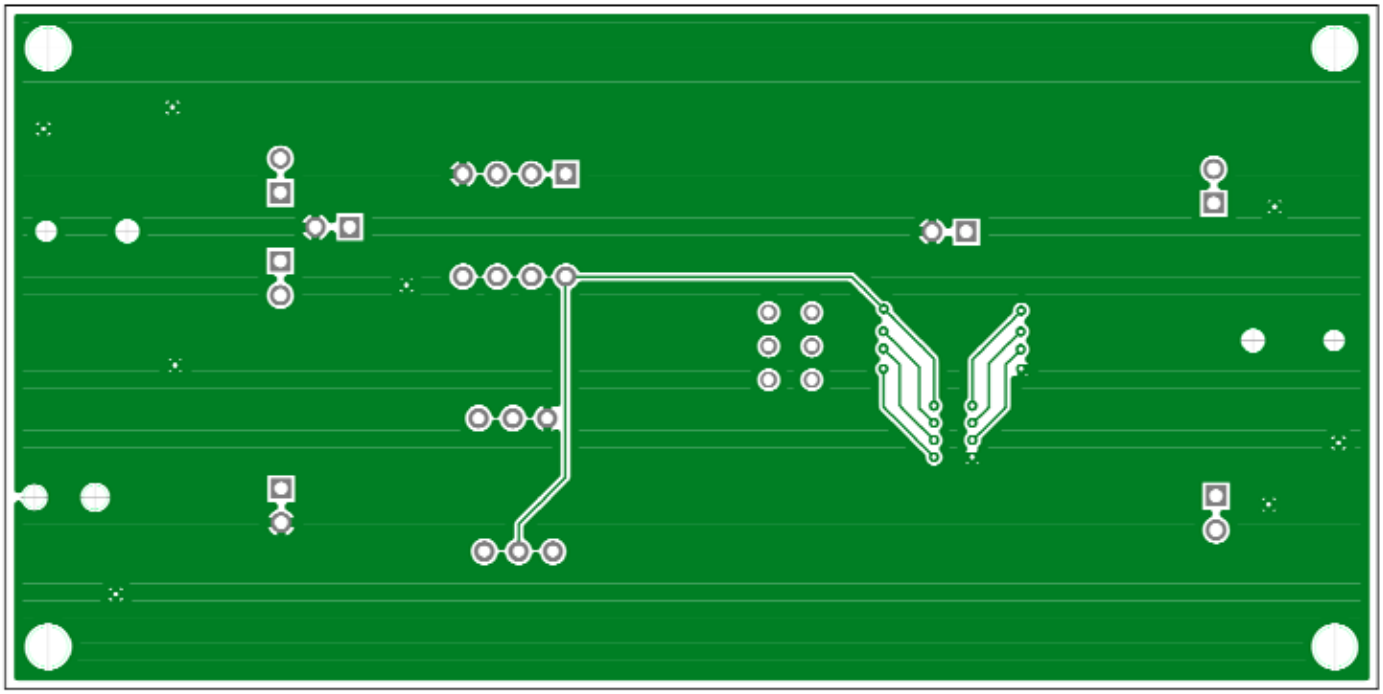

Figure 14: Bottom Side PCB Layout (looking through the top side)