CRD4235-8

Advanced Product Databook

FEATURES

- **WHQL™, PC 97, and PC 98 Compliant**
- **CS4610 PCI Audio Accelerator X-Link**
- **Integrated FM Synthesizer**
- **CrystalClear™ 3D Stereo Enhancement**
- **Integrated 3D-Sound Technology**
- **Demonstrates a 4-Layer Board Layout**
- **Includes a Design Guide Section**
- **Requires only 2.0 sq. in. to Implement**

ORDERING INFORMATION

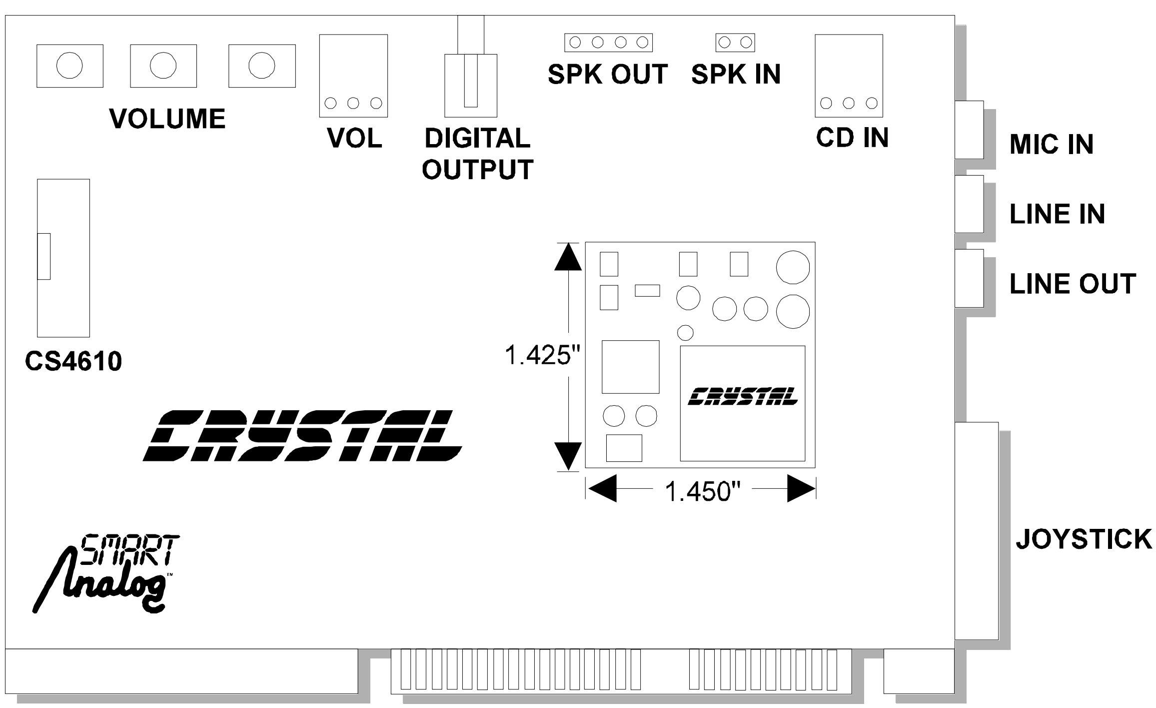
CRD4235-8 Reference Design

CrystalClear™ 16-Bit Audio Motherboard Example Design

DESCRIPTION

The CRD4235-8 is a CD quality reference design that is fully MPC3 compliant and compatible with Ad Lib™, Sound Blaster Pro™, and Windows Sound System™. Based on the CrystalClear™ CS4235 audio codec, it includes internal FM synthesizer, hardware master volume control with volume mute, extensive power management, and 3D sound technology.

The CRD4235-8 operates in both Plug-and-Play compliant systems, as well as, systems that do not support Plug-and-Play. In addition, this reference design includes the CS4610 X-Link PCI audio accelerator interface. The CrystalClear CS4610 is a high performance PCI audio accelerator. This reference design layout is representative of a typical motherboard implementation and requires only 2.0 sq. in.



CIRRUS LOGIC ADVANCED PRODUCT DATABOOK

GENERAL INFORMATION

The CRD4235-8 reference design is a PC-AT adapter card featuring the CrystalClear CS4235 Multimedia Audio codec. This reference design emphasizes the layout space requirements for a motherboard implementation, while delivering superlative audio performance at a low manufacturing cost. This design incorporates industry-leading CrystalClear Delta-Sigma conversion technology, and features a Plug-and-Play multimedia system on a chip. This highly integrated IC contains a full-duplex stereo codec with internal FM synthesizer, an MPU-401 interface, a joystick interface, and CrystalClear 3D stereo enhancement.

Included in this design are CD (red book) audio inputs, a low noise mono microphone preamplifier, and a line/headphone output amplifier. Additionally, stereo jacks are provided for mono microphone (**Mic In**) and stereo line inputs (**Line In**), as well as amplified stereo line output (**Line Out**). The dual joystick and MIDI interfaces are provided at the 15-pin D-shell connector. Support for the CS4610 PCI Audio Accelerator has been added through a buffered digital link.

Due to the nature of this reference design, it does not incorporate build options. However, cost, features, and performance trade-offs were carefully considered and optimized for the OEM.

Software that operates under the Microsoft® Windows™ environment is also included, along with applets that control all of the features supported by this reference design. This software also provides full Windows 3.1™ and Windows 95™ compatibility, with extensions to utilize the powerful features of this single-chip audio codec.

All aspects of the design have been optimized to ensure optimal performance at the lowest cost. Great care was taken with the signal routing and component placement to minimize sources which can degrade audio performance. Cirrus Logic analog design expertise has resulted in a board which preserves the exceptional analog performance of the CS4235 audio codec.

CS4235 Features

The CS4235 codec features an integrated FM synthesizer, a Plug-and-Play interface, hardware master volume control pins, and includes extensive power management and CrystalClear3D stereo enhancement. The CS4235 is compatible with the Microsoft Windows Sound System standard and will run software written to the Sound Blaster™ and Sound Blaster Pro interfaces. The CS4235 is fully compliant with Microsoft's PC '97 and PC '98 audio requirements. Please contact your local sales support for further information.

CRD4235-8 Card Features

The major features included on this reference design are:

Audio Codec, ISA Interface	Figure 1
Joystick/MIDI Interface	Figure 2
CS9236 (Not Supported)	Figure 3
Microphone Pre-amp	Figure 4
Line In	Figure 5
PC Speaker In	Figure 6
Line Out/Headphone Driver	Figure 7
PC Spker Driver (Not Supported)	Figure 8
CDROM Input	Figure 9
Hardware Volume Control	Figure 10
CS4610 Link	Figure 11
MIDI TXD Buffer	Figure 12

The CS4235 audio codec performs the analog-to-digital, digital-to-analog, and signal mixer functions. It also provides emulation for games and support for wavetable-based audio. Three externally accessible stereo jacks allow connections to the mono **Microphone Input**, stereo **Line Input**, and stereo **Line Output**. Headers allow internal connections to the CDROM drive's analog output (using the codec Auxiliary 2 inputs). The Plug and Play base addresses, DMA channels, and IRQ information needed for the codec has been programmed in the E^2PROM.

External Analog Inputs

The mono microphone input level is boosted 18 dB by the amplifier shown in Figure 4. For microphones with small signals, increased internal gain inside the codec can be enabled through software. The microphone amplifier input is single-ended (as opposed to differential), and supports most of the common microphones available. Phantom powered microphones with a stereo 1/8 inch plug are also supported, with power being supplied to the microphone via the ring portion of the connector.

The second input jack (shown in Figure 5) designated **Line In**, is for line inputs and connects to the AUX1 (Auxiliary 1) input of the analog codec through a -6 dB voltage divider. Each channel has an input impedance of approximately 12 kΩ. The maximum full scale signal into the **Line In** jack is 2 V_{rms} or 5.6 V_{pp}.

FM Synthesis

FM synthesis is achieved through Cirrus Logic internal FM synthesis. For a complete description, please refer to the CS4235 Data Sheet.

Plug & Play E^2PROM

The Plug and Play configuration data is contained in an external 8-pin E^2PROM. On power up or hardware reset, the codec detects the presence of the E^2PROM and transfers the E^2PROM contents into the internal RAM of the codec. An E^2PROM is recommended for all Cirrus Logic codec applications. Complete BIOS kits to replace the E^2PROM are also available.

The CS4235 has 768 bytes of internal RAM, therefore the size of the E^2PROM has been reduced to a 24C08. An E^2PROM is required for add-in cards to pass Microsoft Windows WHQL testing, since WHQL requires a unique vendor ID for certification. A 24C01 E^2PROM can be used to provide the unique OEM ID requirements, but no firmware updates or resource changes will fit into this smaller device. The 24C08 E^2PROM will allow full resource changes and firmware updates along with the OEM ID, and is the recommended device for designs requiring an E^2PROM. Please contact your Cirrus Logic representative for more information on the option of implementing the 24C01 E^2PROM.

Joystick/MIDI Interface

The 15-pin D-shell connector, shown in Figure 2, provides an interface to an external joystick and MIDI I/O. The joystick interface supports two joysticks, with two pairs of X/Y coordinates and four "fire" buttons. The codec internal pull-up resistors and external 1000 pF capacitors provide the correct debounce period for the joystick buttons. The joystick's physical position is calculated from an RC time constant. The timing for the joystick positioning is determined by the joystick potentiometers, the series 2.2 kΩ resistors and the 5600 pF capacitors. Deviations from the 2.2 kΩ and 5600 pF component values will result in improper joystick positioning.

MIDI inputs are received by an on-chip UART through a FIFO. The MIDI TXD and RXD signals are TTL level signals and not compatible with direct MIDI cabling. An external "break out" box attached to the 15-pin D connector interfaces the TTL MIDI signals to an isolated MIDI connector.

The 500 mA polyfuse shown in Figure 2, will limit the current to the joystick and MIDI break-out box, and complies with UL safety requirements. If the 500 mA rating is exceeded the polyfuse will trip, but will reset itself after being allowed to cool down.

Line Out/Headphone Drive

The third and lower-most jack is Line Out. The amplifier circuitry is shown in Figure 7. This low-noise, dual-function, amplifier reference design is intended to drive amplified speakers or line level signals at greater than 10 kΩ impedance with exceptional quality. Additionally, this amplifier design can deliver 31 mW of power and drive 32 Ω headphones at normal listening levels. The output jack has a maximum voltage of 1.4 V_{RMS}, with the amplifier gain fixed at 3.3 dB. By directly coupling the codec **Line Out** signals to the amplifier, a very flat low-end frequency response is achieved.

Microphone Pre-amp

A dual, low noise MC33078 op-amp comprises the microphone pre-amplifier as shown in Figure 4. One section of the op-amp is a unity gain buffer for the 2.1 Volt V_{REF} signal originated by the audio codec. The buffered 2.1 Volt reference provides a low noise source for phantom powered microphones, due to the excellent PSRR (Power Supply Rejection Ratio) of the op-amp, as well as setting the operating bias for the microphone pre-amp section. Phantom power is permanently applied through a 2.2 kΩ resistor to the ring portion of the microphone stereo jack. This is required for microphones which need a voltage bias on the right channel or ring of the microphone's plug.

The second half of the amplifier package is used as a high impedance, microphone pre-amplifier. The voltage gain of the amplifier is set at 18 dB, and corresponds to a maximum full scale of 146 mV_{RMS} at the microphone jack. The upper frequency response is set to -3 dB at 15 kHz, and the low frequency response is -3 dB at 25 Hz. The amplified output is AC coupled to the microphone analog input of the codec. A 78M05 voltage regulator supplies a clean analog +5 Volt supply for the microphone pre-amp, the headphone amplifier, and the codec analog section. The use of a single supply op-amp guarantees that under any conditions the output swing from the amplifier cannot exceed the maximum input limits of the CS4235 codec.

PC Speaker Input

This feature requires a cable, and uses the circuitry shown in Figure 6. Connect the cable, which goes between the PC speaker connector on the mother board and the PC speaker, to the **SPK IN** header. Pin 1 of the 2-pin cable connector, should be placed on pin 1 of the **SPK IN** header on the reference design card. The 4-pin side of the cable should be connected to the mother-board speaker connector, with pin1 of the cable connector and pin 1 on the mother board connector aligned. If the PC speaker beeps are not mixed into the codec, try reversing the connector on the mother board four pin connector, or the 2-pin connector on the audio card.

Volume Controls

This reference design implements external push-button switches for volume control for demonstration purposes: (VOL_UP), (VOL_DOWN), and (VOL_MUTE). The CS4235 codec supports two different volume control mute formats, with the format determined by the VCF1 bit in the E^2PROM or Host Load (BIOS kit).

An external connector is provided to cable external switches to the front of the PC. The hardware volume control schematics are shown in Figure 10. Please note the CS4235 codec requires the push button switch debounce capacitors values be increased to 10 nF. See the CS4235 data sheet for the complete details.

CS4610 Audio Accelerator X-Link

A 14-pin keyed connector is the link to the CS4610 high performance audio accelerator DSP for the PCI bus. For CS4610 applications which require ISA legacy support in hardware, this reference design supports a buffered, bi-directional serial link. This configuration is illustrated in Figure 11.

The CS4235 provides all analog audio converter functions in this configuration. Digital audio is transferred between the codec and the CS4610 via this proprietary, bi-directional serial channel. MIDI data from the codec MPU-401 UART is also transferred serially to the CS4610, which implements wavetable synthesis in hardware. Please see the CS4610 Data Sheet for a complete description of CS4610 features.

MIDI Buffer

Short circuit protection as illustrated in Figure 12, is included on the MIDI TXD signal connecting to the joystick. This transistor buffer circuit was included to protect the operation of the CS4610 and CS9236 wavetable synthesizer from external shorts on the MIDI TXD signal.

CRD4235-8 vs. CRD423xB-8 Differences

The PC board used on the CRD4235-8 and CRD423xB-8 are identical, but a different bill of material was used to assemble each kit. The component population option differences between the CRD4235-8 and CRD423xB-8 kits are shown in Table 1. The changes can be attributed to the use of the Cirrus Logic 3D audio circuitry, and the CS4235 audio codec which does not support mono (**PC SPK**) and S/PDIF outputs.

REF DES	CRD423xB-8	CRD4235-8
R13	0 Ω	No Pop
R14	No Pop	0 Ω
J8	Populate	No Pop
U1	Populate	No Pop
C32-33 C35-36	Populate	No Pop
RP26	Populate	No Pop
RP30	Populate	No Pop
R33	Populate	No Pop
C46	Populate	No Pop
J9	Populate	No Pop
T1	Populate	No Pop
R7-8	Populate	No Pop
C78	0.1 µF	0.01 µF
C77	No Pop	1000 pF
C58-59	470 pF	No Pop
U7	CS423xB-KQ	CS4235-KQ
RP20	Populate	No Pop
RP22	39 kΩ	82 kΩ
RP25	27 kΩ	56 kΩ
C20-22	100 pF	0.01 µF

Table 1. Bill of Material Differences

DESIGN GUIDE INTRODUCTION

This design guide is presented to educate customers using the Cirrus Logic Delta-Sigma audio codecs with printed circuit board layout requirements. The intent is to achieve maximum audio quality, and meet FCC and international EMC (Electromagnetic Compliance) requirements. While these two goals are usually mutually exclusive, this design guide will illustrate some generally accepted methods to achieve both optimum audio quality, and the reduction of Electromagnetic Interference (EMI).

Of course, the implementation of these methods will vary for each particular PCB platform, and each suggestion should be considered for its individual merits and cost trade-offs. A checklist at the end of this section is provided for review both during and after card layout. And while superb audio performance is always desirable, Cirrus Logic is also very aware of our customer's need for manufacturability. Based on input from our customers, techniques for increasing manufacturing yields will be discussed in this section.

Audio Design Fundamentals

To achieve CD-quality audio internal to the personal computer requires attention to both the digital and analog portions of the audio subsystem. A large portion of the PC is dominated by high speed digital circuitry, which is relatively insensitive to noise. This is not true for the analog audio section. The typical line-level audio signals are 2 V_{RMS}. To achieve a dynamic range of 90 dB requires the noise to be 67,000 times smaller. That translates to a noise floor level of only 30 μV_{RMS}. By using the techniques described in the following sections, a dynamic range of greater than 90 dB can be achieved.

Connecting Analog Ground to Digital Ground

The best implementation to ensure that interactions between analog and digital signals will be minimized, is isolating each circuit area on separate analog and digital ground planes. It is very important the analog plane and digital plane be tied together at some point to establish a common voltage between analog and digital sections of the audio codec. Without a common tie point, severe damage to the CS4235 audio codec may occur. In most layouts, the best tie point is close to a chassis ground location, at the analog voltage regulator, or at the power supply connector entry point. A wide copper connection permanently etched into the printed circuit board provides a good connection between both grounds at all frequencies.

Flux Contamination

Contamination from water base flux can leave residue under the crystal oscillator and audio codec. This residue can be conductive, causing digital noise to couple into the audio paths. This coupled noise may take the form of buzzing, clicks, or whines. In some instances, the contamination is so great that it causes total failure of the audio codec. Complete and proper cleaning of the boards after assembly is essential. This reference design board includes techniques that help minimize flux contamination. For example, sealing all vias on the component side with solder mask, but leaving a "vent" hole in the solder mask on the solder side.

Additionally, the lead spacing of the 16.9344 MHz crystal was widened slightly from the normal recommended value to raise it higher off the PCB. Raising the 16.9344 MHz crystal further off the board allows for better cleaning under the crystal and prevents the accumulation of contamination.

Voltage Regulator Selection

Linear regulators provide up to 80 dB of power supply noise rejection. When properly used, they can help eliminate mouse, disk drive, and digital noise. Consider using at minimum the 500 mA 78M05 regulator when selecting components. Many designers implementing PC audio choose to substitute the recommended 78M05 voltage regulators with the 78L05. 78L05 voltage regulators do not usually meet the current requirements of the audio system. Base the calculations on the ±5% PC voltage tolerance and maximum internal PC operating temperatures of 55° C. Under these conditions, all voltage regulators must be derated, and the actual maximum current available from the 78M05 is only 220mA.

As illustrated in the following formulas, the National Semiconductor 78L05 regulator, at worst case operating conditions, can only supply 39 mA of current before reaching thermal shutdown. The analog current requirement for the audio codec is 35 mA, and the TDA1308 amplifier driving 32 Ω headphones will require an additional 100 mA of current. It's evident that the 78L05 series of regulators are not adequate for this task.

Calculating the available current of any voltage regulator can be determined by following the example:

National Semiconductor 78L05 (TO-92)

T_J = Junction temperature

T_A = Ambient temperature

J_A = Thermal resistance (junction to ambient)

P = Power dissipated

V_{OUT} = 5 V (±5%)

STEP 1

From National Semiconductor data sheet find J_A and T_J for the 78L05.

J_A = 230° C/W (Thermal resistance)

T_J = 125° C/W (Junction temperature max)

STEP 2

Determine the power (heat) this package can dissipate in 55° C ambient air.

$P = T_J - T_A/J_A$

P = (125° C/W) - (55° C)/230° C/W = 304 mW

The maximum power this device can dissipate in 55° C ambient air is 304 mW.

STEP 3

Determine the voltage drop across the voltage regulator at worst case conditions.

$V_{IN} - V_{OUT} = V_{DROP}$

12 V @ +5% = 12.6 V

5 V @ -5% = 4.75 V

12.6 V - 4.75 V = 7.85 V (V_{DROP} of regulator)

STEP 4

Determine the maximum current based on the power dissipation and voltage drop.

I = P/E

$I_{(MAX)}$ = 0.304 W/7.85 V

$I_{(MAX)}$ = 39 mA

The maximum current available from National Semiconductor 78L05 voltage regulator is **39 mA** during worst case conditions.

Power & Ground Planes

The Cirrus Logic CS4235 audio codec integrates multiple functions into a single TQFP package and can be thought of as having three distinct functions:

- ISA Bus interface

- Digital processing
- Analog processing

The ISA Bus interface connects directly to the +5 Volt source. The Digital processing sections should have filtering of the +5 Volt source provided by ferrite(s) and capacitors. The use of the linear voltage regulators for the analog audio section and analog amplifiers is strongly recommended.

This reference design partitions both the power and ground planes in the audio section and connects them together to create two analog ground planes. This is shown on Figures 16 and 17. The analog signals can now be routed on both the component and solder side layers, with an analog plane directly beneath the analog traces. Use vias to connect the two analog planes together wherever a signal changes from one plane to the other to prevent ground loops.

Analog power is routed to the analog amplifiers with a wide power trace. This trace is only wide enough to supply adequate current capabilities, since the goal is to reduce area and therefore coupling to the analog plane. Another benefit of using multi-layer PCBs is the placement of power and ground planes adjacent to each other. This physical relationship creates a large decoupling capacitor. In fact, power and ground planes separated by a 0.01 inch of FR-4 material will form a capacitance of 100 pF/sq. inch. This technique can usually provide adequate decoupling for low-speed designs with signal edges of 10 ns or slower.

High frequency currents do not flow in the center of traces or planes, this phenomena is called “skin effect”. The skin depth of copper is extremely shallow above 30 MHz, and the use of 1ounce copper planes will have no additional benefit over 1/2 ounce planes.

Clock Traces

The CrystalClear delta-sigma oversampling converters offer significant performance advantages over Nyquist sampling successive approximation methods. Delta-sigma converters are less susceptible to the effects of clock “jitter” than successive approximation converters. However, careful placement of the clock traces are still necessary to prevent coupling from external digital noise sources.

Testing has shown that a 2 ns white noise clock jitter can degrade the dynamic range of a 16-bit ADC from 98 dB to 91 dB. To combat the effects of clock jitter, locate crystal oscillators over an isolated ground plane and never use a socket. In addition to their effects on audio dynamic range, clock signals are the greatest contributors to the generation of RF energy, and should be manually routed on the PCB first. Never place a clock trace along the edge of the board or next to an I/O cable. Avoid routing any other traces under or near the clock areas.

Microstrip refers to the outer traces on a PCB, which are separated by a dielectric and a solid plane. Stripline refers to traces sandwiched between two solid planes (voltage or ground). Stripline provides better noise immunity for RF emissions. Stripline has been used on this reference design to route the CS4610 digital clocks, including the 16.9344 MHz (MCLK) between the audio codec and the CS4610 link connector. When using common FR-4 PCB material, these simplified equations can be used to determine the maximum length for clock lines for both microstrip and stripline:

$L(_{MAX}) = 9 \times t(r)$ (microstrip)

$L(_{MAX}) = 7 \times t(r)$ (stripline)

$L(_{MAX})$ = length in cm & t(r) = edge rate in ns

For example, if the clock edge is 800 ps, the maximum length is 7.2 cm or 2.9 inches. A signal trace greater than 7.2 cm (2.9 inches) would exhibit signal reflection (ringing) and must be treated as a transmission line.

Ground Loops

One of the most important design considerations for EMI suppression is the control of ground loops. They are the major contributor to the propagation of RF energy. RF currents will attempt to return though any available path or medium: components, ground planes, adjacent traces, and so forth. During board layout, keep in mind that current will always attempt to flow back under a trace to the current source.

In any PCB, a choice must be made between two basic types of grounding methods, single-point ground and multi-point ground. This reference design uses single-point grounding in the analog I/O section and multi-point grounding in the digital sections. This is acceptable since the design allows for isolation between planes and functional sections. Single-point grounding is preferred when speeds are 1 MHz or less, and commonly used with audio circuits. However, at higher frequencies, the impedance of the power and interconnect traces can become very high, especially if the lengths coincide with odd multiples of a quarter-wave of the edge rate of periodic signals (clocks).

High frequency digital designs generally require use of multi-point ground connections. This method was used in the reference design ISA digital section. Low-inductance grounding is necessary on any PCB containing digital logic circuits. Ground planes internal to the PCB generally provide a low-inductance ground return for the power supply and signal currents.

During PCB layout, do not allow excessive use of through-holes in the power or ground planes. The anti-copper relieve areas around the through-holes will add together and "cut up" the ground plane.

Partitioning Planes

Most good audio designs incorporate partitioning or isolation between functional subsection areas to prevent coupling. Partitioning is physically separating functional areas with gaps on the PCB. Partition the slow analog signals from high speed digital signals, even on two layer boards. Partitioning functional areas minimizes trace lengths and signal reflections, allowing the circuit designer to control the flow of currents in the PCB. Figure 16 illustrates the SGND partition to keep unwanted random digital currents out of the digital audio portions of the codec. Switching currents generated by the codec itself will be synchronous with the codec clock and will be filtered out.

Each I/O should be considered as a different subsection on the PCB, since each may be unique in its particular application. The analog I/O, analog amplifiers, digital and filtered digital sections have been partitioned to control the flow of switching currents. For example, the ADC section of the audio codec is sensitive to frequencies at 5.6 MHz ±22 kHz. Any frequency in the range of 5.63 MHz through 5.67 MHz that couples into the ADC will show up as a "tone" in the audio frequency. Partitioning helps prevent this type of interference from occurring.

Component Selection

The use of SMT (surface mount technology) components are preferred over through-hole components for minimizing RF emissions. This is due to the shorter lead lengths and the resulting lower inductance. SMT components also have a smaller "ground loop size" due to the smaller package size. Decoupling and bypass capacitors are affected by their lead length and PCB trace length, since they become inductive above their self resonance. For this reason SMT capacitors are generally better for decoupling because their self resonance is ten times higher than leaded devices.

Avoid IC Sockets

The greatest contributor to RF energy is the edge rate of the device, not the actual operating frequency. For example, a 1.5 ns edge of a digital device will generate spectral energy at 212 MHz. Sockets will add additional lead length inductance and potentially greater amounts of EMI. Some audio designs use sockets for the CS9236 wavetable parts. Exercise care, since sockets are potentially an EMI problem, due to the combined effects of the socket lead inductance and the sharp edges of the 16.9344 MHz clock trace (MCLK).

20-H Rule

RF currents exist on the edges of power planes due to magnetic flux linkage. This is called fringing, and is generally observed in very high speed logic circuits. To minimize this fringing effect, all digital power planes should be physically smaller than the corresponding ground plane per the 20-H rule. 20-H is defined as 20 times the distance between the power and ground planes. On a 4-layer PCB this calculates to about 0.125 inches.

Printed circuits with power and ground planes have self-resonant frequencies between 200 MHz and 400 MHz. Using the 20-H rule will increase this self resonance by a factor of two or three. Also, the distance between the power and ground plane can be adjusted to affect this self resonance. Serious EMI problems can occur when frequencies approach this self resonance, because the assembled board can become an unintentional transmitter. The +5 V digital power plane on this reference design is 0.125 inch smaller than the digital ground plane to increase the self resonance frequency. This is illustrated on the power plane in Figure 17.

Avoid VIAs

Avoid the use of vias whenever possible, especially when using decoupling capacitors or in the clock traces. Vias add approximately 1 to 3 nH of inductance per via, which can defeat the function of the decoupling capacitors and cause signal quality problems.

Decoupling Capacitors

Decoupling capacitors are required by the audio codec to provide sufficient DC voltage and peak surge current for proper operation during clock or data transitions. This is especially true when the ISA bus signal pins switch simultaneously under maximum load. Locate decoupling capacitors on the component side, close to the codec power and ground pins, and avoid the use of vias if possible.

In certain applications, two decoupling capacitors in parallel are required to provide greater spectral bandwidth RF suppression. The parallel capacitors should differ by a factor of 100 times for optimal performance. Parallel capacitors typically provide a 6 dB improvement for suppression of RF currents. When used with power and ground plane, a “triple decoupling” is achieved. This reference design utilizes both techniques on the ISA bus power pins. A 0.1 µF and 0.001 µF capacitor are placed in parallel, with the 0.001 µF capacitor placed closest to the power pins.

Bypass Capacitors

Bypass capacitors remove unwanted RF energy that couples common-mode EMI into susceptible areas, and removes RF energy generated on power planes by high-frequency switching. 100 pF capacitors have been placed on the analog I/O connector pins and ISA power pins to provide additional protection from RF currents generated by both signal traces and power planes.

Bulk Capacitors

Bulk capacitors (10 µF minimum) are used to maintain constant DC voltages and currents to the audio codec when all signal pins switch simultaneously under maximum capacitive load. Bulk capacitors should be primarily located at the opposite edge of the power entry points. It is also good practice to include bulk capacitors at the power entry points if feasible.

Ground Guards & Signal Spacing

Ground guards (ground traces running between signal traces) are particularly useful at reducing the signal loop areas of clock signals on two-layer boards. As as an example, the ISA bus signals on this reference design have been separated with ground guards between signal paths. Since the ISA bus traces can be a transmission path for RF energy, these guards act like an electrical “short” to EMF induced fields generated by the digital switching currents. With 4-layer boards, the “3-W” rule can also be used as an adequate flux boundary if space is not a problem. The 3-W rule can be defined as three times the width of the signal trace, measured center to center. In plain terminology, “if the trace is 6 mils, the gap is 12 mils.”

Chassis GND Connectors

Quiet areas are sections of the PCB that are physically isolated from digital circuitry, analog circuitry, power planes, and ground planes. Each and every I/O port or section should have a partitioned (quiet) ground/power plane. The lower-frequency audio and joystick I/O ports may be bypassed with high-frequency capacitors (100 pF to 470 pF) located near the connector pins.

This reference design implements a quiet or “clean” ground by creating a partition or moat in the analog I/O areas. Isolation is created by the absence of copper on ALL planes or layers of the reference design. This moat serves as a keep-out area for signals or traces. Additionally, the analog signals are routed internally and protected by clean chassis ground “grids”. Ground grids are just as effective in the suppression of RF energy as solid copper. An additional benefit of the grid is that the boards are easier to manufacture, because the grids provide a consistent copper “etch” across the entire PCB.

EMI Containment

A cost effective method to contain the common-mode RF energy inside the PC is achieved by using ferrite beads to “bridge” the moat between chassis, analog, and SGND signals. This method involves the use of ferrite beads and 100 pF bypass capacitors connected to the clean chassis ground. High frequency RF energy is dissipated in the form of heat by the lossy ferrite material. At high frequencies, the 70 Ω impedance of the ferrite material and the bypass capacitors form a low pass filter. The critical frequency formed by this filter is approximately 5 MHz. A 5 MHz signal would be attenuated 3 dB by the low pass filter, and a 214 MHz frequency would be attenuated by 40 dB.

DESIGN GUIDE CHECKLIST

This ckecklist should be used by the audio circuit designer and board layout specialist as a general guideline in the planning, layout, and review process to insure the highest sound quality.

- ❑ Connect analog ground to digital ground at a chassis ground tie point, analog voltage regulator, or at the power supply connector. Severe damage to the audio codec will occur without a solid connection between the analog and digital grounds.
- ❑ Avoid using vias under the audio codec to reduce the risk of flux contamination, or use solder mask to cover the vias. Modify the spacing of through hole crystals to suspend them off the printed circuit board to aid the cleaning process.
- ❑ Select the proper size voltage regulators (do not use a 78L05). Use the regulator calculations shown earlier in this document as an example.
- ❑ Use multi-layer boards with internal power and ground planes to improve audio performance and EMI compliance. Do not overlap digital and analog planes.
- ❑ Partition the audio circuitry in one section and the digital circuitry in another. The separation should be duplicated on all layers including the power and ground planes.
- ❑ Route analog signal traces only above the analog ground and digital traces above the digital ground.
- ❑ When placing audio on a mother board, never create an audio "island" in the center of the board. The audio partitions should be located at the edge of the board.
- ❑ Analog and digital grounds should be connected together at one point. This reference design connects these two planes together with a ferrite bead next to the power supply pins. Provide other locations for alternative connections, then characterize the audio performance for the optimum location.
- ❑ Decoupling capacitors should be located next to the component power supply pins, connected with short traces. Avoid the use of vias on decoupling capacitors. Using two different decoupling capacitor values will increase the spectral bandwidth RF suppression.
- ❑ Use bypass capacitors at I/O locations to remove unwanted RF energy. Use SMT components for bypassing, since their self resonance is ten times greater than leaded components.
- ❑ Use ground guards in the high speed digital sections to reduce magnetic coupling between signal traces.
- ❑ Route clock traces first, on internal layers if possible, and never near the edge of the printed circuit board.
- ❑ Use quality amplifiers with low noise numbers to drive analog signals. Using single supply op-amps on the microphone inputs avoids the risk of negative voltage transients.
- ❑ The +5 Volt supply to the joystick (pins 1, 8, and 9) must be current limited to comply with UL safety regulations. Do no use the +5 VA voltage regulator to limit the current supply. A polyfuse is desirable, since it will reset itself when allowed to cool down. A 78L05 voltage regulator will work well also.

ACCESSORIES

The five accessories that are included with this reference design kit:

1) A 6 foot cable that has a 1/8 inch plug on one end, and two male RCA phono plugs on the other end. The RCA phono plugs connector scheme is:

   TIP = LEFT = BLACK or ***ORANGE***
   RING = RIGHT = RED or ***GRAY***

2) A short 6 inch cable that has RCA female connectors on one end and a 1/8 inch plug on the other. The RCA phono plugs connector scheme is:

   TIP = LEFT = BLACK
   RING = RIGHT = RED

   These two adapters allow connection to most external audio equipment. Together they provide an 1/8 inch plug to 1/8 inch plug cable. Apart, they provide a 1/8 inch plug that connects into the audio jacks with the other end being RCA male and RCA female phono plugs.

3) Telex “Voice Commander II” phantom powered microphone.
4) PC Speaker In cable.
5) CD-ROM Audio Cable.
6) CDROM with device drivers and documentation.

SCHEMATICS

The following pages contain the full schematics for this reference design, along with board layout gerber plots and the Bill-Of-Materials.

DESIGN GUIDE REFERENCES

1) Montrose, Mark I. 1996. “Printed Circuit Board Design Techniques for EMC Compliance.” Institute of Electrical and Electronics Engineers, Inc. N.Y., New York.
2) Harris, Steven. 1989. “The effects of Sampling Clock Jitter on Nyquist Sampling Analog-to-Digital Converters, and on Oversampling Delta Sigma ADC's.” Crystal Semiconductor Audio Databook, 1994. Cirrus Logic, Inc., 4210 South Industrial Drive, Austin, TX 78744.
3) “Delta Sigma A/D Conversion Technique Overview.” Crystal Semiconductor Audio Databook, 1994. Cirrus Logic, Inc., 4210 South Industrial Drive, Austin, TX 78744.
4) Knapp, Ron. Harris, Steven. “Layout and Design Rules for Data Converters.” Crystal Semiconductor Audio Databook, 1994. Cirrus Logic, Inc., 4210 South Industrial Drive, Austin, TX 78744.
5) Harris, Steven. “How to Achieve Optimum Performance from Delta-Sigma A/D & D/A Converters.” Crystal Semiconductor Audio Databook, 1994. Cirrus Logic Inc., 4210 South Industrial Drive, Austin, TX 78744.

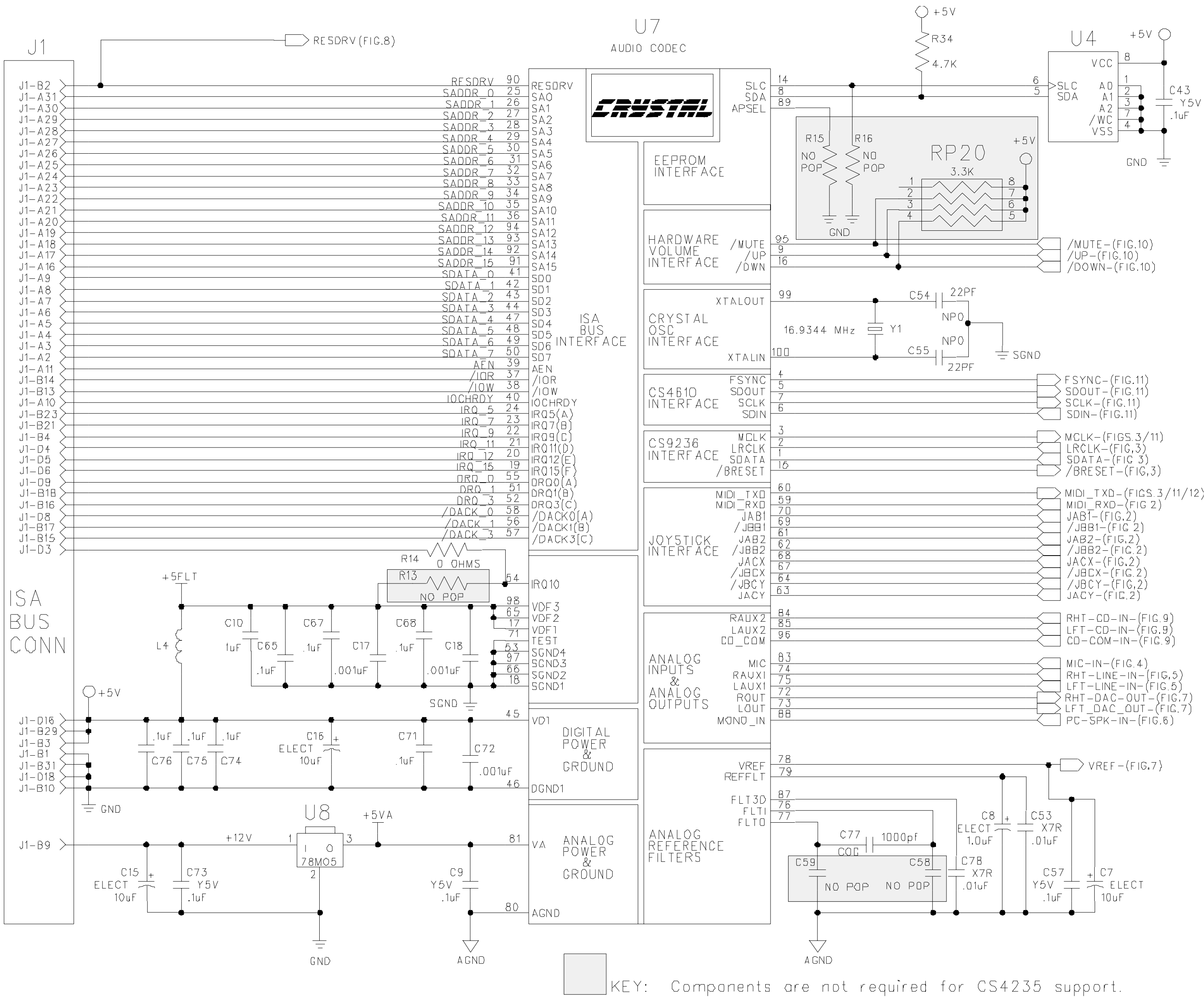


Figure 1. ISA Bus, CS4235

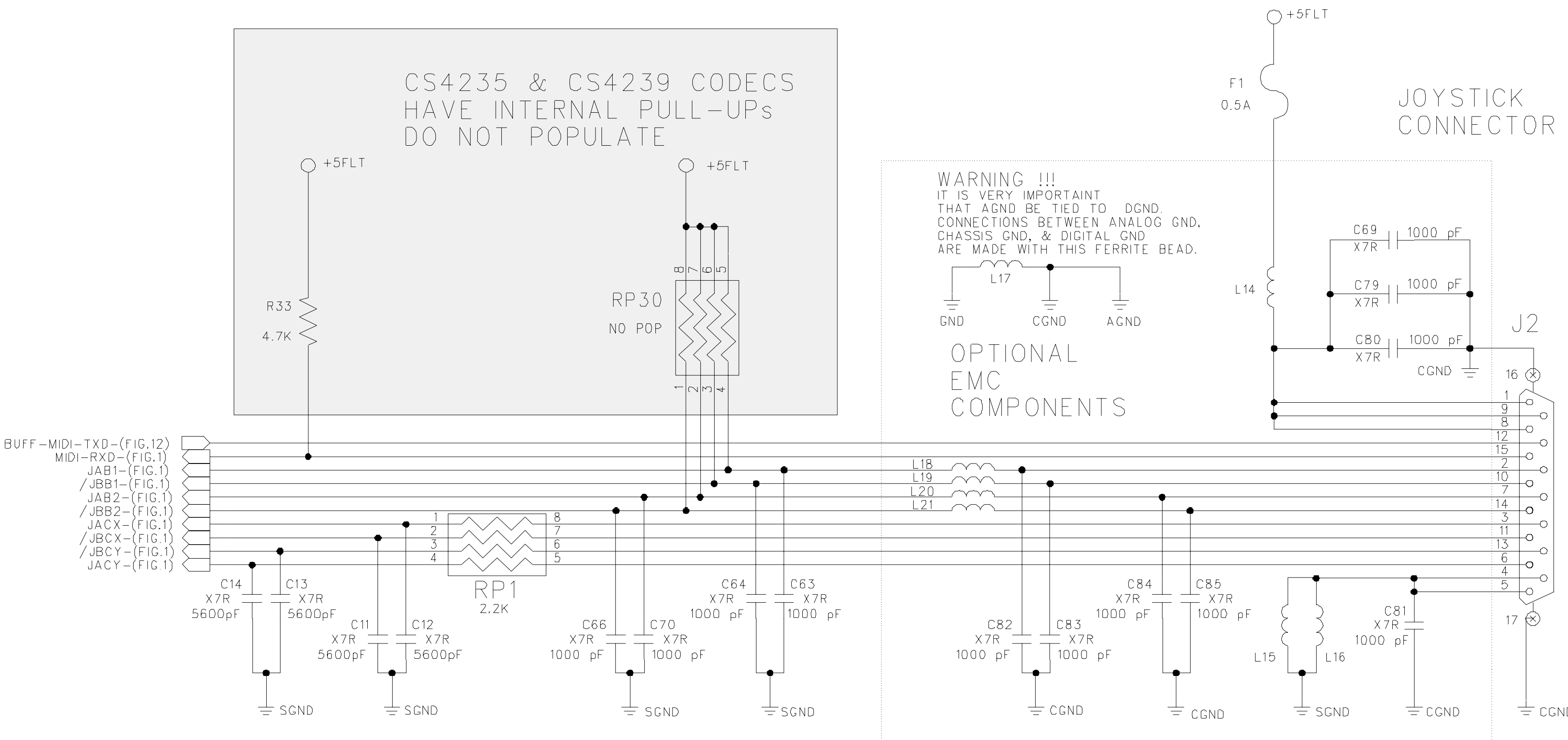


Figure 2. Joystick/MIDI Interface

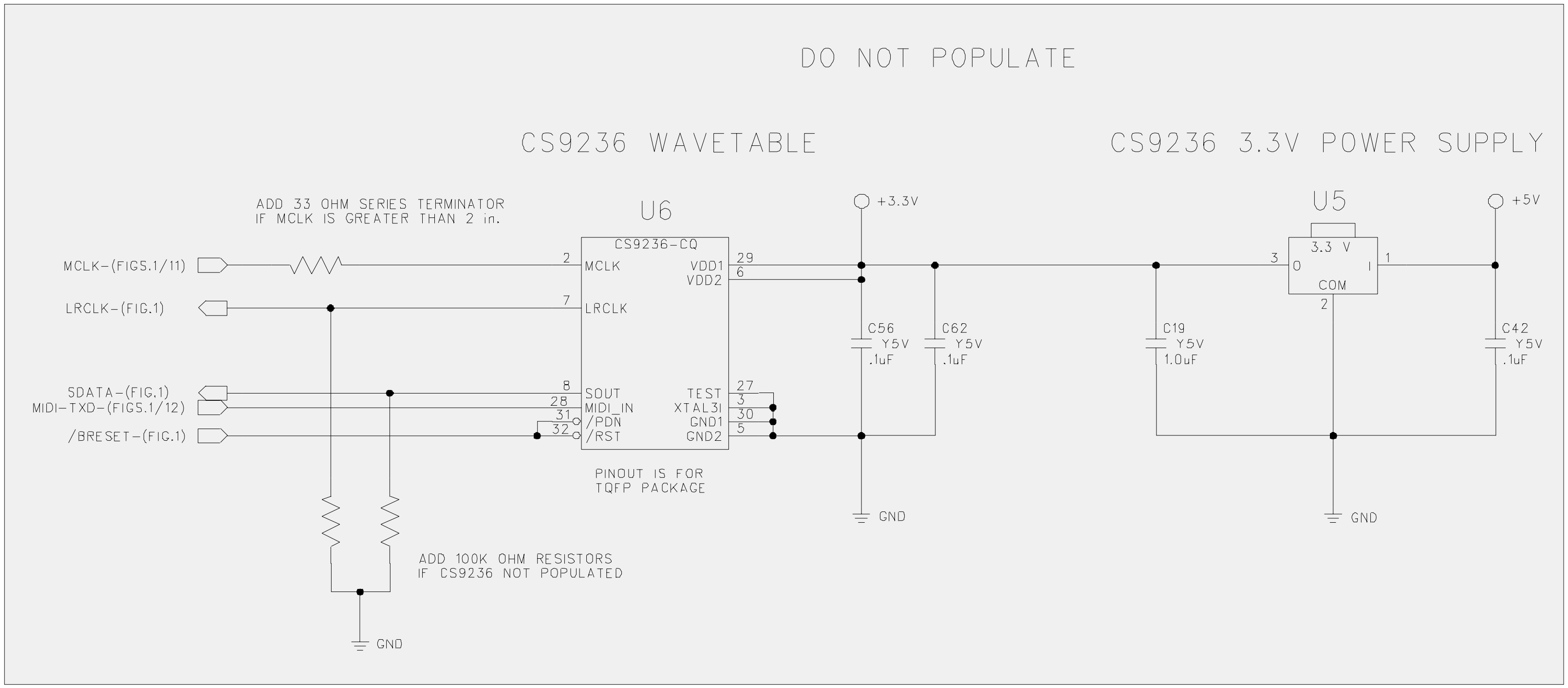


Figure 3. CS9236 Wavetable

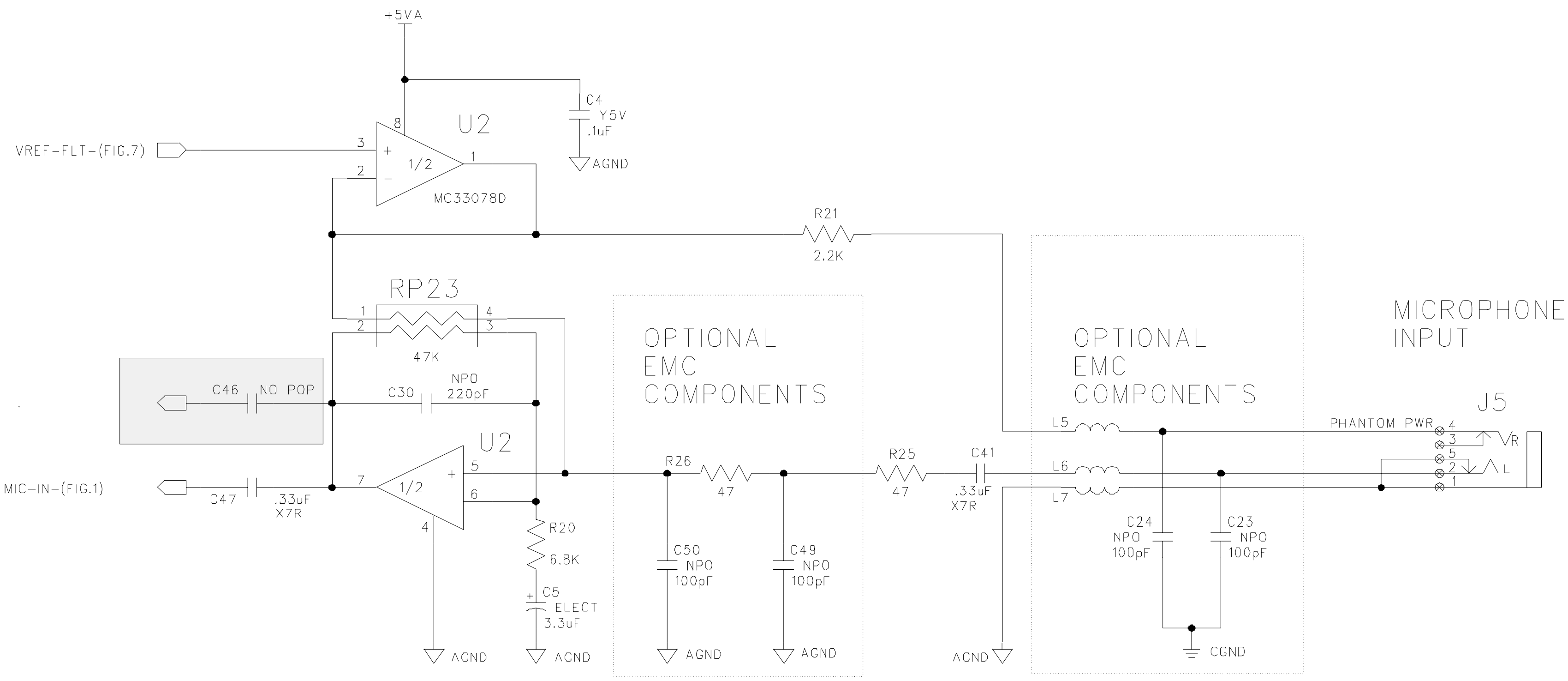


Figure 4. Microphone Preamp, Phantom Power

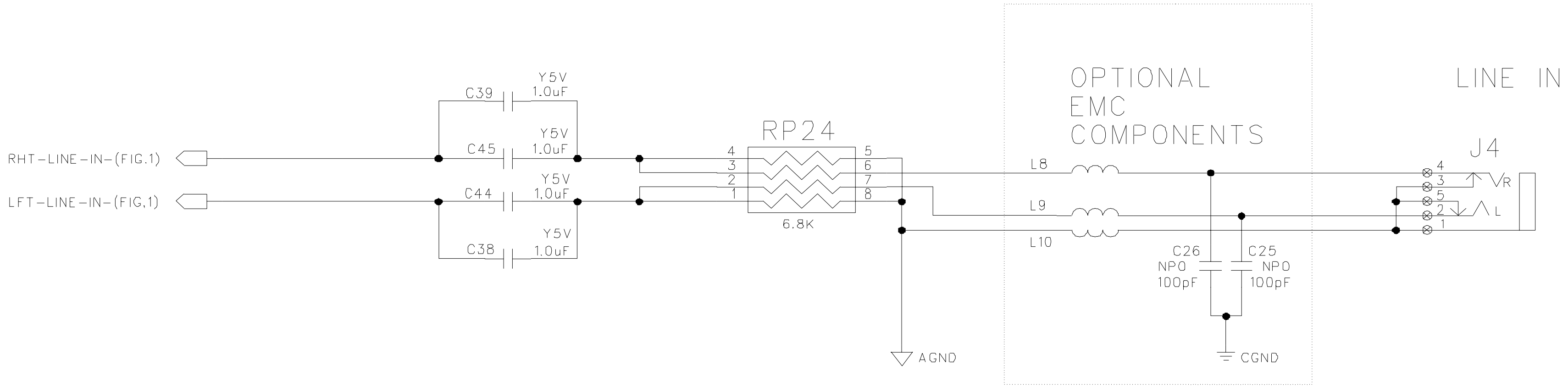


Figure 5. Line In

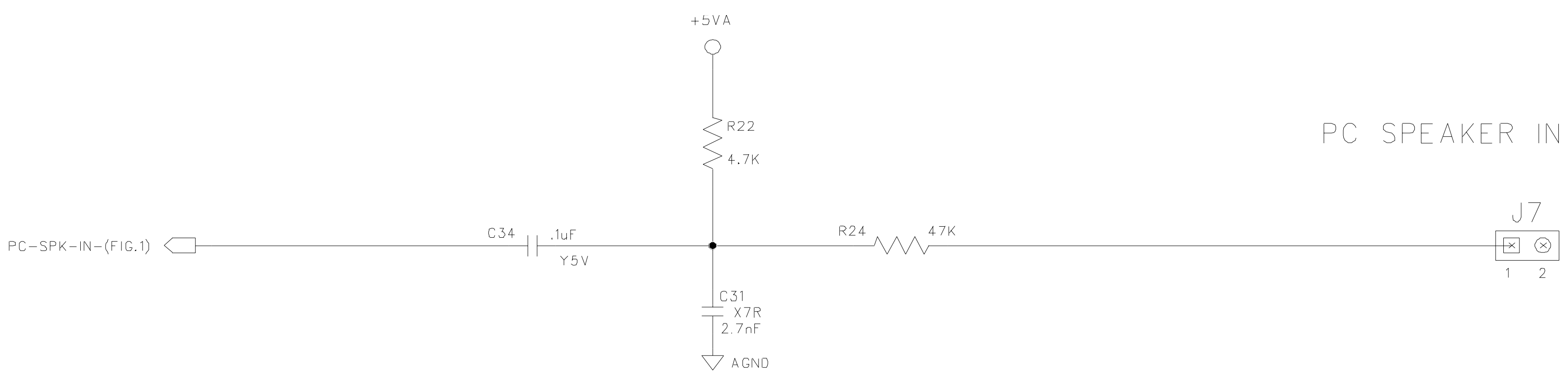


Figure 6. PC Speaker In

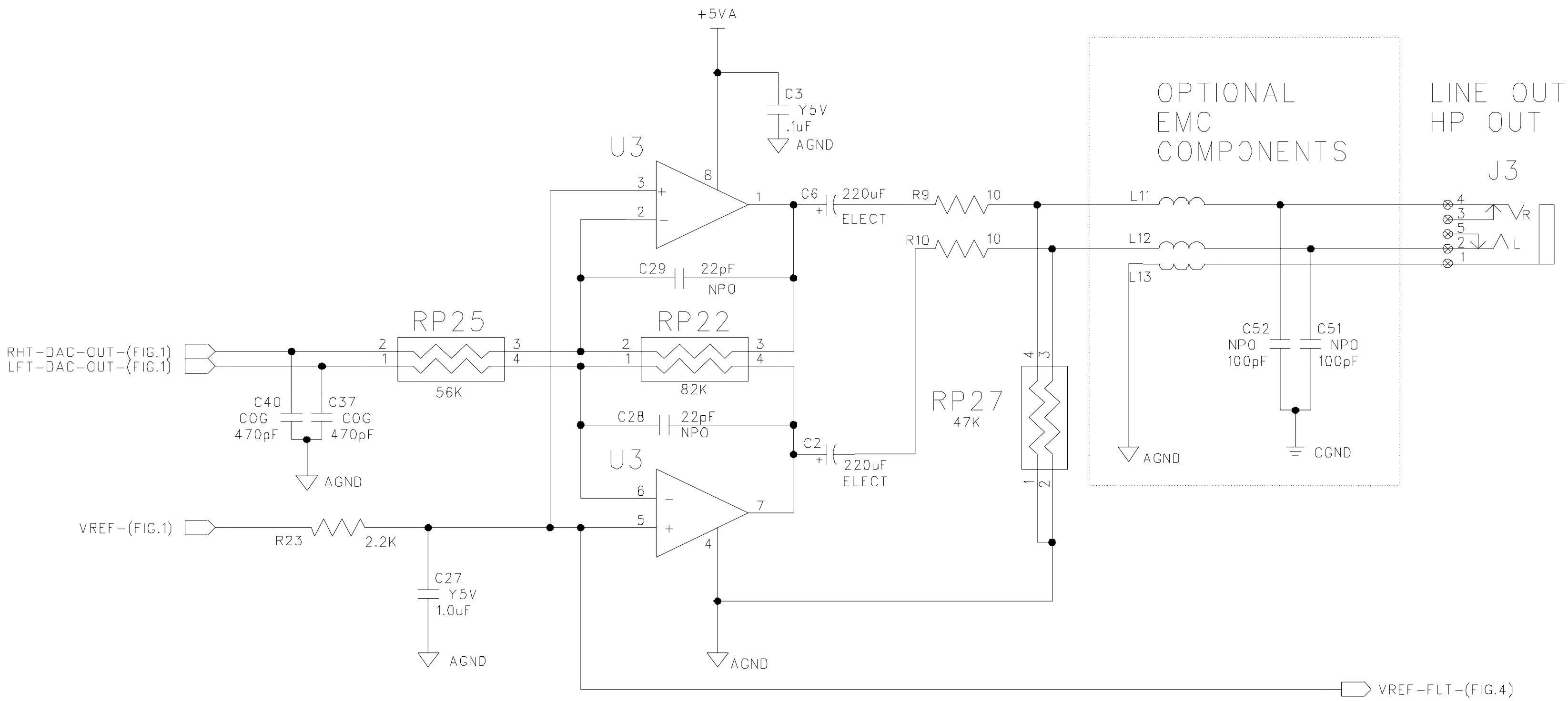


Figure 7. Line Out/Headphone Driver

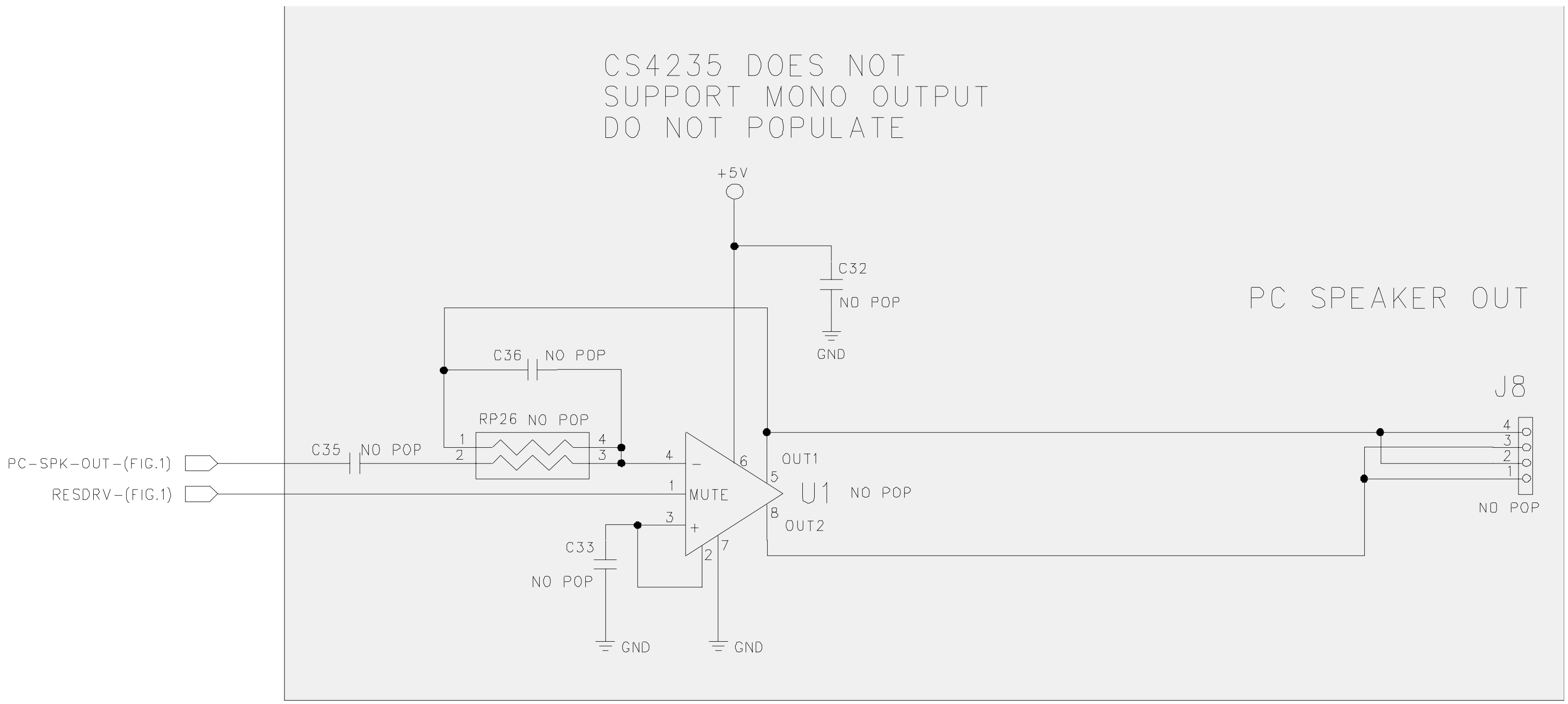


Figure 8. PC Speaker Driver

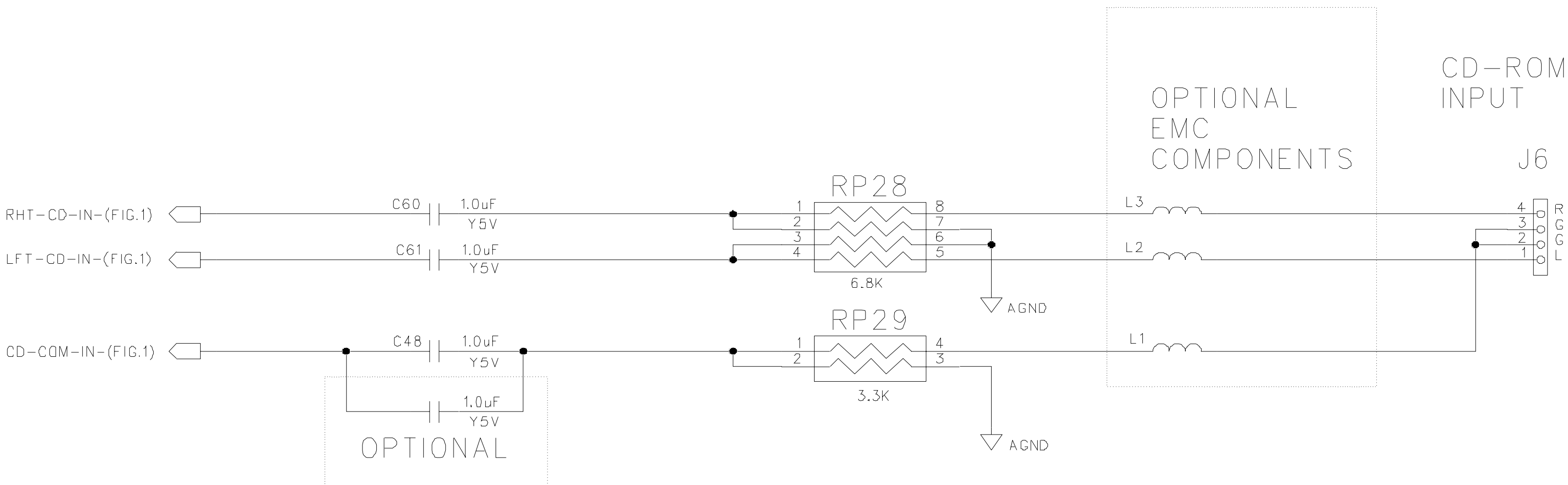


Figure 9. CDROM In

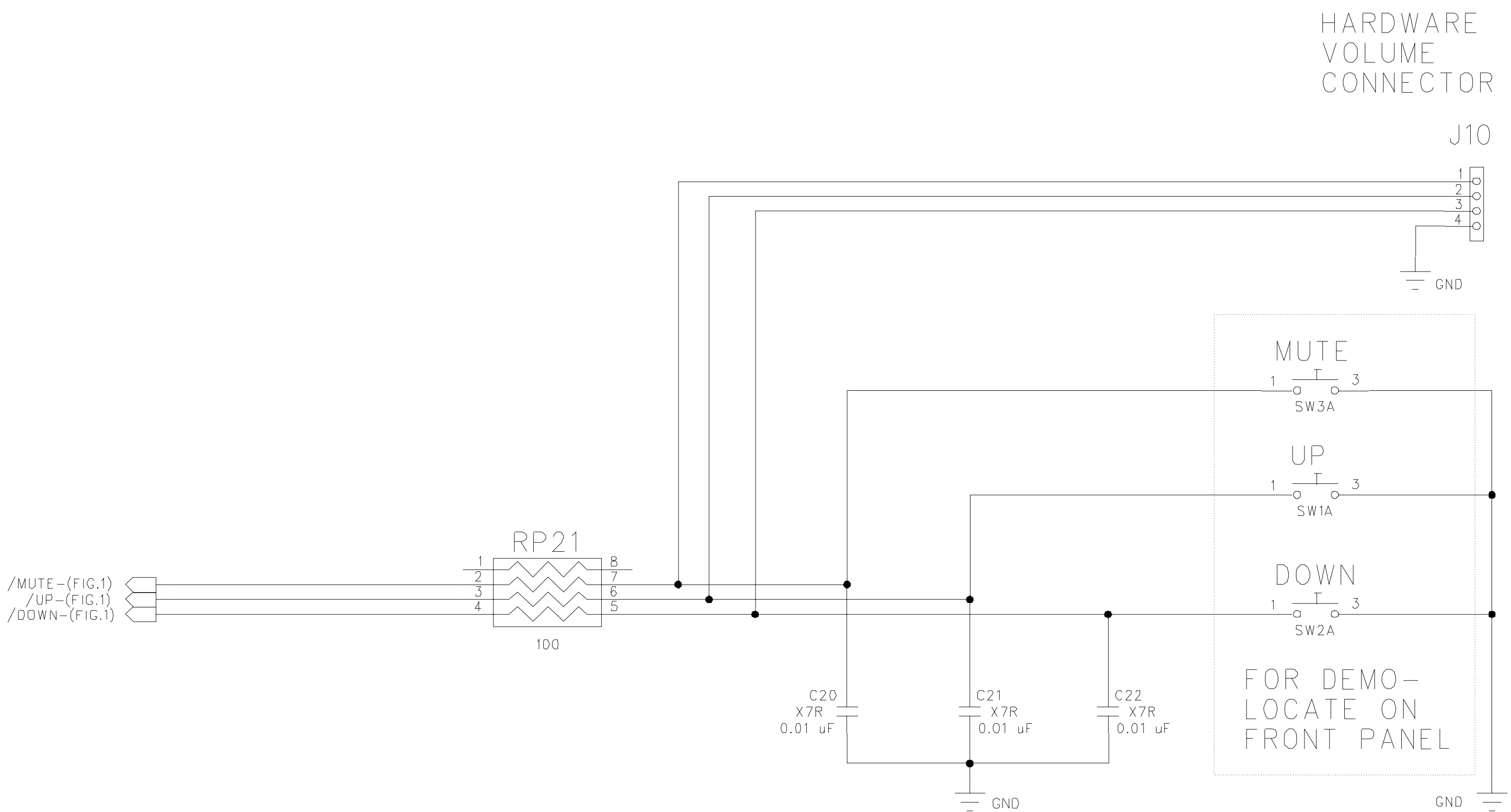


Figure 10. Hardware Volume Control

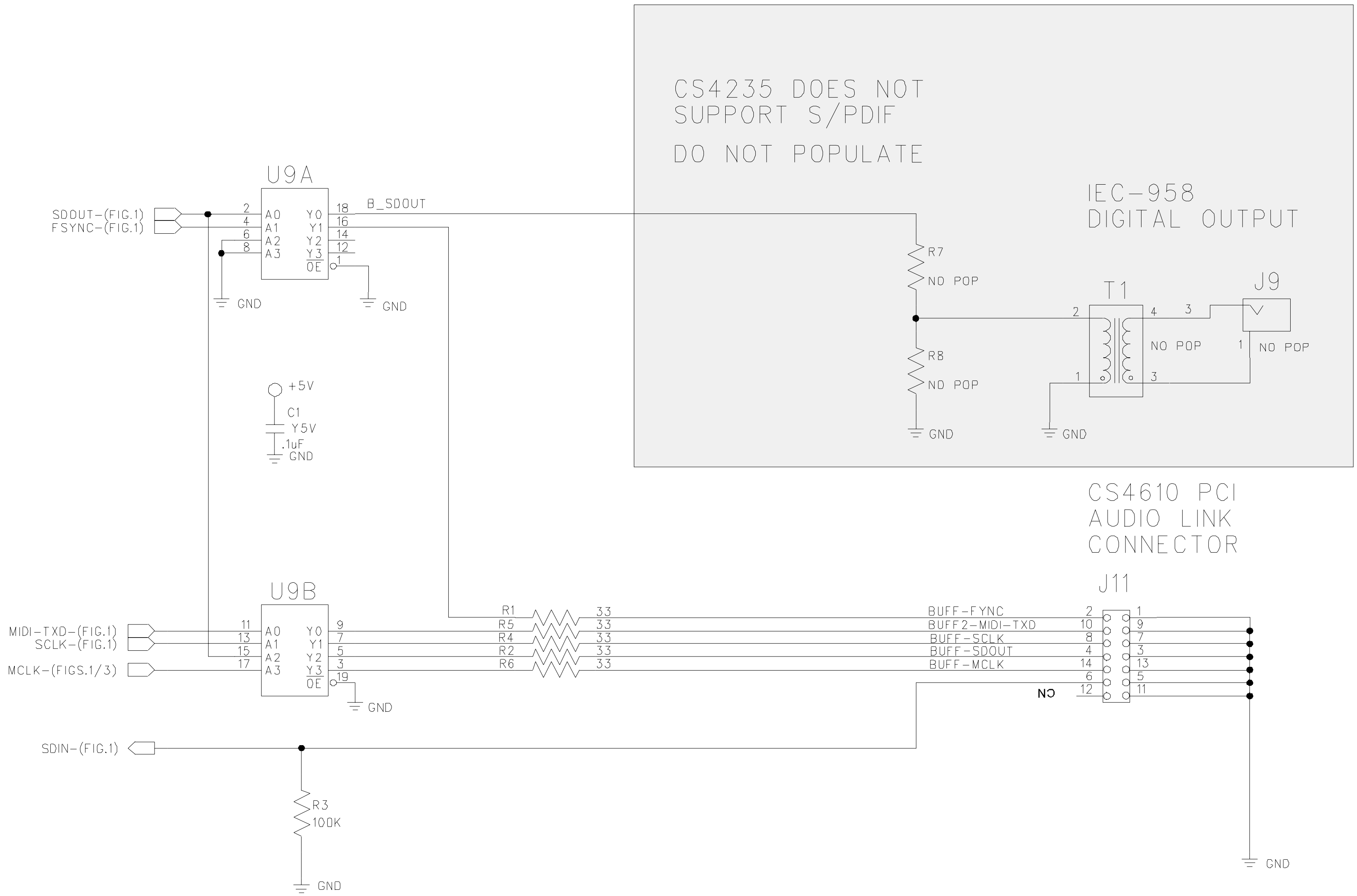


Figure 11. CS4610 Link and Digital Output

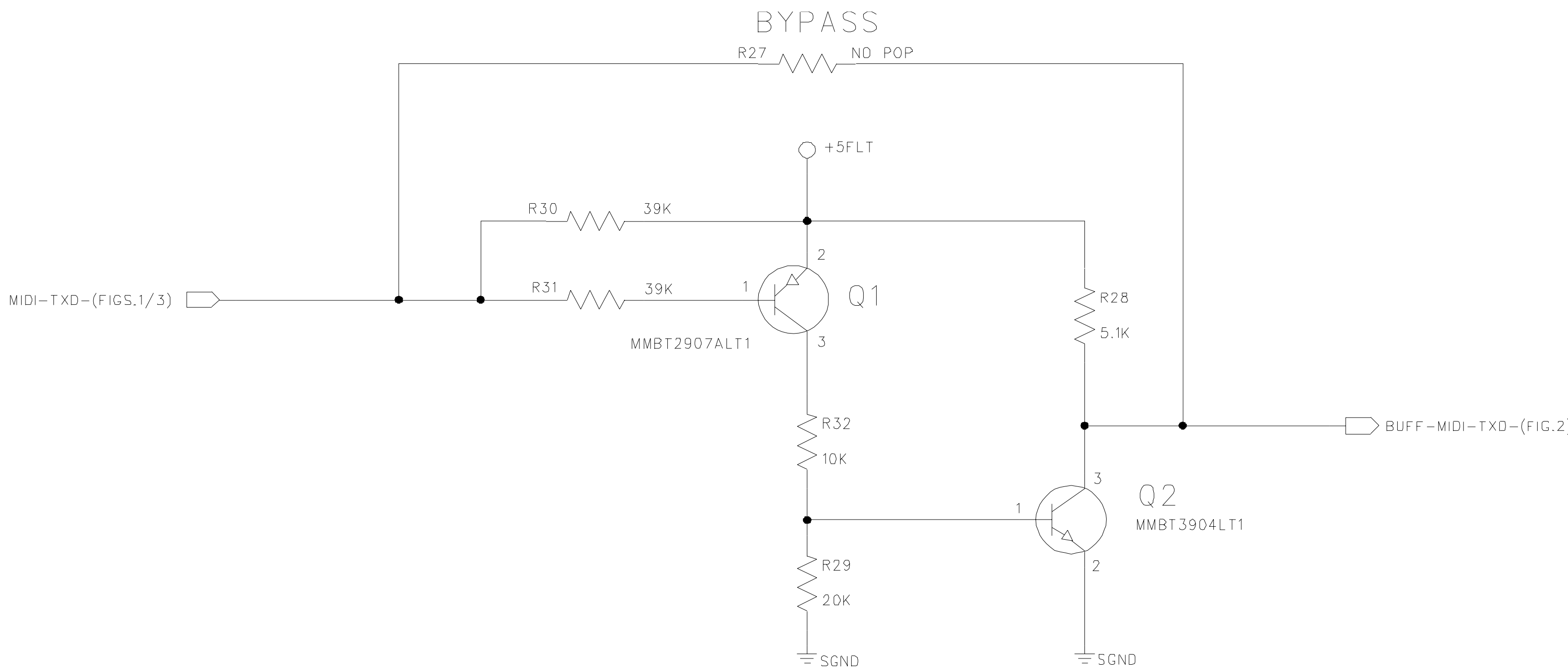


Figure 12. MIDI TXD Buffer

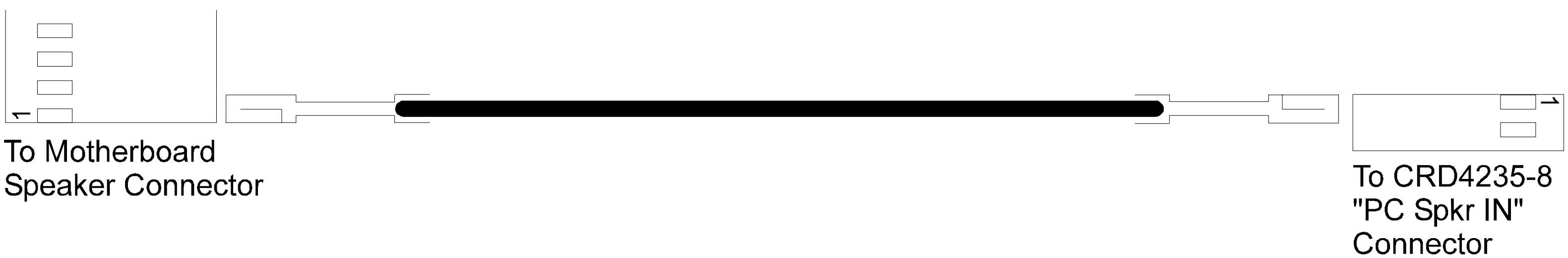


Figure 13. PC Speaker Cable

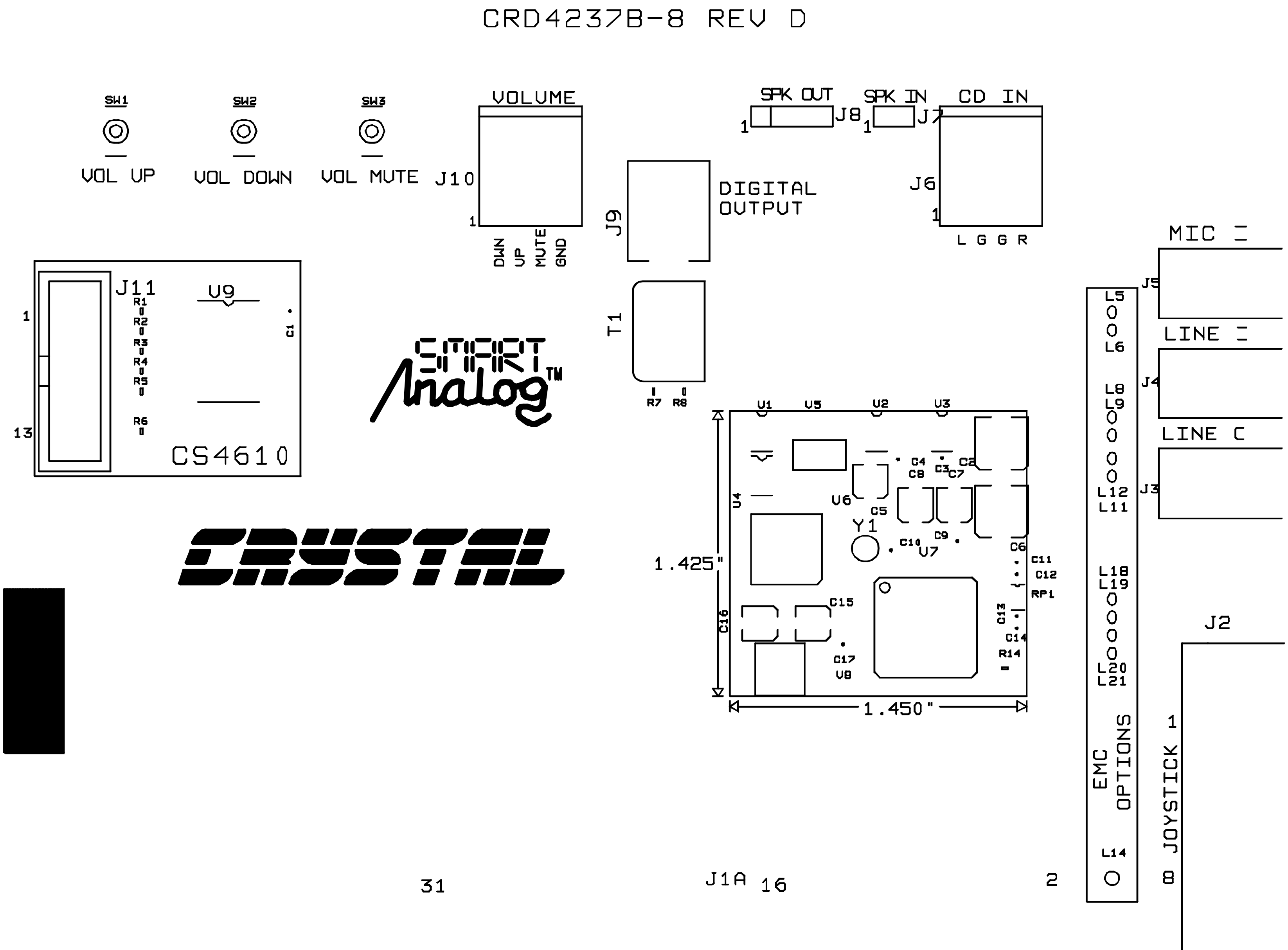


Figure 14. Top Silk (Enlarged for detail)

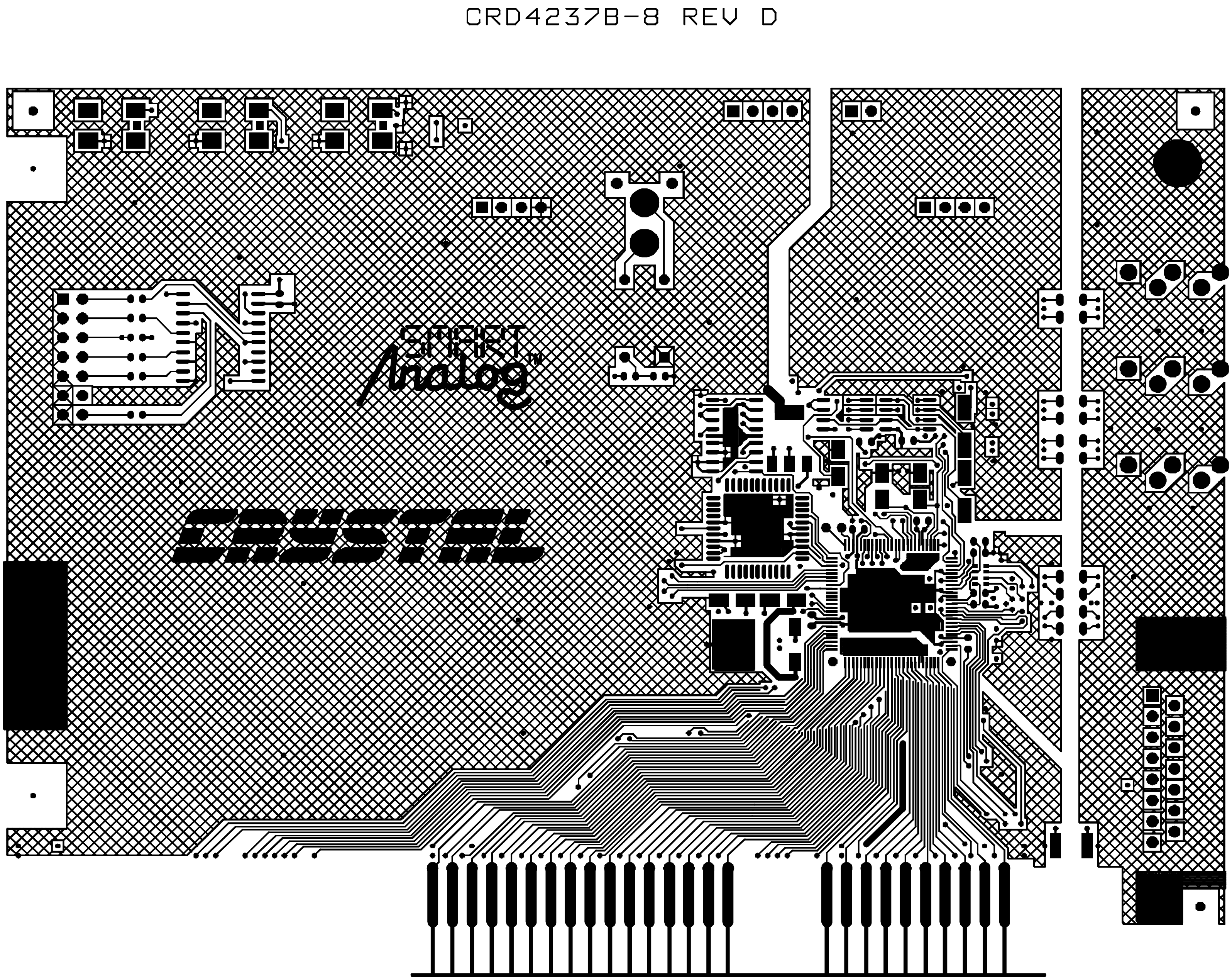


Figure 15. Component Side (Enlarged for detail)

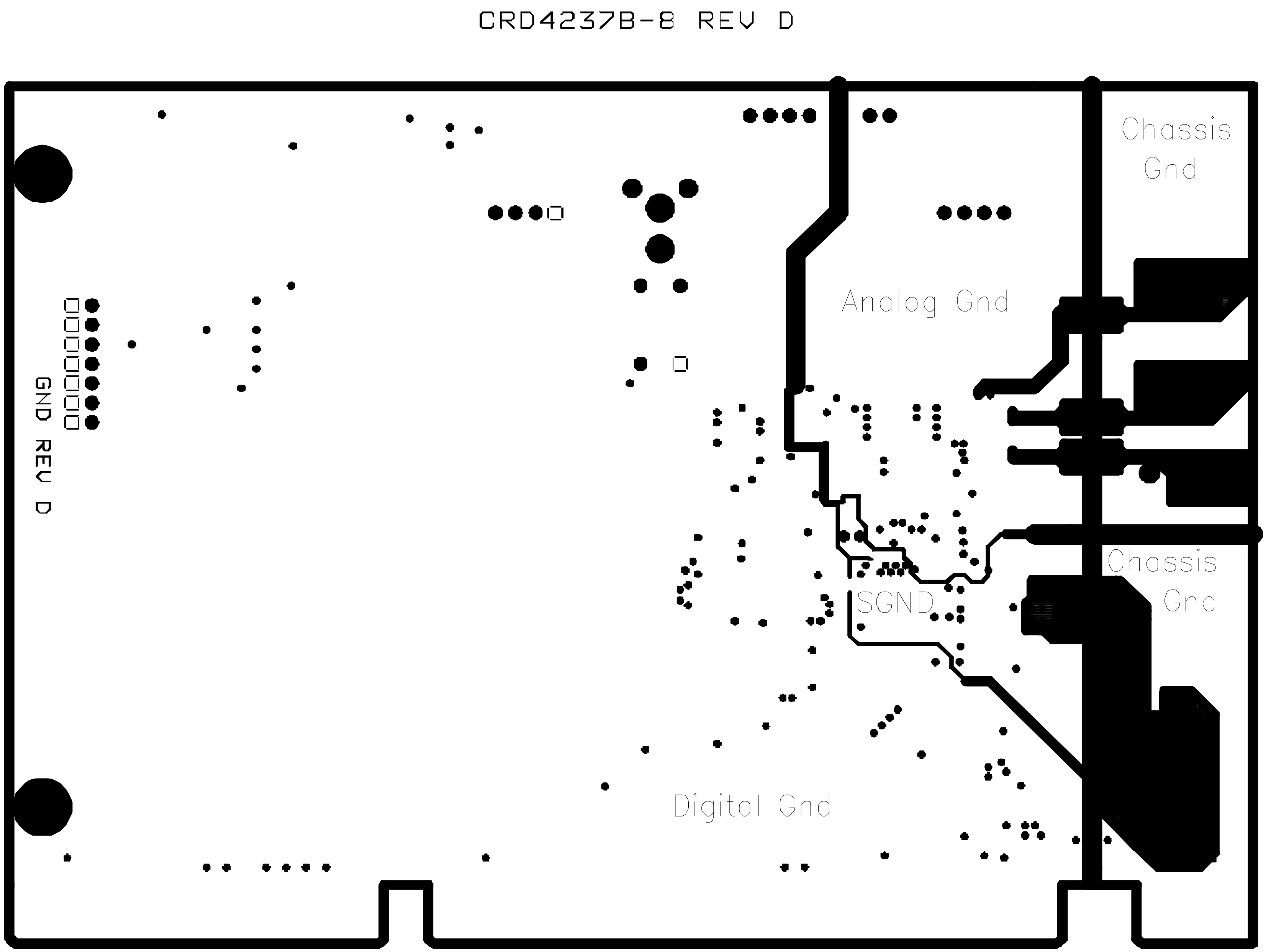


Figure 16. Ground Layer (Negative - Enlarged for detail)

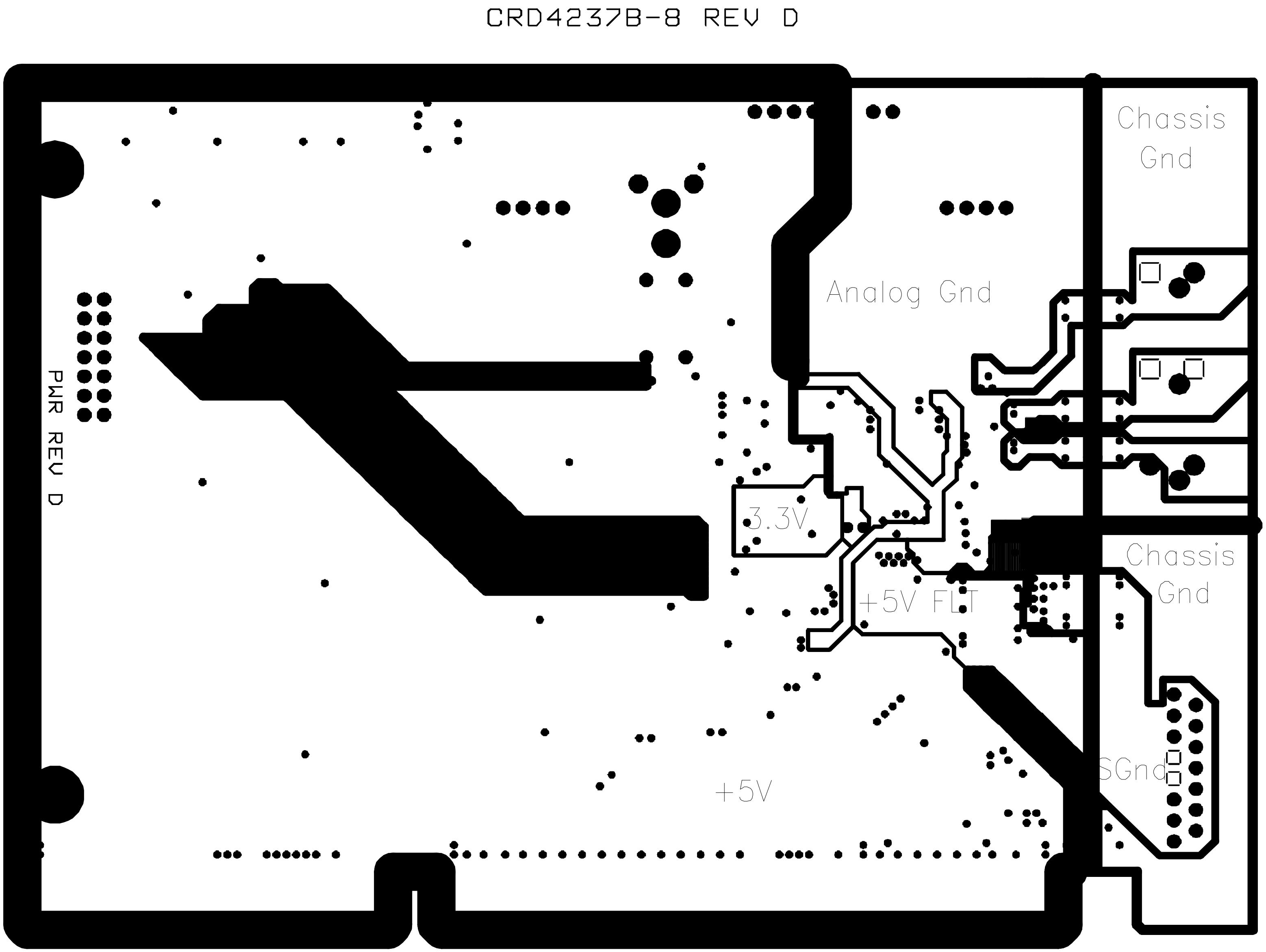


Figure 17. VCC Layer (Negative - Enlarged for detail)

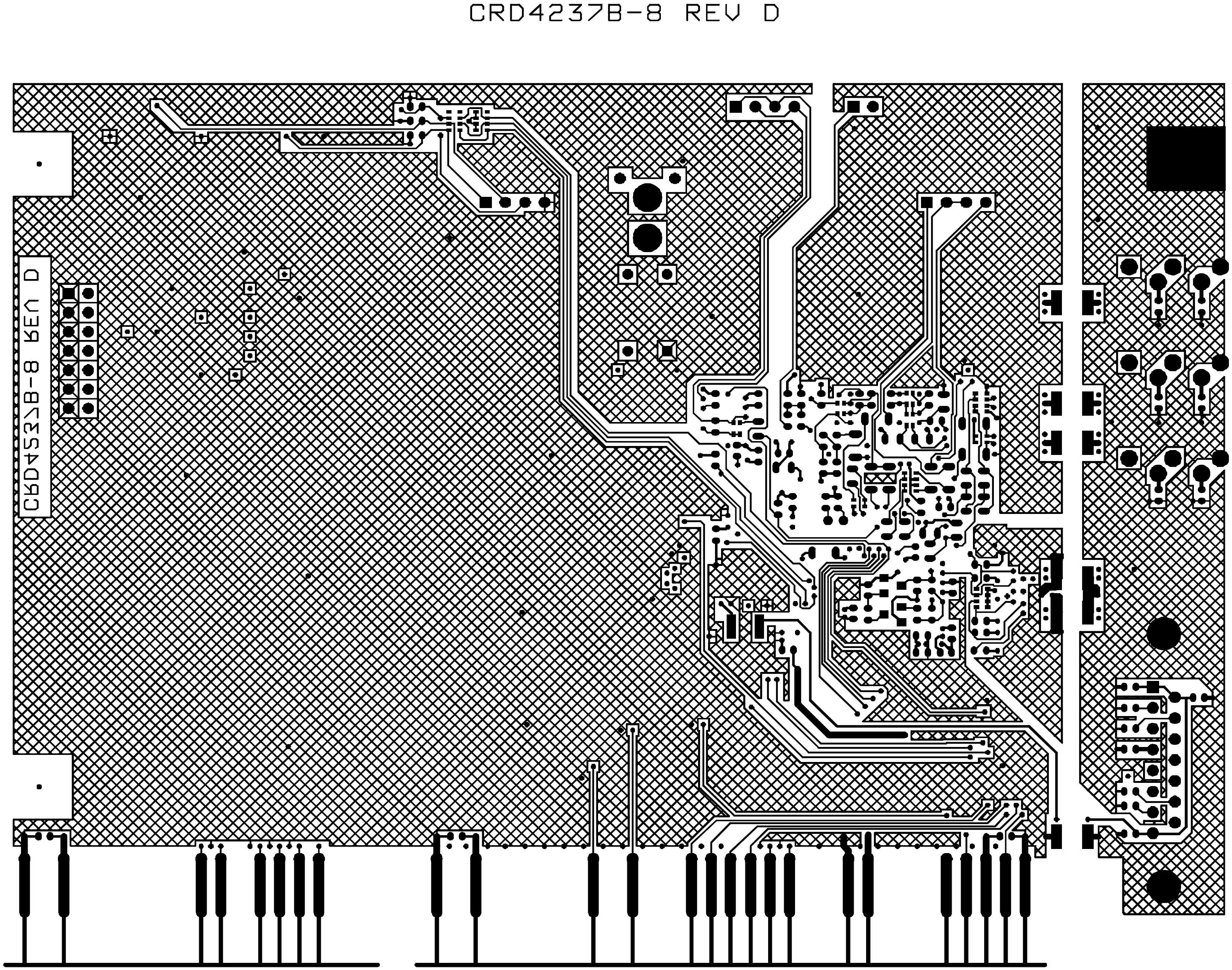


Figure 18. Solder Side (Enlarged for detail)

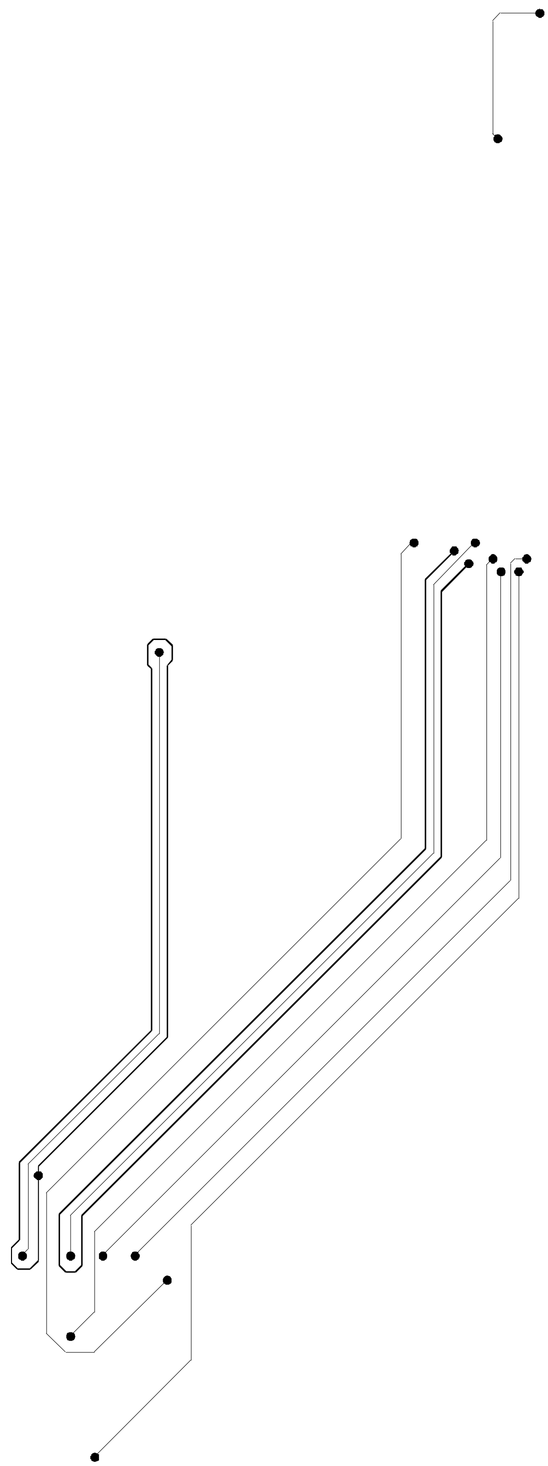


Figure 19. Inner Traces 1 (Enlarged for detail)

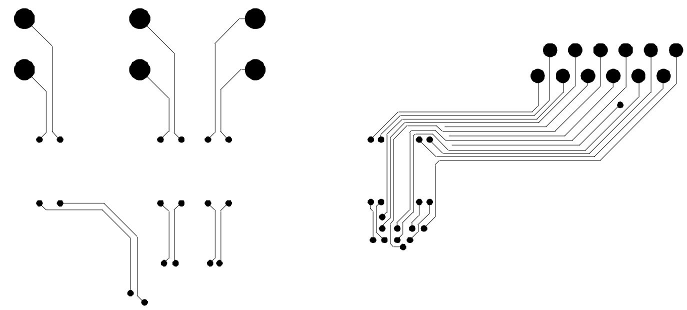


Figure 20. Inner Traces 2 (Enlarged for detail)

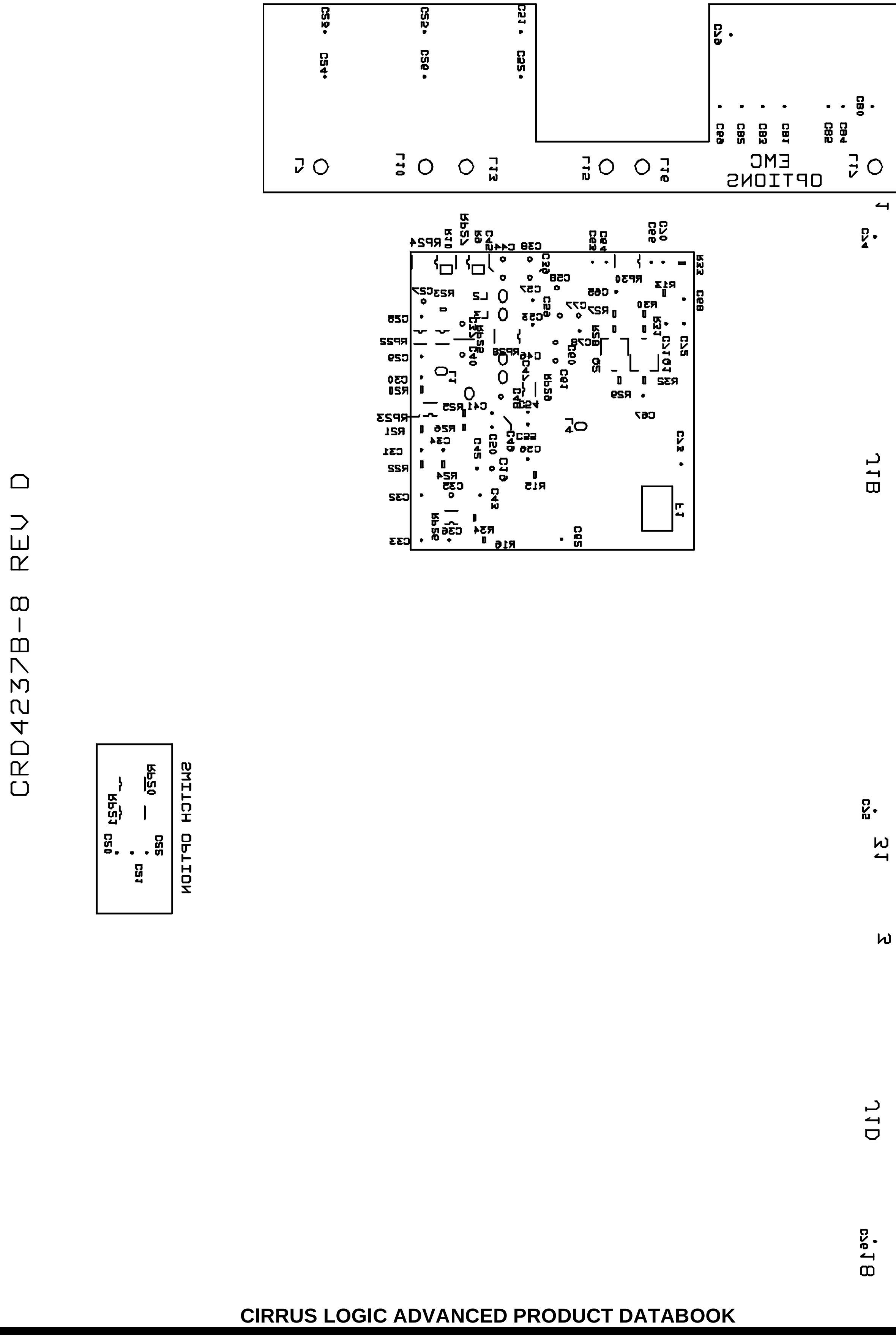


Figure 21. Bottom Silk (Enlarged for detail)

BILL OF MATERIALS

Qty	Ref	Value	Type	Tol	Description	MFG	PN	Pkg
1	U4				8K EEPROM	ATMEL	AT24C08N-10SC	SO8
3	J3-5				3.5MM JACK	LZR	SJ-372	CONN5
1	U9				OCTAL BUFFER	TI	74HCT244DW	SO-20
1	U8				+5V REG	MOTOROLA	MC78M05CDT	SMT369
1	U7				AUDIO CODEC	CRYSTAL	CS4235-KQ	QFP100
1	J2				15 D-SHELL	AMP	747845-3	CONN15
7	L7 L10 L13-17				FERRITE BEAD	TDK	CB70-1812	L-1812
14	L1-6 L8-9 L11-12 L18-21				FERRITE BEAD	TDK	CB70-1206	L-1206
1	F1				.5A POLYFUSE	RAYCHEM	MINISMD050-2	MINISMD
2	J6 J10				4 PIN HEADER /w KEY	MOLEX	70553-0038	SIP4
1	J7				2 PIN HEADER	SAMTEC	TSW-102-07-G-S	SIP2
1	J11				14 PIN HEADER /W KEY	AMP	103309-2	DIP14
								SOT-223
1	U2				DUAL OP AMP	MOTOROLA	MC33078D	SO8
3	SW1-3				PB SWITCH	PANASONIC	EVQ-PHP03T	SWT-5
1	U3				OP AMP	PHILIPS	TDA1308S8	SO8
1	Q2				NPN SMT TRANSISTOR	MOTOROLA	MMBT3904LT1	SOT-23
1	Q1				PNP SMT TRANSISTOR	MOTOROLA	MMBT2907ALT1	SOT-23
3	C17-18 C72	.001 µF	X7R	10%	SMT CAP	PHILIPS	0603R102K9B20	C0603
2	C53 C78	.01 µF	X7R	10%	SMT CAP	PHILIPS	0603R103K8B20	C0603
16	C1 C3-4 C9-10 C34 C43 C57C65 C67-68 C71 C73-76	.1 µF	Y5V	20%	SMT CAP	PHILIPS	0603F104M8B20	C0603
2	C41 C47	.33 µF	X7R	10%	SMT CAP	MURATA	GRM42-6X7R334K016AD	C1206
1	R14	0 Ω		5%	SMT RESISTOR	PHILIPS	9C06031A0R0J	R0603
1	C8	1.0 µF	ELECT	10%	SMT CAP	PANASONIC	ECE-V1HA010R	CASE_4
8	C27 C38-39 C44-45 C48 C60-61	1.0 µF	Y5V	80%	SMT CAP	MURATA	GRM40-6Y5V105Z016AD	C0805
2	R9-10	10		5%	SMT RESISTOR	PHILIPS	9C12063A10R0J	R1206
1	RP21	100		5%	4 RESISTOR ARRAY	PANASONIC	EXB-V8V101JV	ARRAY4
12	C63-64 C66 C69-70 C79-85	1000 µF	X7R	5%	SMT CAP	PHILIPS	06032R102K9B20	C0603
1	R3	100 kΩ		5%	SMT RESISTOR	PHILIPS	9C06031A1003J	R0603

BILL OF MATERIALS (CONTINUED)

Qty	Ref	Value	Type	Tol	Description	MFG	PN	Pkg
11	C20-26 C49-52	100 pF	NPO	10%	SMT CAP	PHILIPS	0603CG101K9B20	C0603
1	R32	10 kΩ		5%	SMT RESISTOR	PHILIPS	9C06031A1002J	R0603
3	C7 C15-16	10 µF	ELECT	10%	SMT CAP	PANASONIC	ECE-V1CA100R	C4343
1	Y1	16.9344 MHz			16.9344 MHz CRYSTAL	EPSON	CA301_16.9344	CA301
1	RP1	2.2 kΩ		5%	4 RESISTOR ARRAY	PANASONIC	EXB-V8V222JV	ARRAY4
2	R21 R23	2.2 kΩ		5%	SMT RESISTOR	PHILIPS	09C06031A2201J	R0603
1	C31	2.7 nF	X7R	10%	SMT CAP	PHILIPS	06032R272K9B20	C0603
1	R29	20 kΩ		5%	SMT RESISTOR	PHILIPS	9C06031A2002J	R0603
1	C30	220 pF	NPO	10%	SMT CAP	PHILIPS	0603CG221K9B20	C0603
2	C2 C6	220 µF	ELECT	10%	SMT CAP	NICHICON	UUK0G221MCU1GS	CASE_6.3
4	C28-29 C54-55	22 pF	NPO	10%	SMT CAP	PHILIPS	0603CG221K9B20	C0603
1	RP25	56 kΩ		5%	2 RES ARRAY	PANASONIC	EXB-V4V563JV	ARRAY2
1	RP29	3.3 kΩ		5%	2 RES ARRAY	PANASONIC	EXB-V4V332JV	ARRAY2
1	C5	3.3 µF	ELECT	10%	SMT CAP	NICHICON	UUK1H3R3MCU1GS	CASE_4
5	R1-2 R4-6	33		5%	SMT RESISTOR	PHILIPS	9C06031A33R0J	R0603
1	RP22	82 kΩ		5%	2 RES ARRAY	PANASONIC	EXB-V4V823JV	ARRAY2
2	R30-31	39 kΩ		5%	SMT RESISTOR	PHILIPS	9C06031A3902J	R0603
2	R22, R34	4.7 kΩ		5%	SMT RESISTOR	PHILIPS	9C06031A4701J	R0603
2	R25-26	47		5%	SMT RESISTOR	PHILIPS	9C06031A47R0J	R0603
2	C37 C40	470 pF	COG	5%	SMT CAP	PHILIPS	08052R471J9B20	C0805
2	RP23 RP27	47 kΩ		5%	2 RES ARRAY	PANASONIC	EXB-V4V473JV	ARRAY2
1	R24	47 kΩ		5%	SMT RESISTOR	PHILIPS	9C06031A4702J	R0603
1	R28	5.1 kΩ		5%	SMT RESISTOR	PHILIPS	9C06031A5101J	R0603
4	C11-14	5600 pF	X7R	10%	SMT CAP	PHILIPS	06032R562K9B20	C0603
2	RP24 RP28	6.8 kΩ		5%	4 RESISTOR ARRAY	PANASONIC	EXB-V8V682JV	ARRAY4
1	R20	6.8 kΩ		5%	SMT RESISTOR	PHILIPS	9C06031A6801J	R0603
1	C77	1000 pF	COG	5%	SMT CAP	PHILIPS	08052R102J9B20	C0805
7	R7-8 R13 R15-16 R27 R33	NO POP			SMT 603 PADS ONLY		NO POP	
3	C32-33 C36	NO POP			SMT 603 PADS ONLY		NO POP	
1	C35	NO POP			SMT 805 PADS ONLY		NO POP	
1	RP26	NO POP			ARRAY2 PADS ONLY		NO POP	
1	C46	NO POP			SMT 1206 PADS ONLY		NO POP	
1	T1	NO POP			PE4 PADS ONLY		NO POP	
1	J9	NO POP			TRCA PADS ONLY		NO POP	
2	C58-59	NO POP			SMT 805 PADS ONLY		NO POP	

BILL OF MATERIALS (CONTINUED)

Qty	Ref	Value	Type	Tol	Description	MFG	PN	Pkg
1	RP30	NO POP			ARRAY4 PADS ONLY		NO POP	
1	U5	NO POP			+3.3 REG PADS ONLY		NO POP	
1	J8	NO POP			SIP4 PADS ONLY		NO POP	
1	U1	NO POP			SO8 PADS ONLY		NO POP	
1	U6	NO POP			WAVETABLE PADS		NO POP	
1	C19	NO POP			SMT 805 PADS ONLY		NO POP	
3	C42 C56 C62	NO POP			SMT 603 PADS ONLY		NO POP	
1	RP20	NO POP			ARRAY4 PADS ONLY		NO POP	