

Introducing Freescale's ColdFire-Based Compressed Audio Solutions

MCF5249, MCF5249L, SCF5249, SCF5250

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1 Is this MP3 Thing a Fad with Computer Geeks that Will Pass?

Although compressed audio (generally referred to as “MP3”) may have started life as a computer application, there are now many emerging markets where it can be found.

The rapid spread of digital audio compression technologies, such as MP3 (MPEG Audio Layers 3), is transforming the way we record, transport, and listen to music. The approximate 10:1 data compression achieved by MP3 makes it practical to transfer music files via the internet or via wireless interfaces, as well as requiring significantly less storage space.

The availability of recordable CD drives at consumer price points is also giving a new lease of life for the compact disc format. Indeed the relatively low cost and high storage capacity of blank CD media, together with its compatibility with existing playback systems in use all over the world may make the CD the ultimate MP3

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music medium. A single CD can hold over 100 hours of music in MP3 form.

However the actual storage media used is not important and dependent on the intended application. Hard Disk Drives (HDD) are now small enough, with low power consumption, to provide a battery operated, hand held device capable of storing more than the average person's entire music collection.

Flash based products, either using discrete chips and/or one of the numerous commercially available flash sticks may not be able to offer the storage capabilities of a CD or HDD, but can provide very small, pen-like products with no moving parts and very long battery life.

MP3 compatibility is very quickly spreading through numerous product ranges, portable audio players, home hi-fi, car audio, DVD players and game consoles are some good examples, but there are also some less obvious areas where MP3 is emerging, elevator music and floor announcements for example.

Although MP3 may be the most commonly known form of audio compression, there are several other algorithms available, such as Windows Media Audio (WMA) and Advanced Audio Codec (AAC), with the story unlikely to end there as new ways to improve quality and/or compression levels are discovered.

2 Why the MCF5249?

In terms of their demands on a microprocessor, MP3-based digital audio systems share the requirement for significant amounts of control processing as well as digital audio signal processing. Control processing includes file management, data buffering, system control and user interface control, while the MP3 decode algorithm itself involves roughly 50 percent control-type functions and 50 percent signal processing. Other signal processing tasks include audio effects processing (e.g., dynamic bass boost) and digital volume control.

Typically these systems use separate Digital Signal Processing (DSP) and microcontroller devices to perform the signal processing and control tasks. Clearly a more efficient, lower cost solution would be to implement both tasks on a single microprocessor. The ColdFire 32-bit microprocessor provides a compact engine for control code processing with its variable-length RISC architecture, and the addition of the Enhanced Multiply and ACcumulate (EMAC) unit adds powerful DSP capability to the ColdFire architecture.

The MCF5249 integrated microprocessor combines a Version 2 ColdFire[®] processor core operating at 140MHz with the following modules:

- DMA controller with 4 DMA channels
- Integrated Enhanced Multiply-ACcumulate Unit (EMAC)
- 8-Kbyte Direct Mapped Instruction Cache
- 96-Kbyte SRAM (A 64 Kbyte and a 32 Kbyte bank)
- Operates from external crystal oscillator
- Supports 16-bit wide SDRAM memories
- Serial Audio Interface which supports IIS and EIAJ audio protocols
- Digital audio transmitter and two receivers compliant with IEC958 audio protocol
- CD-ROM and CD-ROM XA block decoding and encoding function
- Two UARTs

- Queued Serial Peripheral Interface (QSPI) (Master Only)
- Two timers
- IDE and SmartMedia interfaces
- Analogue to Digital Converter
- Flash Memory Card Interface
- Two I2C modules
- System debug support
- General Purpose I/O pins shared with other functions
- 1.8 V core, 3.3 V I/O
- 160 pin MAPBGA package (qualified at 140 MHz) and 144 pin QFP package (qualified at 120 MHz)

2.1 MCF5249 Block Diagram

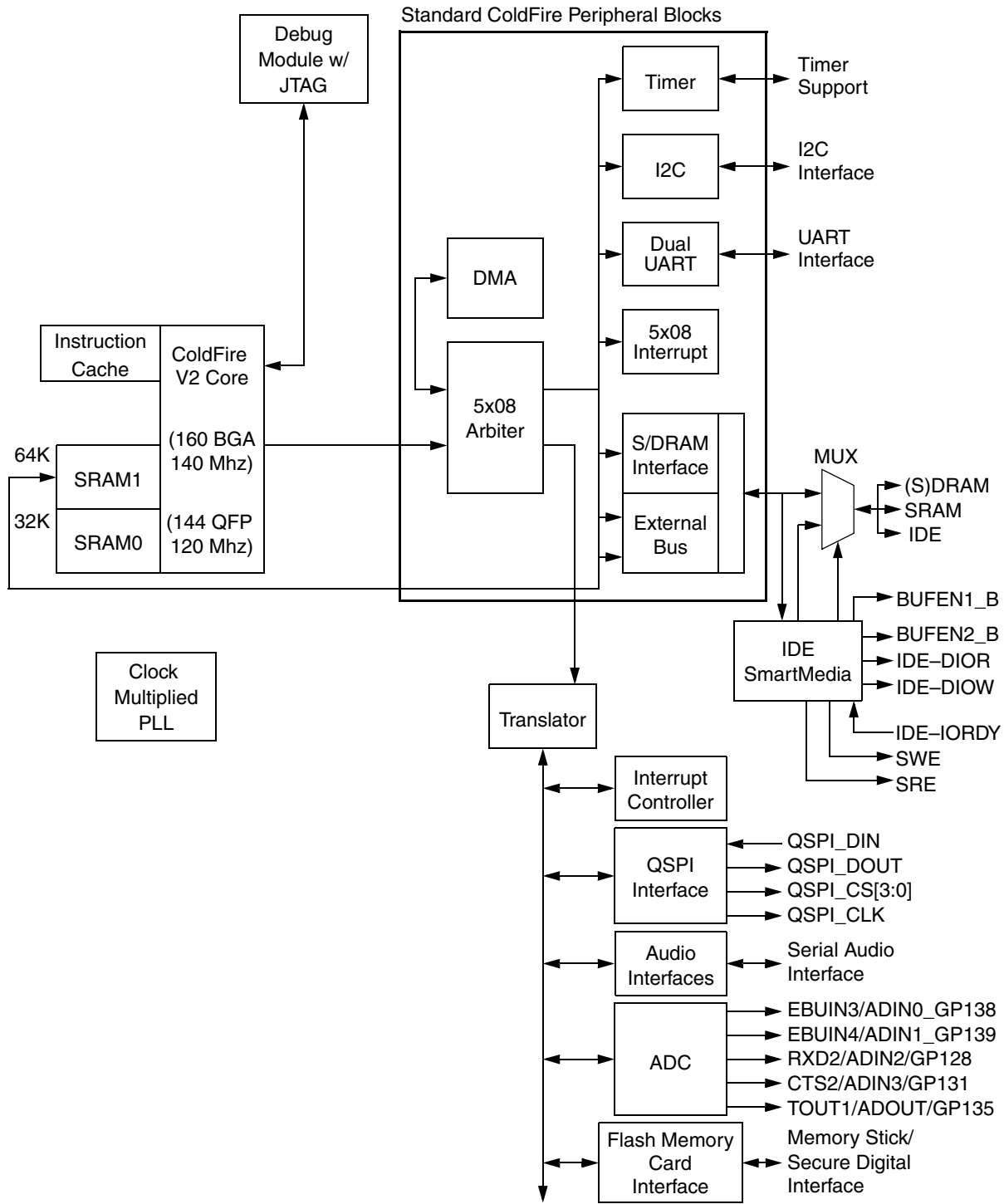


Figure 1. MCF5249 Block Diagram

2.2 ColdFire EMAC Unit

The ColdFire EMAC unit is an enhanced version of the existing MAC unit with additional features to improve signal-processing performance especially for digital audio applications. These new features include:

- Improved performance for 32x32 fractional and integer multiply-accumulate operations, with an effective issue rate of 1 clock cycle per MAC.
- Addition of three more accumulators to minimize MAC pipeline stalls caused by exchanges between the accumulator and the general purpose ColdFire registers. Many algorithms require multiple calculations on a given data set. By applying different accumulators to these calculations, it is often possible to store one accumulator without any stalls while performing operations involving a different destination accumulator.
- Implementation of 48-bit accumulation data path to allow the use of a 40-bit product plus the addition of 8 extension bits to increase the dynamic number range when implementing modern signal processing algorithms. Existing MAC features which are also important for efficient digital audio signal processing include:
 - Support for signed, unsigned integer and signed fractional operands.
 - Operand fetch in parallel with multiply accumulates.

2.3 Audio Interface Module

The advanced ColdFire audio peripherals that have been developed include IIS-compatible serial ports and an IEC958/SPDIF transceiver. A unique on-chip TDM (time-division multiplexed) bus has been engineered to allow signals to be routed easily between peripherals and CPU. These integrated audio peripherals help to lower overall system costs, as external audio interface devices are not required.

In CD and CD recordable systems, the CPU must be able to route digital audio signals to and from the drive electronics, from analogue-to-digital and to digital-to-analogue converters, and to and from the outside world. In addition, the transmission and reception of CD subcodes must be accommodated. Finally, it should be noted that compressed audio formats, such as MP3, use the CD-ROM file format for storage on CD.

A new Audio Interface Module has been designed to facilitate audio interchange in CD systems with the minimum of CPU intervention. The Audio Interface Module allows the device to receive and transmit digital audio over serial audio interfaces (IIS/EIAJ) and over digital audio interfaces (conforming to the European Broadcast Union (EBU)-IEC958 standard, and compatible with the Sony/Philips Digital Interchange Format).

The device is equipped with four serial audio interfaces, compliant with Philips IIS and Sony EIAJ format, two IEC958 receivers with four multiplexed inputs, and one IEC958 transmitter with two outputs (one for professional sub-code and one for consumer sub-code).

The Audio Interface Module connects all the audio interface ports to an internal 40-bit TDM bus to allow the direct retransmission of an audio signal received on one receiver to another transmitter, without CPU intervention. In parallel, the CPU is able to receive or transmit digital audio to and from any of the audio interfaces.

2.4 Audio Interface Module Functional Diagram

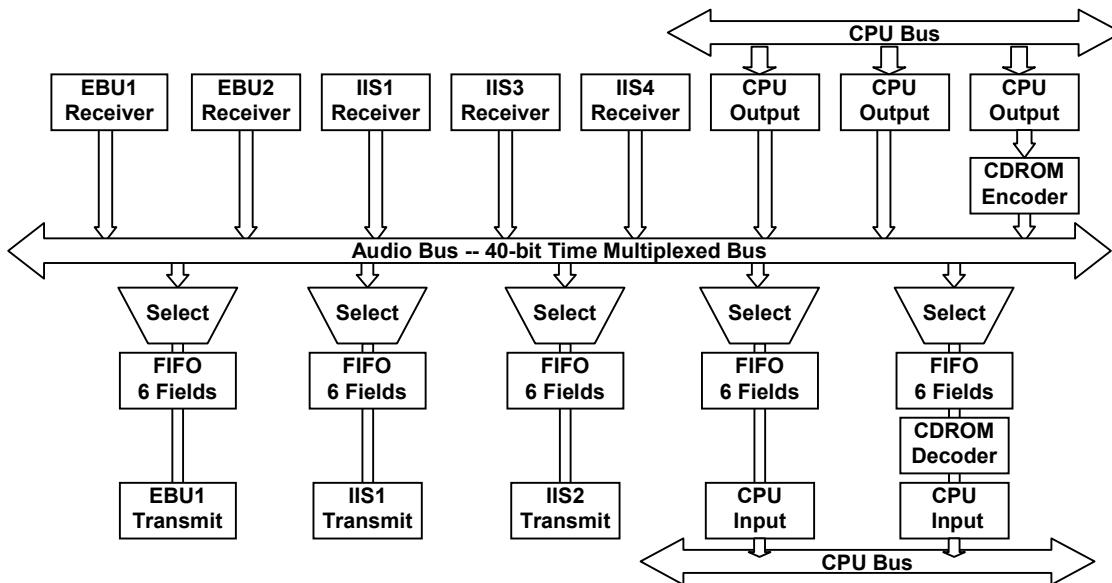


Figure 2. Audio Interface Module Functional Diagram

The Audio Interface Module includes a hardware CD-ROM encoder/decoder, which optionally applies CD-ROM header detection, scrambling/de-scrambling, and electronic data check functions required for reading and writing CD-ROMs. This allows the device to provide MP3 functionality using only low-cost audio drives, computer CD-ROM-type drives are not required.

2.5 32-Bit Data Path

It is generally accepted in digital audio engineering that to process 16-bit signals with no loss of audio quality requires a processor with greater than 16-bit precision. This is because the internal data path of a 16-bit processor has the same resolution as the desired output and rounding errors, which occur during arithmetic operations, are inevitably transferred to the output. DSPs that are 16-bit often have to use extended precision modes requiring three to four times the number of CPU cycles to achieve acceptable audio quality.

With its 32-bit data paths and 48-bit accumulators, the ColdFire with EMAC architecture is capable of extremely efficient processing of certain audio algorithms. For example, Freescale's ColdFire MP3 decoder has been tested as having 18 bits of accuracy compared to the ISO standard floating point implementation, equivalent to a signal-to-noise ratio of 108 dB. However, the MP3 decoder requires just 19 MHz* on a ColdFireV2 with EMAC core.

NOTE

Worst-case data and assume single cycle memory accesses.

2.6 Low System Power Dissipation

In battery operated systems, such as portable MP3 players, it is important to minimize the system power consumption in order to minimize the inconvenience and expense of changing or recharging the battery. The following factors are identified as significantly contributing to the power dissipation of an electronic system:

- **Operating Voltage:** This is perhaps the most important factor as power dissipation is proportional to the square of the voltage, thus a reduction of operating voltage from 2.5V to 1.8V reduces power dissipation by approximately one half. The available operating voltage range is essentially a function of the semiconductor process technology used to manufacture the Integrated Circuit (IC) in question. The fully automated, synthesizable design methodology employed for ColdFire-based Is makes the widest range of manufacturing technologies available with the minimum of effort since only standard library elements and compiled memories are used. Also, the design can be easily migrated to new manufacturing processes, as they become available. Existing 0.18micron CMOS logic processes use core supply voltages in the range 1.5 V–1.8 V. Next generation 0.13micron processes will allow supply voltages of around 1.0 V.
- **Operating Frequency:** Since power dissipation of synchronous digital logic is proportional to the switching frequency, it is important to minimize the operating clock frequency required. Freescale's ColdFire MP3 decoder requires just 19 MHz on a ColdFireV2 with EMAC core, allowing a ColdFire-based MP3 player to operate from a very low system clock frequency.
- **Integration Level:** A highly integrated system solution, with most functions included in a single IC, can dramatically reduce system power dissipation because with multiple separate Is, powerful output drivers are required to overcome the large capacitance of the interconnecting Printed Circuit Board (PCB) traces. Freescale's ColdFire audio solutions combine DSP and MCU functionality with application-specific peripherals and on-chip memory to minimize the number and switching frequency of inter-chip connections.

2.7 Code Density and System Integration

In many designs, the cost of memory exceeds the microprocessor cost, so this factor can significantly impact overall system cost. The ColdFire processor architecture addresses these requirements through a variable-length instruction set to maximize code density implemented in a RISC-based approach, providing a very efficient silicon design.

Simple instructions require only a 16-bit instruction length while more complex instructions are implemented in 32 or 48 bits. Each instruction takes only the amount of space required with the result that both memory storage space and memory interface bandwidth are minimized.

With the addition of the EMAC, the ColdFire CPU becomes a very good control-code processor that is also capable of efficient signal processing. For example, Freescale's MP3 decoder requires just 37 Kbytes of memory, including 17.5-Kbyte ROM and 19.5-Kbyte RAM.

Combining DSP and MCU functionality in the same core together with very efficient use of on-chip and off-chip memory results in lower overall system cost.

The Audio Interface Module provides a high level of digital audio connectivity on-chip, further reducing component count, PCB footprint, and system cost.

2.8 Large Address Range and Cache Architecture

The ColdFire architecture's 32-bit address range and on-chip cache make it well suited for running the large software stacks needed for file management, data buffering, and control in CD and MP3 systems. ColdFire devices can address large continuous address ranges without the need for bank switching required by some 16-bit architectures. On-chip caches deliver good performance and minimize off-chip accesses (and therefore power dissipation) even with slow external memory.

2.9 Programmable Flexibility

The fact that a software programmable architecture is used, rather than hardwiring certain algorithms, means that the system can be easily upgraded to support new algorithms and standards as they emerge. Competitors to the widely used MP3 compression algorithm, such as AAC and WMA, which claim improved quality and/or compression levels have already emerged and there will surely be others in future. A programmable signal-processing engine also allows customers to implement their own proprietary audio processing algorithms in order to differentiate their product from competitors.

2.10 Tools Support—RTOS and Development Tools

All ColdFire based devices include a Background Debug Module (BDM) on chip with a common interface to debug tools available from third party vendors and Freescale's Metrowerks division.

The BDM enables the programmer to directly control the CPU, access its registers, as well as the use of breakpoints, single stepping through code, and real-time trace of application code.

The BDM interfaces to development tools via a standard 26-pin header, so a simple register map change is all that is required for development tools to support new ColdFire family members.

The similarity of the ColdFire programming model to that of the industry standard 68K architecture has made it easy for a wide range of development tools suppliers to support the ColdFire product family. A list of third party development tools can be found on Freescale's web site at www.freescale.com.

The standard BDM interface and wide range of development tools contribute to the "ease of use" of the ColdFire architecture. Hardware and Software developers have a choice of powerful solutions to meet their development tool needs, and new system-on-chip derivatives can be accommodated by the tools with little or no delay to the time to market of the customer's end product.

3 The Trio Software Demonstration

The software demonstration was developed by part of Freescale's Global Software Group (GSG), based in India. The Trio demonstration, along with several other software packages, can be downloaded from www.freescale.com.

The demonstration is intended for evaluation only, to show how easily MP3 compatibility could be added to any system. If appropriate the Trio code can be supplied as a fully supported library module, via a license agreement.

3.1 Software Features

- Audio CD playback
- MP3 playback (MPEG-1 Layer 3 and MPEG-2 Layer 3 with lower sampling rates)
- WMA playback (high rate, mid rate and low rate)
- WAV file playback (16- or 8- bit linear samples; sampling rates supported same as for MP3 and WMA)
- CD-DA, CD-R, CD-RW and CD-ROM discs
- 12 cm discs
- ISO-9660 Level 3 file system with Joliet extension
- ISO-9660 Joliet format for Macintosh
- UDF file system, version 1.5, with fixed and variable packets
- Multi-session discs (up to five sessions)
- Mixed discs (data and audio tracks)
- Copy-protected CD-DA discs
- Display of ID3 tags V1.1, V2.2, V2.3, V2.4
- Disc start-up retry (for open discs and discs with errors)
- Servo switch-off after filling up internal buffer
- Basic player controls
 - Play/Pause/Stop
 - Next track/Previous track
 - Fast forward/Rewind
 - Digital Volume Control
 - Hold (disable keypad)
- Track/File programming
- Flat/Hierarchical/Collapsible file system browsing
- Playlist
- Shuffle
- Repeat (None/One/All/AB)
- Pre-set 5-Band Graphical Equalizer (Flat/Rock/Classic/Jazz/Ultra bass modes)
- User Definable 5-Band Graphic Equalizer
- ESA, with 4X ADPCM compression
- Intro-Scan
- Lid Open/Close detect, with player stop on Lid Open
- Booting from Flash memory
- Last three file systems stored during power-down in flash memory for quick start-up
- Resume on power-up with previous settings and playing position
- Software update from CD

- Additional displays through Menu
 - Hold/Resume setting
 - Decoder Information (type, sampling rate, bit rate)
 - Time (Elapsed/Remaining time for current track)
 - ID3 and WMA tags display of artist, title, album, genre and year
- Configurable SSC (sub-code and sector controller) and BFM (buffer and file management)
- Easy to add new decoders (e.g., Ogg Vorbis, MP3Pro) and additional audio post processing (e.g., SRS WOW, QSound Sizzle)

3.2 System Testing

The demo has gone through some basic system tests using various types of disc. In total about 130 discs have been used. Different CD writers (HP and Sony) have been used. In addition, testing has been done using the ABEX test discs from Almedio Japan. These cover a range of tests, including scratches, black dot, black band, fingerprints, multi-session, MP3 and WMA, tones of various frequencies, left and right channel separation, directory structure, nested directories, ID3 tags etc.

For more details, refer to the Almedio web-site at www.almedio.co.jp/english/tmsection_index.phtml.

4 Hardware Requirements

To run the demo requires a modified M5249C3 evaluation board (EVB), an audio daughter card and a modified CD player based on Philips's CD10 Servo chipset.

4.1 M5249C3 Modifications

First, check expansion connectors (J4 and J5) are fitted, allowing connection to the daughter card. If required to retro-fit the connectors, various height options are available, it is recommended to use the tallest option (13 mm), allowing easier access to the numerous connectors on the daughter card and reducing the risk of component fouling between the two boards. The connectors are available from AMP, part number 5-179010-5.

It is also necessary to remove some components from the board to prevent IO conflicts when running the demo, U13, U14, U19, R109, R110, and R115 to R117 must be removed.

NOTE

Ensure short circuits are not introduced when adding and/or removing components.

The demo software can be built to run either from Flash or SDRAM, see software documentation. In order to build and run a suitable image requires a Diab ColdFire Compiler licence (version 4.3f) and WindRivers's VisionProbe II BDM cable (or suitable alternative).

Alternatively contact your local Freescale representative about acquiring an appropriate ROM image to program the onboard memory with any suitable programming tool, including the M5249C3's dBUG command line monitor/debugger.

NOTE

If using dBUG, program the Flash memory before modifying the EVB itself.

After successfully running the demo, audio output from the CD player can be heard from the headphone jack plug (J1), with interaction possible through the daughter card's user interface—LCD and keypad.

4.2 M5249C3 EVB (Required Jumper Configuration and Modification)

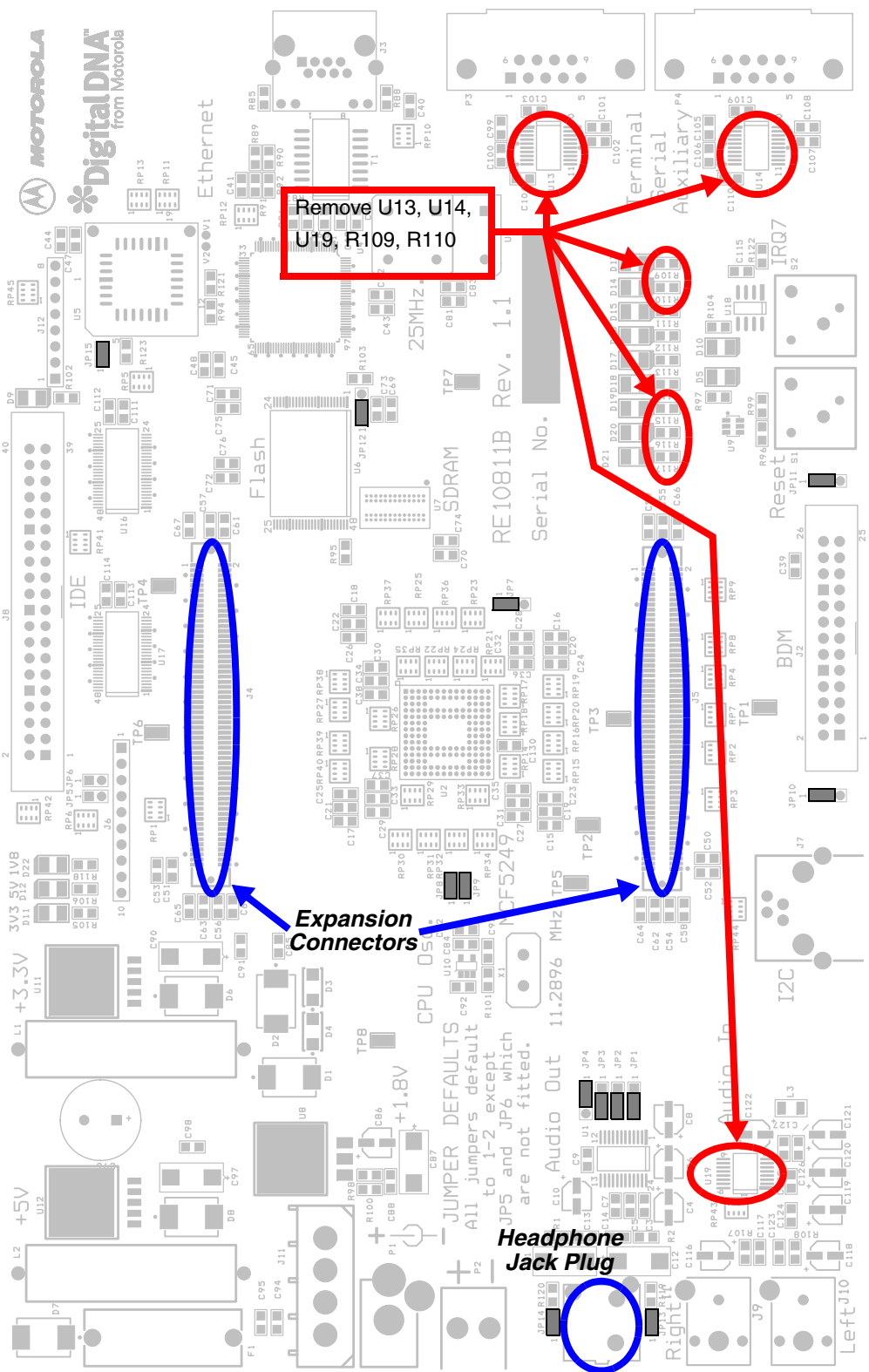


Figure 3. M5249C3 EVB Required Jumper Configuration and Modification

4.3 Audio Daughter Card (Required Jumper Configuration)

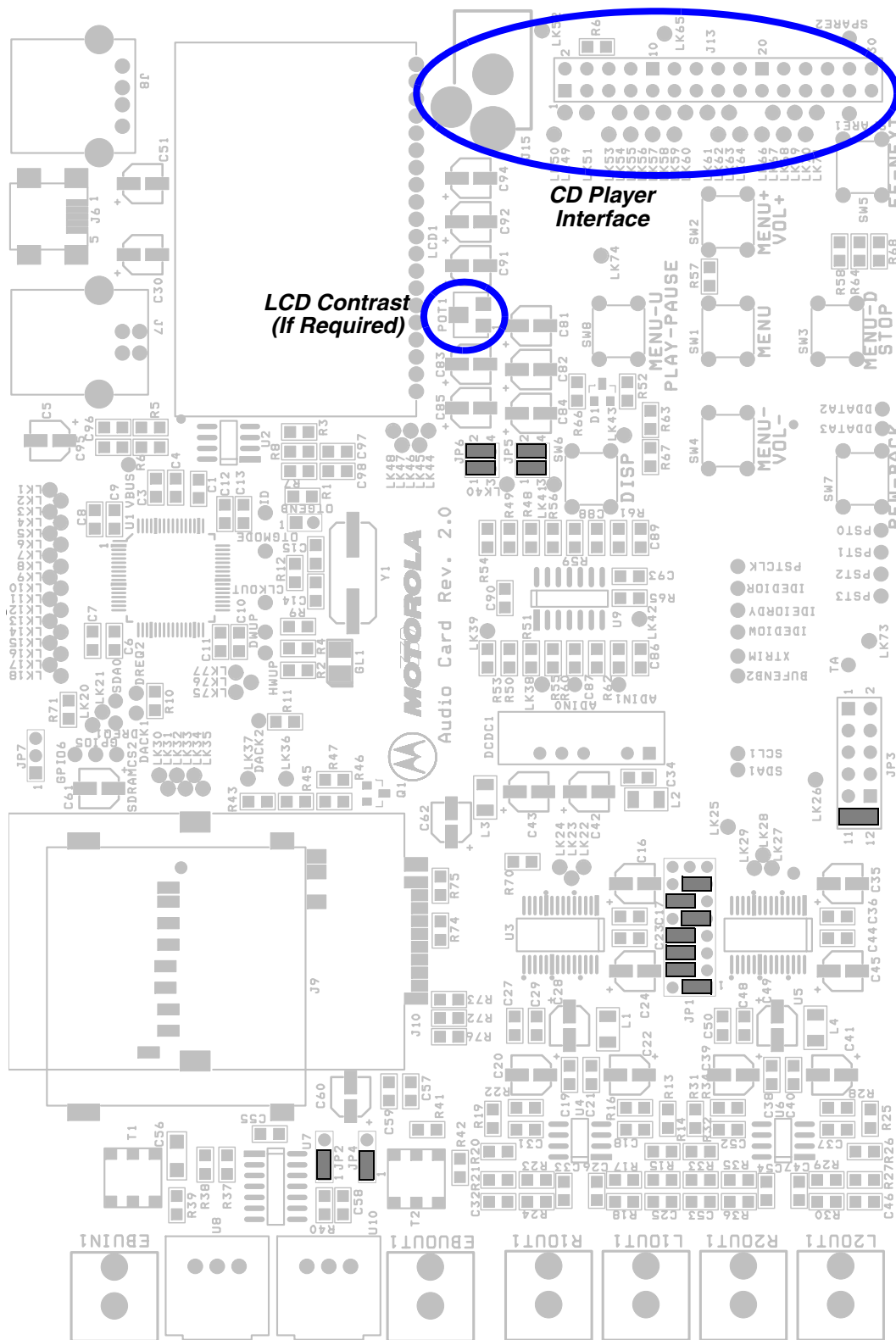


Figure 4. Audio Daughter Card (Required Jumper Configuration)

4.4 CD Player Modifications

Although in theory it should be possible to convert any CD player, based on the CD10 servo chipset, to run the demo, in practice it would be simpler to follow the worked example shown.

Any of the following Philips's portable CD player model numbers should be suitable, however the one used in the demo, which is known to work, is the AX5015:

AX2000, AX2001, AX2002, AX2003, AX2011, AX5000, AX5001, AX5002, AX5003, AX5004, AX5006, AX5011, AX5012, AX5013, AX5014, AX5015, AX5016, AX5017, AX5018, AX5019

The modifications required, include removing and refitting some components on the CD player circuit board and providing a wired interface between the modified CD player and the daughter card.

NOTE

Ensure short circuits are not introduced when removing components from the circuit board.

J13 and J15 on the daughter card are intended to provide the necessary interface, J15 can be used to power the CD player, with a +5 volt DC, centre +ve, power supply. The following table details the minimum required interface between J13 and the CD player.

Table 1. CD Player Interface

J13 Pin Number	MCF5249 Pin Name	MCF5249 Function	CD Player Connection	CD Player Reference
1	SDATAI1	IIS1	SDATAI	7880-11
2	SCLK1	IIS1	SCLK	7880-13
3	LRCK1	IIS1	LRCK	7880-12
4	EF/GPIO19	EF	EF	7830-30
5	CFLG/GPIO18	CFLG	CFLG	7830-53
6	SCLK4/GPIO50	GPO	SDA	3413
7	LRCK4/GPIO46	GPO	SCL	3412
8	RTS0/GPO30	GPO	RAB	3861
9	RTS1/GPO31	GPO	SILD	3860
10	RCK/GPIO51	GPO	PORES	3864
11	SFSY/GPIO52	GPO	SMUTE	7400-63
12	SUBR/GPIO53	GPO	SLEEP	7400-64
13	CTS0/GPI30	GPI	WAKE	6400
14	TIN0/GPI33	GPI	RESUME	3403
15	TIN1/GPIO23	GPI	HOLD	3402

Table 1. CD Player Interface (continued)

J13 Pin Number	MCF5249 Pin Name	MCF5249 Function	CD Player Connection	CD Player Reference
16	RXD0/GPI27	GPI	LID SWITCH	3404
17	RESET	RESET	RESET	2405
18–28	—	—	—	—
29–30	GND	GND	GND	2257–2250

4.5 Circuit Board Modifications

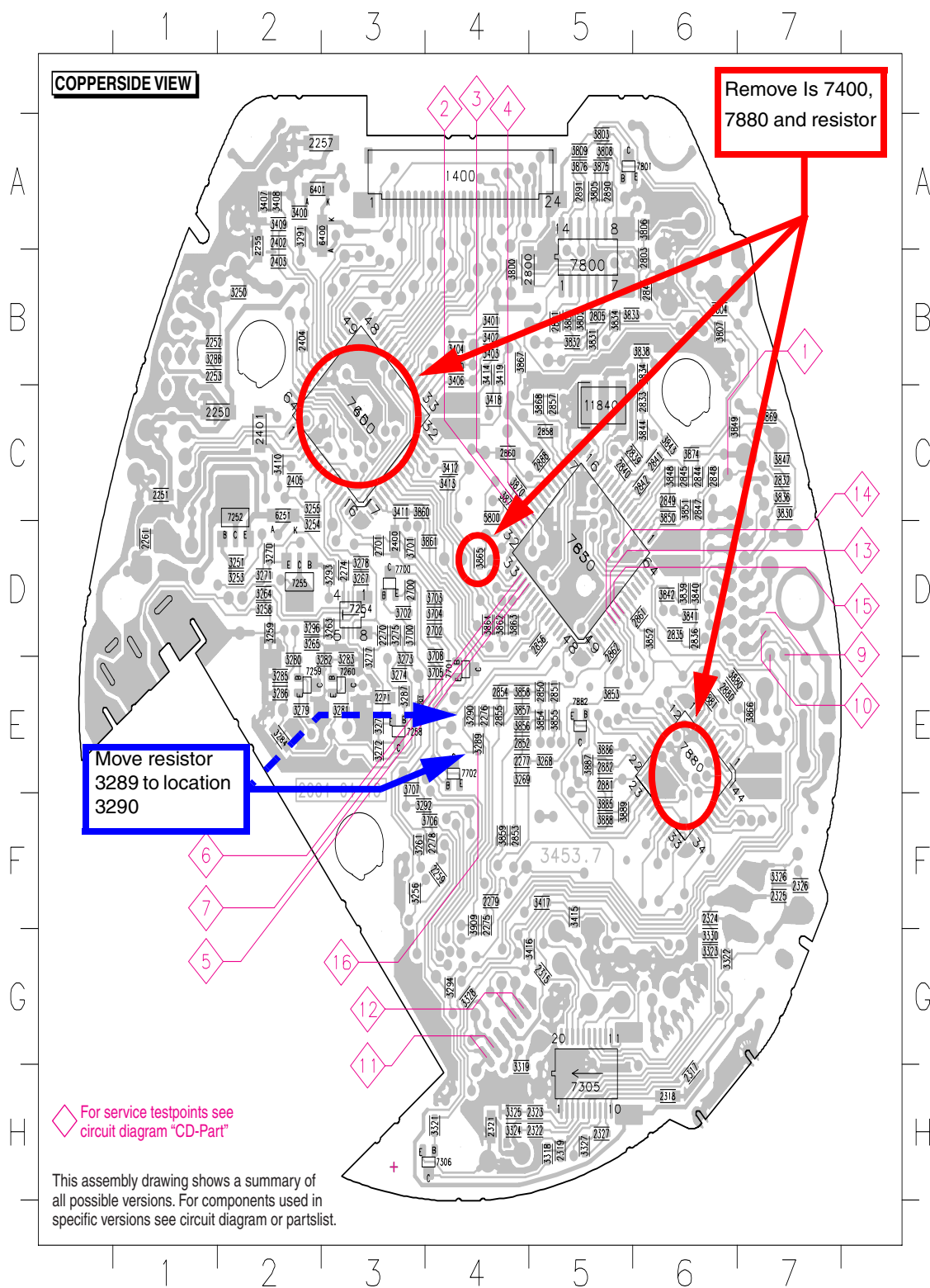


Figure 5. Circuit Board Modifications

5 Conclusion

5.1 Advantages of the MCF5249 for Digital Audio

To achieve high volume sales, consumer audio equipment must have the following attributes:

- **Affordability:** Low system cost by having control and DSP functions on a single CPU, good code density for efficient use of memory and high levels of integration.
- **Ease of Use:** Compiler friendly architecture, good development tools, fully automated design methodology for faster time to market and flexibility to changing requirements.
- **Long Battery Life (in portable applications):** Operation at low voltages and low clock frequencies, high levels of system integration.

The MCF5249 is a low cost, high performance (125 MIPS @ 140 MHz), low power (1.3 mW per MHz), highly integrated processor designed specifically for compressed audio applications, capable of supporting CD, HDD and/or Flash Media stick applications.

The software implemented decoder approach provides excellent performance (MP3 decoder requires only 19 MHz), whilst future proofing designs against new algorithms, by allowing software upgrades.

A fully supported software library, via a license agreement, is readily available.

5.2 Additional Information

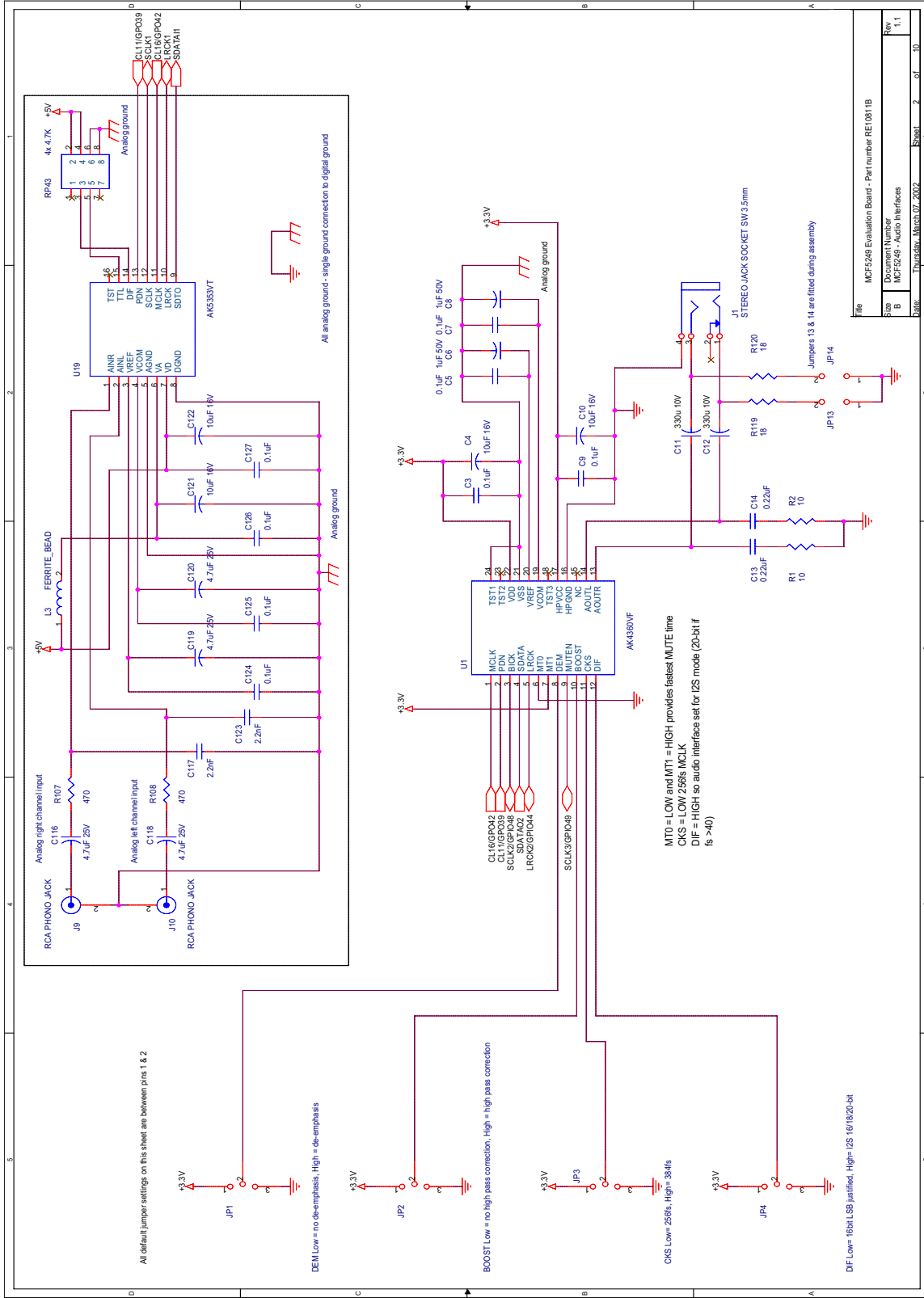
There are numerous CD servo chipsets available, and although this demo is based on Philips's CD10, support is also available for Sony and Sanyo chipsets, with additional support being added as required.

In addition to the decoder, Freescale has also implemented a real-time MP3 encoder on the ColdFire architecture. A high quality MP3 encoder has been developed, rivalling the best MP3 encoders available in terms of audio quality, this allows the MCF5249 to meet the requirements of CD burner products.

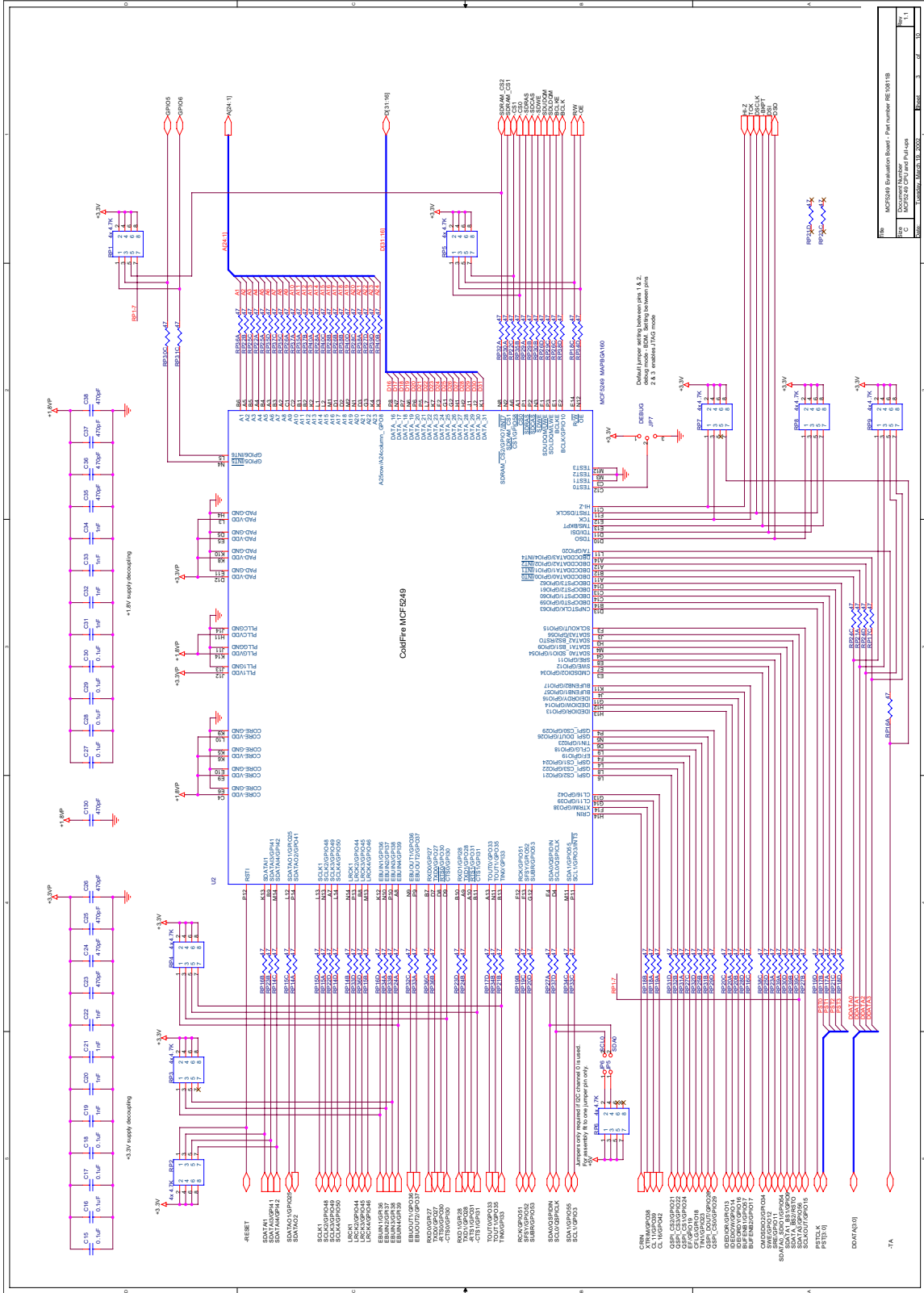
The Trio demo is currently based on the CD platform, the HDD demo is in development.

Although the MCF5249 was originally intended for compressed audio applications, its low cost, high performance is helping it find other markets requiring a similar split between control and signal processing, such as biometric applications, for example, finger print recognition.

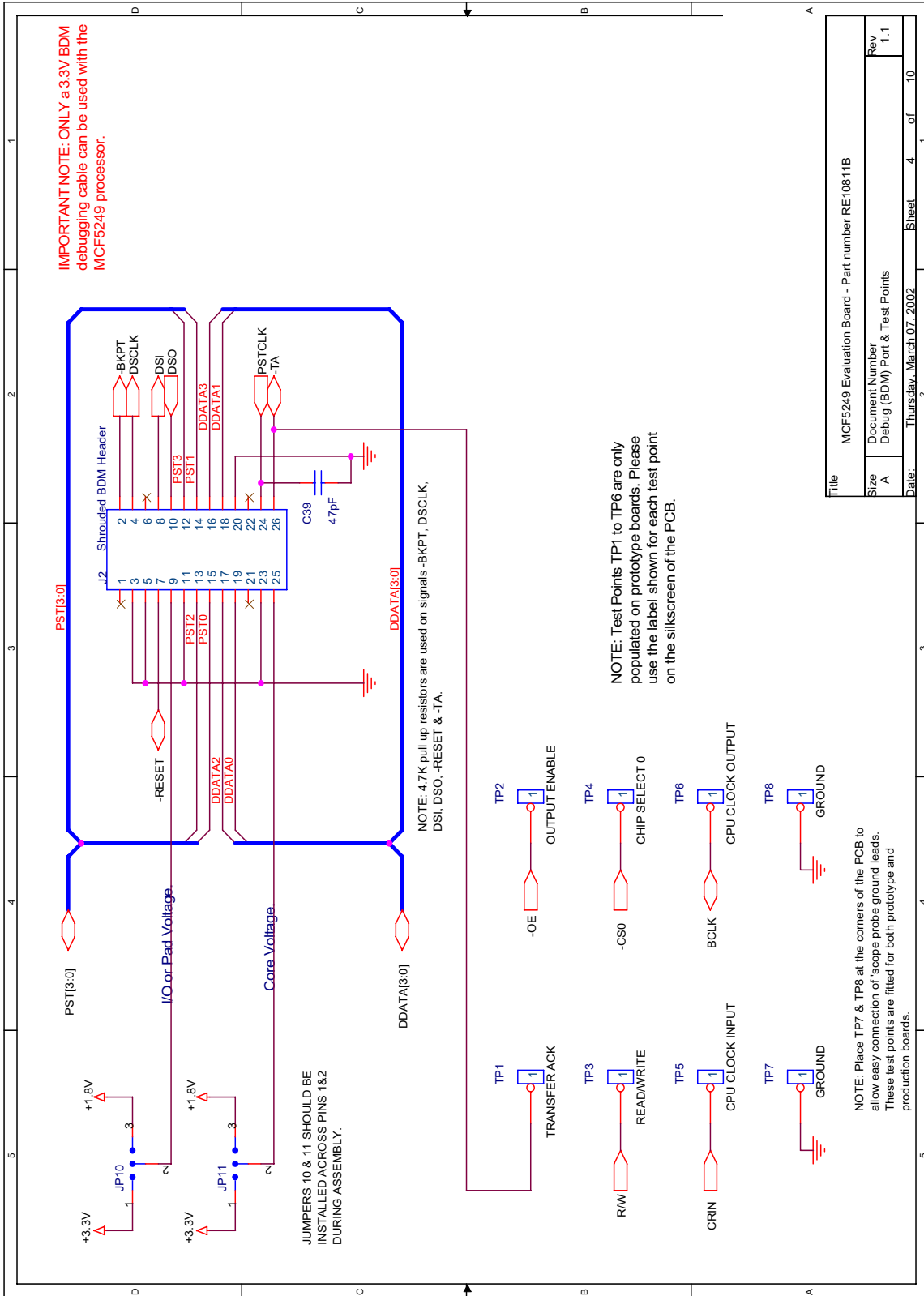
6 Appendix A: M5249C3 Schematics

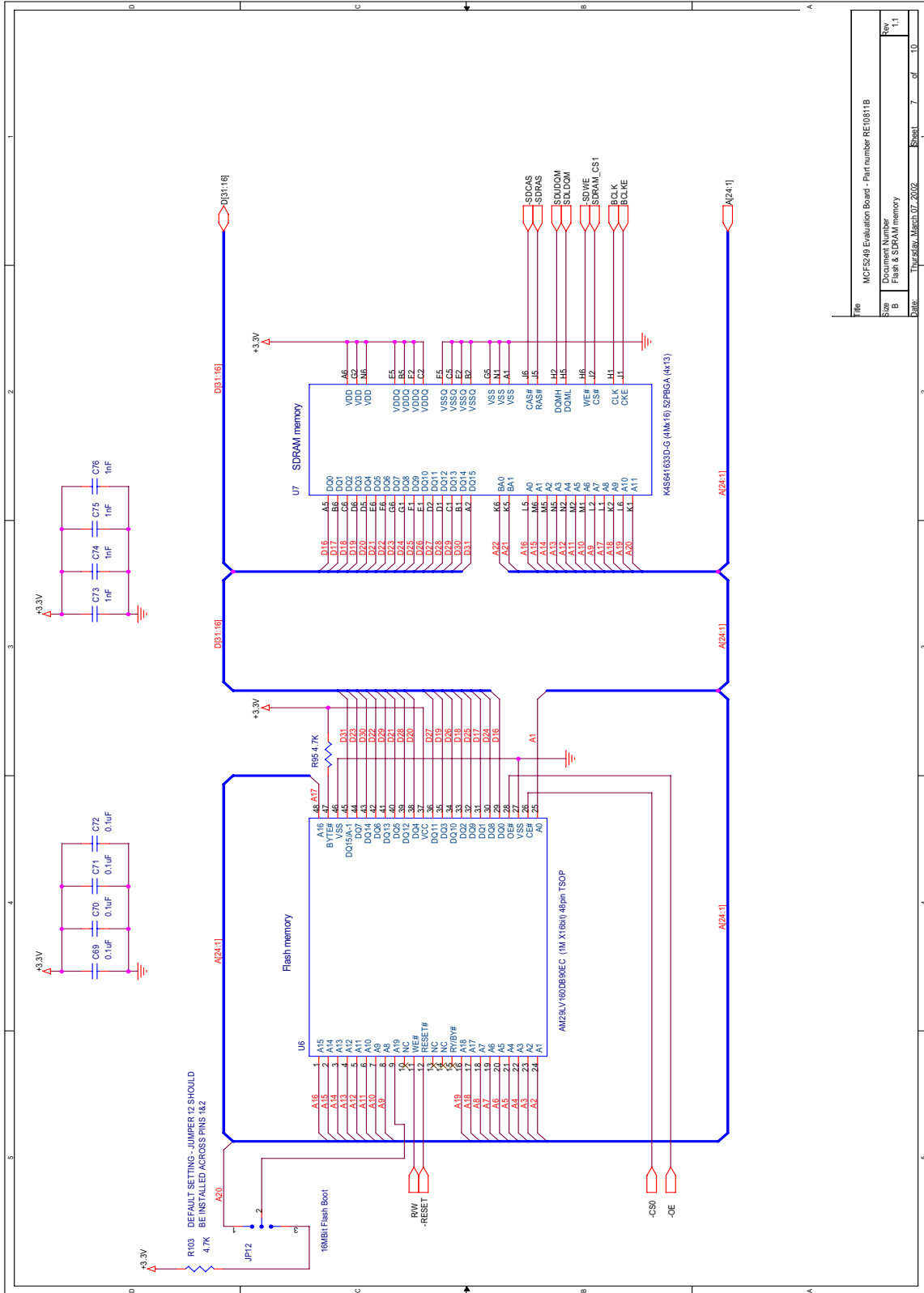


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Rev	1.1
Date	Thursday, March 07, 2002
Sheet	2 of 10

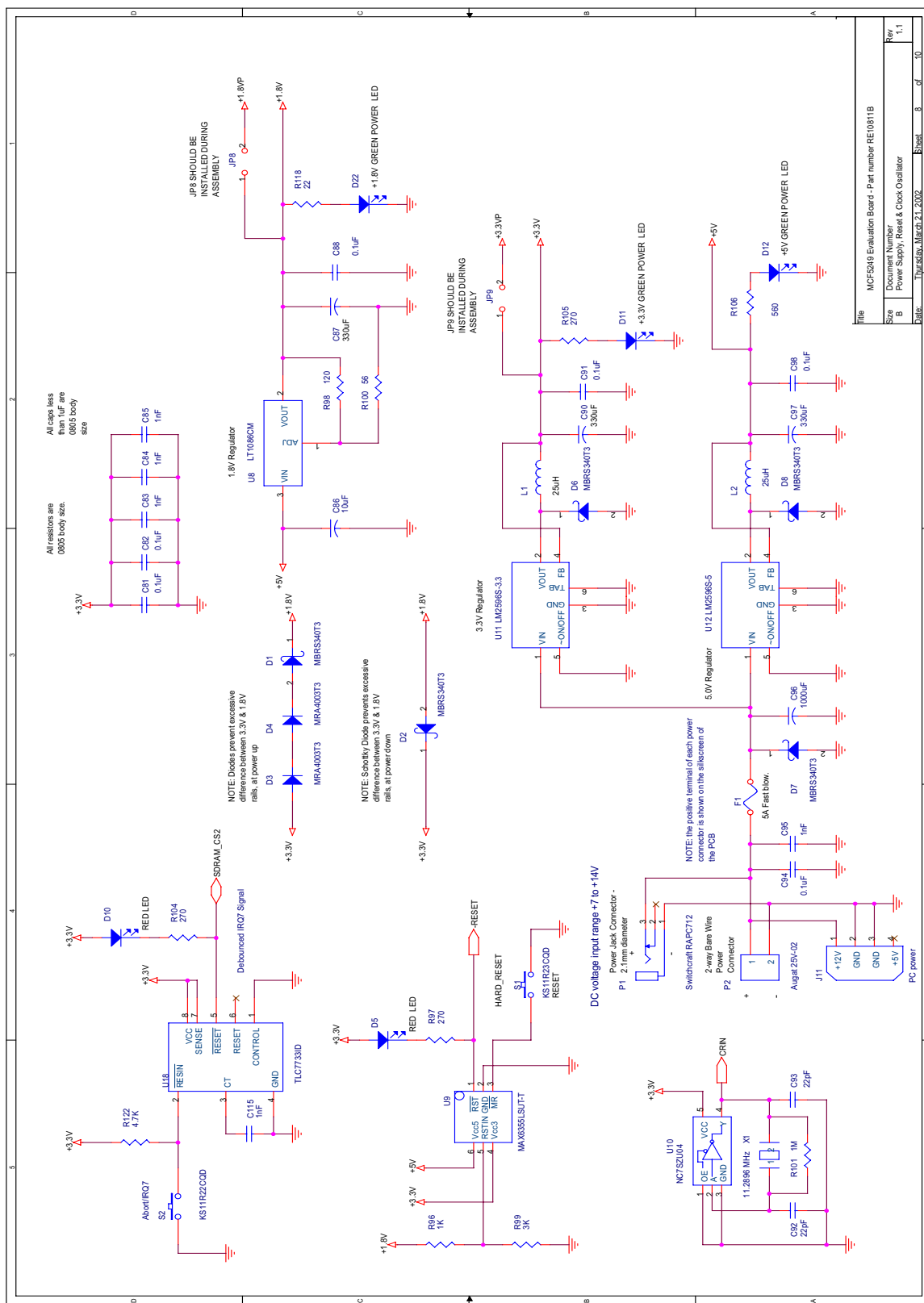


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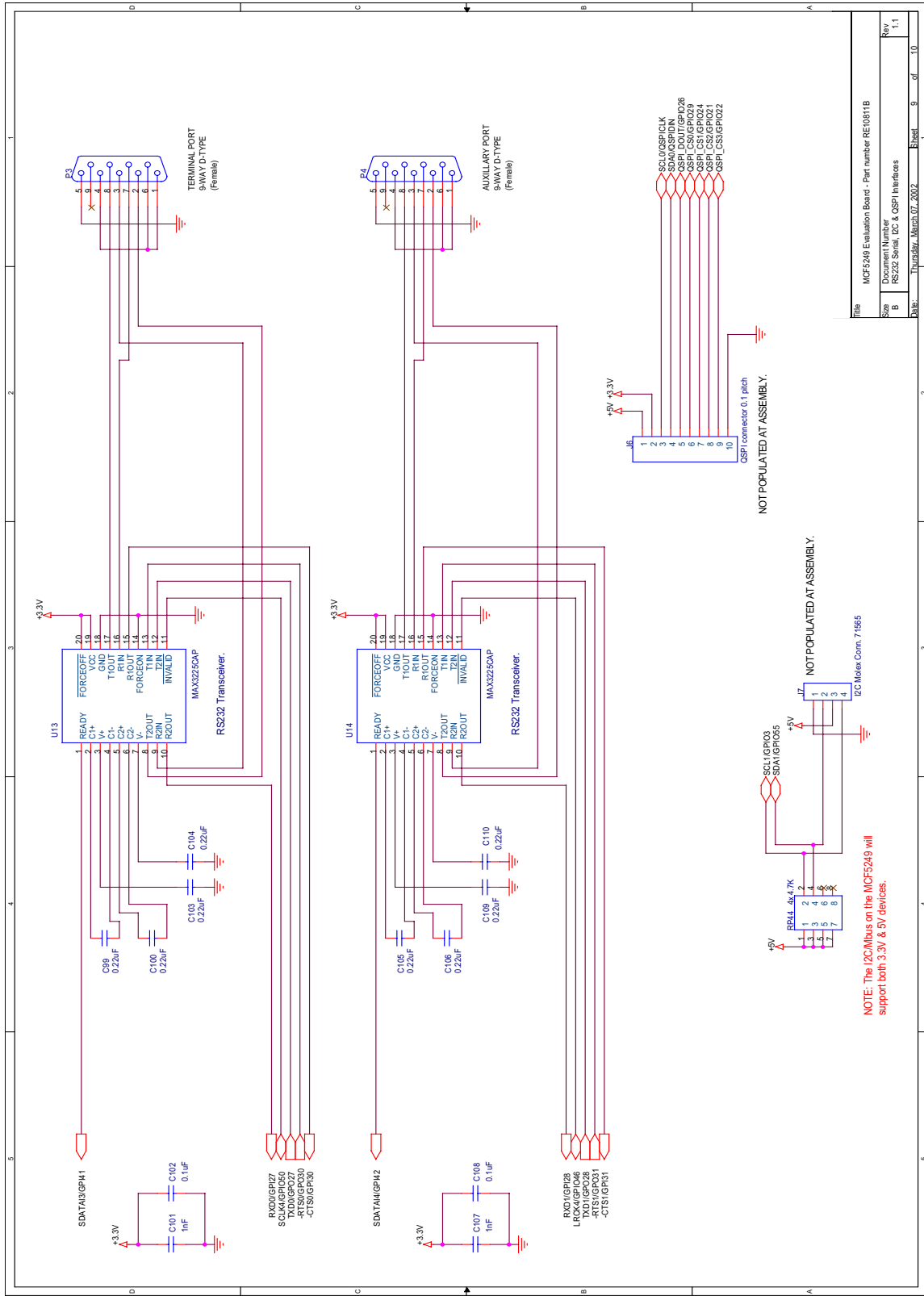




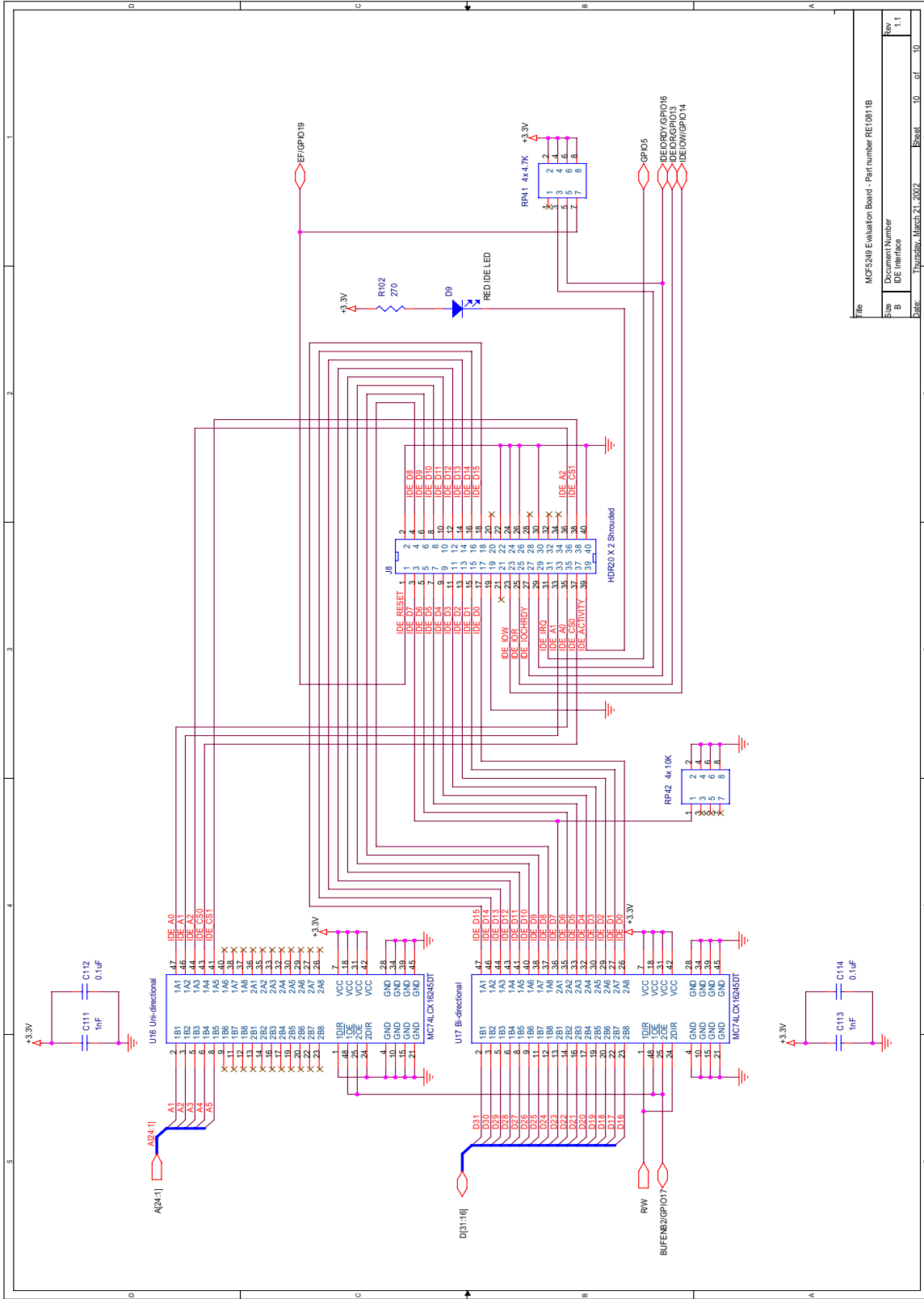
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Docu. Number	Flash & SDRAM memory
Rev.	v.1.1
Date	Thursday, March 07, 2002



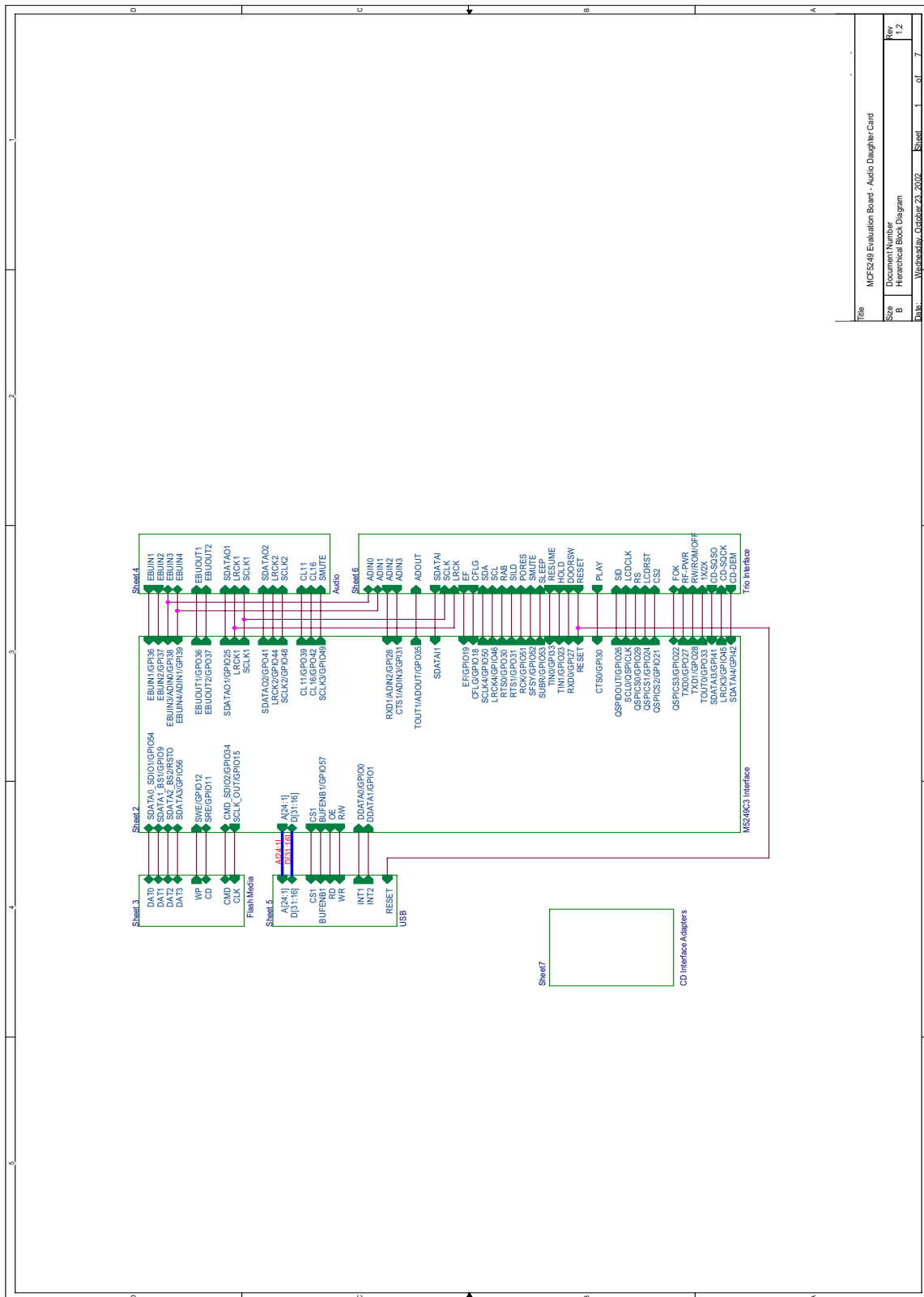
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Date	Thursday, March 21, 2002
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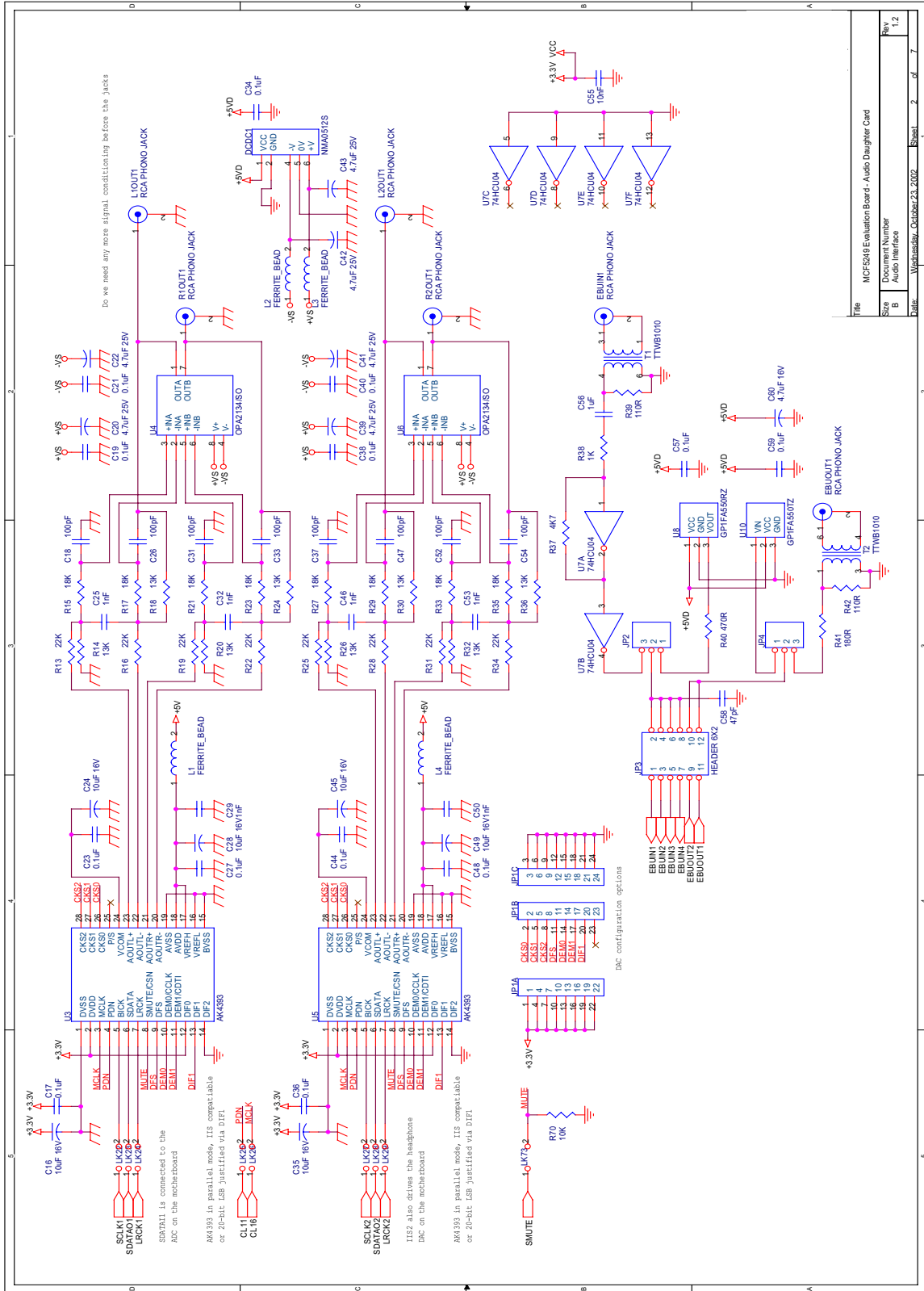
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Document Number	RS232 Serial IC & CSPI Interfaces
Rev	1.1
Date	Thursday, March 07, 2002
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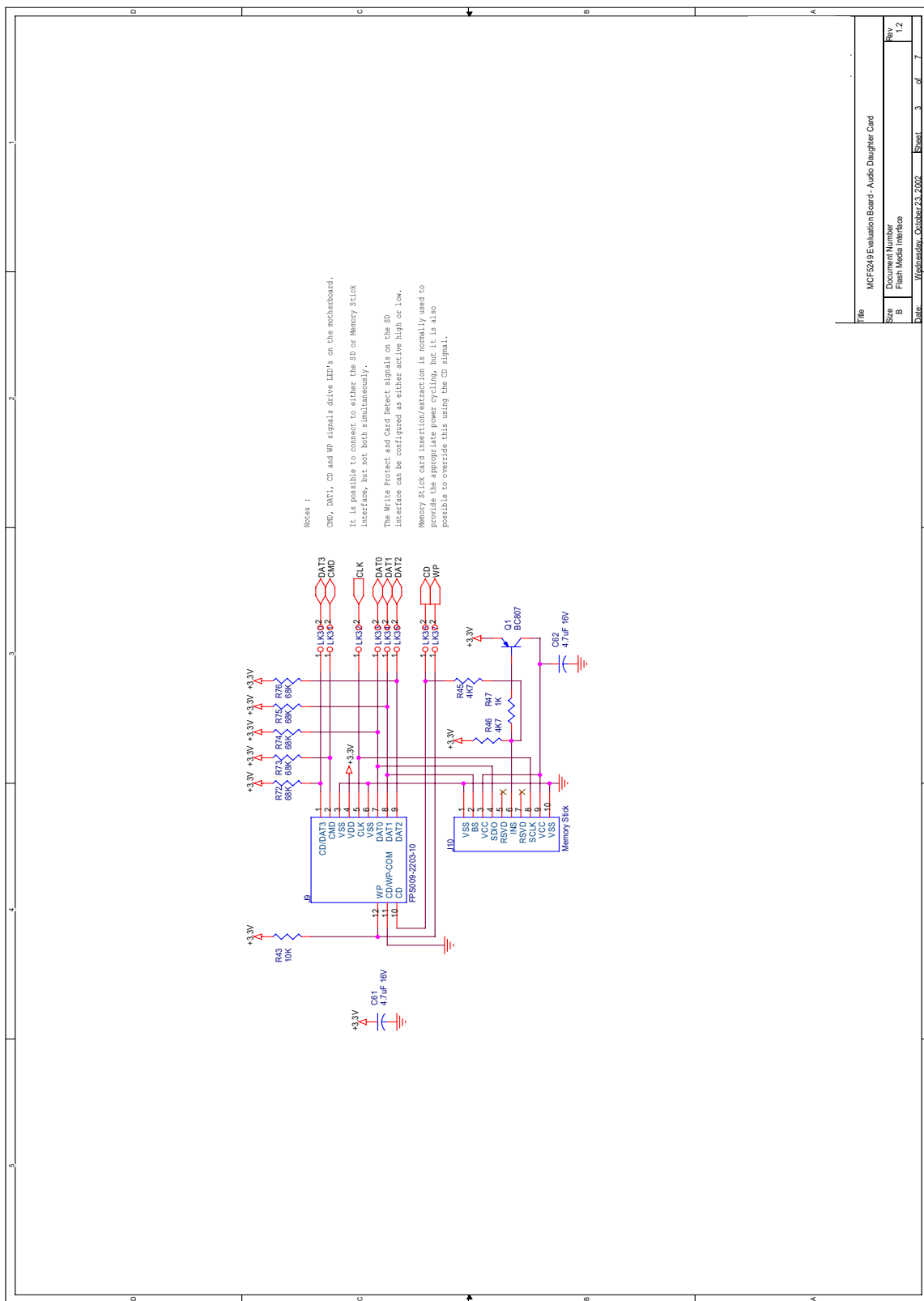


7 Appendix B: Audio Daughter Card Schematics

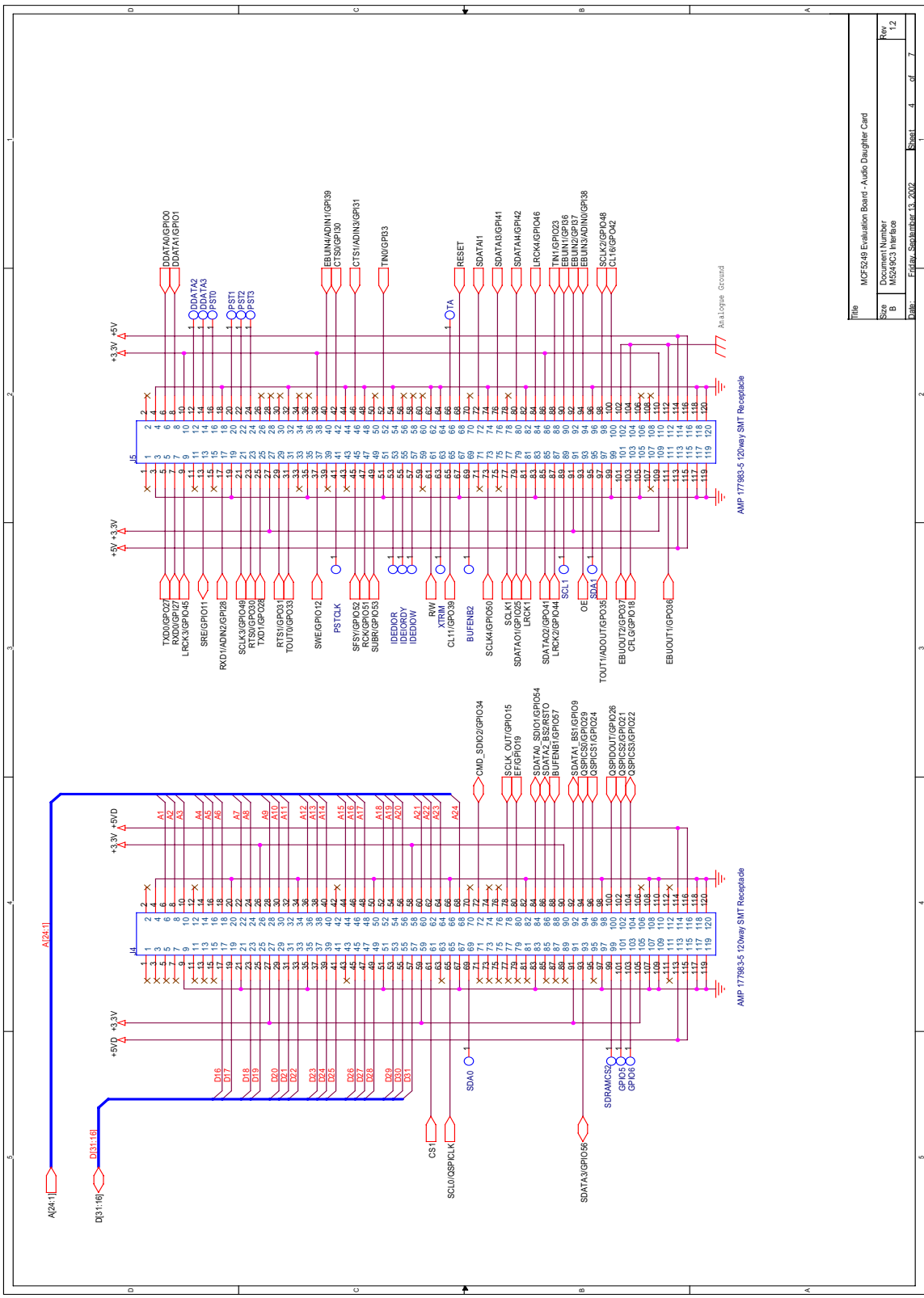


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Rev	1.2
Date	Wednesday, October 23, 2002
Sheet	1 of 7

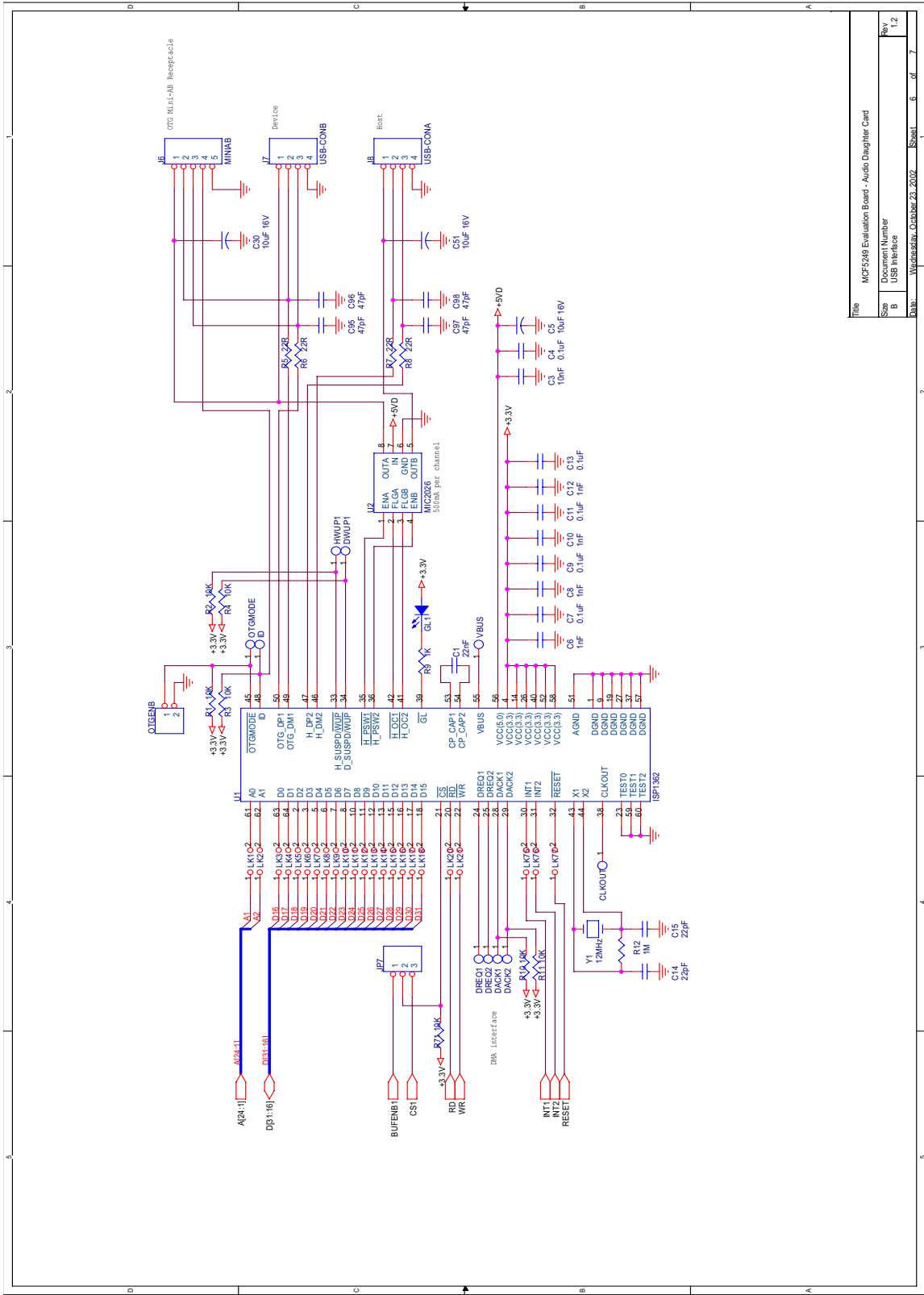




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Size	Document Number
B	Flash Media Interface
Rev	1.2
Date	Wednesday, October 23, 2002
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Sheet	Document Number	Rev.	
B	MCF5248 Rev. B	v.1.2	
Date:	Friday, September 13, 2002	Sheet	9 of 7



Title	MCF5249 Evaluation Board - Audio Daughter Card
Size	Document Number
B	USB Interface
Rev	1.2
Date	Windsor, October 23, 2002
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Title	MCF5248 Evaluation Board - Audio Daughter Card
Size	Document Number
B	CD Interface Adapters
Rev	1.2
Date	Monday, October 25, 2002
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