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March 2, 2004

Dr. Lakshman One
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Re: ENSC 440 Design Specification for Digital Audio Input Speakers

Dear Dr. One,

Attached is the document, *Design Specification for Digital Audio Input Amplified Speakers*, which illustrates the design methods for the required functions as stated in the *Functional Specification for Digital Audio Input Speakers.* The methods of design for a prototype system that will use a common power supply to power to the speaker system and amplify the audio signals are presented. This document will focus primarily on design requirements for a prototype model, however a final production version will be referred to where appropriate. This document is referenced at: http://www.sfu.ca/~bmpun/teampower/documents/DesSpec_r1_TeamPower.pdf.

The attached document closely follows the sections defined in the functional specifications for ease of reference.

Should you have any questions, comments, or concerns, please feel free to contact us at our group e-mail: 440-team-power@sfu.ca. Or please contact our CEO, Dave Steele, by phone at 604-944-2626 or 604-944-6716 after hours. We thank you for your time and effort.

Sincerely,

*Dave Steele*

Dave Steele
President

Team Power Audio Solutions

**Enclosure:** Design Specification for Digital Audio Input Amplified Speakers

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Team Power Audio Solutions

Design Specification for

# Digital Audio Input Amplified Speakers

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*Revision:* 1

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# Abstract

The Design Specification details the method for implementing our project, the Team Power Audio Solution, as defined in the Functional Specification. Unlike the Functional Specification, however, this document will focus mainly on implementation of the prototype versions rather than the final version. This is because the implementation details of the final product rely heavily on results obtained by analyzing our prototype data.

The prototype version consists of a hardware module that accepts an analog signal as input and is powered by a 9V DC voltage source, as well as extraneous power supplies required to power the DSP development kits that we are using. The hardware module is designed so that a switching power supply in the Buck configuration supplies power to the speaker unit as well as amplifies the analog input signal. The analog input signal is first sent to a Texas Instruments TMS320C6211 Digital Systems Processing (DSP) Board where it is digitized. The control logic, implemented using the DSP board, is used to control the power supply output so it follows the analog input. This control logic uses the digitized analog input signal and digitized feedback from the output of the power supply to regulate the control of the power supply. The ADCs to be used are found on the MULTI-CNVTR-EVM daughter board connected to the DSP.

Prior to production, considerable research and development must be performed in the prototyping stages in order to better determine the feasibility, performance, and cost-effectiveness of this system as a stand-alone product. This document deals mainly with the implementation of our first prototype.


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# Glossary

2N222 - BJT Transistor, tolerates approximately 400 mW

ADC - Analogue to Digital Converter.

DAC - Digital to Analogue Converter

DAIAS - Digital Audio Input Amplified Speakers, acronym for our product name.

DSP - Digital Signal Processing / Digital Signal Processor

FET - Field Effect Transistor, more ideal switching device.

Minijack - Standard audio device connection type.

MULTI-CNVTR-EVM - Texas Instruments daughter board module for use with TMS320 series DSP kits.

S/PDIF - Sony / Phillips Digital Interface, digital audio interface standard.

TLV2541 - ADC IC, shipped with MULTI-CNVTR-EVM, 1 channel, 200 kHz.

TLC2551 - ADC IC, shipped with MULTI-CNVTR-EVM, 1 channel, 400 kHz.

TMS320 - Texas Instruments DSP board, main logic component of our product.

TPAS - Team Power Audio Solutions, our company name.

# 1) Introduction

## 1.1) General

This document contains the design specification for the Digital Audio Input Amplified Speakers (DAIAS) as proposed by Team Power Audio Solutions. The details for the Functional Specification can be found in the document *Functional Specification for Digital Audio Input Speakers* issued February 17, 2004. This document is located on the web at: http://www.sfu.ca/~bmpun/teampower/documents/TeamPower_FunctionalSpec.pdf

The Design Specification describes in detail our current design of the DAIAS system. The design specification of the overall system and each component — power stage unit, control logic unit, and output feedback are outlined.

Our team of engineers will carry out the design during the next two months. The design will be carefully tested and modified as necessary. Any modification will be noted in the post-mortem. Any ideal requirements listed in the functional specification we implement will also be described in the post-mortem.

## 1.2) Scope

As was previously mentioned, the scope of this project is limited mainly to two prototype phases and does not cover that of the production device except where explicitly specified. With this in mind, however, the final production model is discussed frequently in this document, as it is necessary to have the long term goal in mind at all times when writing specifications for early prototypes.

The first prototype is expected to be complete on time for presentation March 11th, 2004, and is intended as a bare-bones proof of concept model. The second prototype is expected to be complete near the beginning of April 2004, and will be essentially a scaled-up version of the first prototype, ideally capable of amplifying an audio sample without significant distortion and accepting a digital input rather than an analog one. These requirements will be further discussed at a later point in this document.

# 2) Requirements

## 2.1) System Overview

In the prototyping stages, our product will not have any significant enclosure. The Buck power stage will be powered by a 9V DC source. The system will be able to amplify audio signals using a Buck (step-down) switching power supply using the varying audio signal as a reference voltage. In early testing stages we will use a square wave signal supplied by a function generator to verify the functionality of our Buck converter. In all further prototypes, the TMS320 DSP kit will be used to provide a control signal to the Power Converter stage.

The system can be divided into two primary components: Power Converter and Control Logic. Figure 1 illustrates the connectivity of these components. This illustration is redrawn in Figure 2, Section 3 of this document, and discussed in greater detail there.

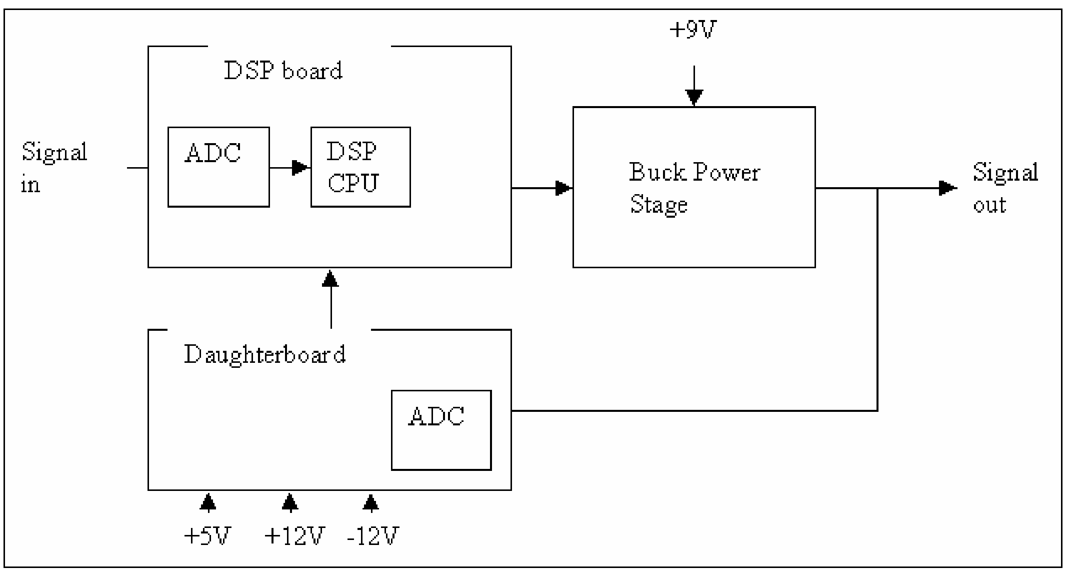


**Figure 1: System Block Diagram**

Input to the system is provided by the following components:

- Power Supply terminals
  - 9V DC for Buck Power stage (prototype 1)
  - +12V, -12V, +5V for DSP daughterboard
  - DSP board power terminal, standard 120 V plug
- DSP board parallel port (to interface with laptop)
- analog audio input jack (minijack)

Output from the system is:

- Analog output signal

The minijack analog input on the TMS320 DSP board is digitized by an onboard ADC, and does not make use of the daughter board. The output of the Buck power stage is fed back to an ADC onboard the MULTI-CNVTR-EVM daughter board connected to the DSP board. The control algorithm software, which runs on the DSP board, compares the output voltage of the Buck power stage to the analog input signal. A control signal in the form of a 100 kHz pulse width modulated square wave controls the output voltage of the power stage in such a way as to reproduce an amplified version of the input audio signal.

## 2.2) Overall System Requirements

The specifications described in this section will apply to the overall system and apply to the proof of concept prototype. Design specifications relating to individual components will be described later in the document.

### 2.3.1) Environmental

The environmental requirements apply to both the production unit and the proof of concept prototype.

As our DAIAS unit will be used mainly for indoor purposes, component selection should comply with current standards for indoor home or theatre entertainment systems. All components used in building the system will be able to operate in temperatures between 10 to 40$^{O}$C and humidity range of 10 to 80% non-condensing to ensure that the DAIAS will work at least under ideal room temperature conditions.

### 2.3.2) Performance

The proof of concept prototype is required to accept a +/- 1V analog sin wave signal and output a +/-5V, 0.5 watt output signal for frequencies between 100Hz-1kHz.

### 2.3.3) Compatibility

The proof of concept prototype will accept an analog input signal from a function generator with a standard minijack connector. It will be powered by +9V, +5V, +12V, -12V from two bench top linear power supplies.

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# 3) Interface Requirements

In the following sections we will discuss the interface requirements of our system. We will first look at the interface between internal components of the system, and then look at the external interfaces as specified in the Functional Specification document[1].

## 3.1) Internal Interfaces

As is illustrated in the block diagram of Figure 2, there are two primary components of the system: Power Converter and Control Logic. The third component distinction can be made between the actual control logic DSP board and the ADC that resides on the daughter board. Both the Power Converter and Control Logic are double input single output devices, as is the system as a whole.

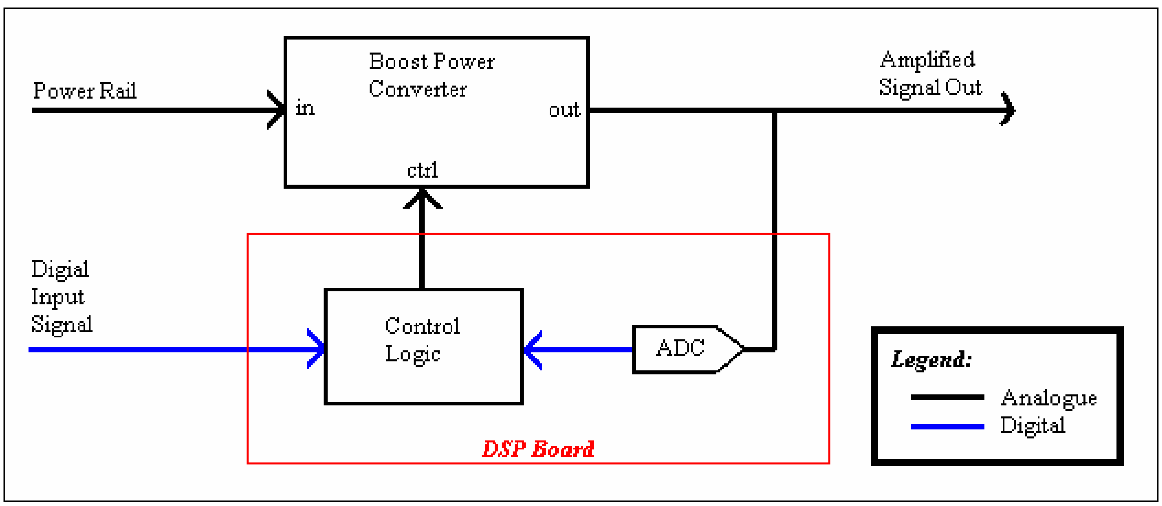


**Figure 2: Component Breakdown**

It should also be noted that the Control Logic forms a feedback loop within the system and that all lines representing information flow are unidirectional. In the following sections, we will discuss the interface of each of these components as seen from the input side.

[1] http://www.sfu.ca/~bmpun/teampower/documents/TeamPower_FunctionalSpec.pdf

### 3.1.1) Digital Input Signal

As specified in previous documents, for the final revision, the input signal to our product will be in the form of an S/PDIF encoded digital audio signal. This encoding type was chosen because it is already a common standard with which CD players and home stereo systems are being equipped. It is low power (as compared to a typical speaker output) and digital in nature, thus satisfying two of our key design requirements: to minimize line interference and to maximize power efficiency.

During the prototyping phase, however, it is more straightforward for us to utilize existing hardware on the DSP board to receive a pure audio input signal through a standard minijack microphone jack as could be supplied from a standard CD or tape player. Using this method also makes it a simpler code modification to switch back and forth between using actual input and generating simulated input using the DSP.

### 3.1.2) Amplified Signal Out

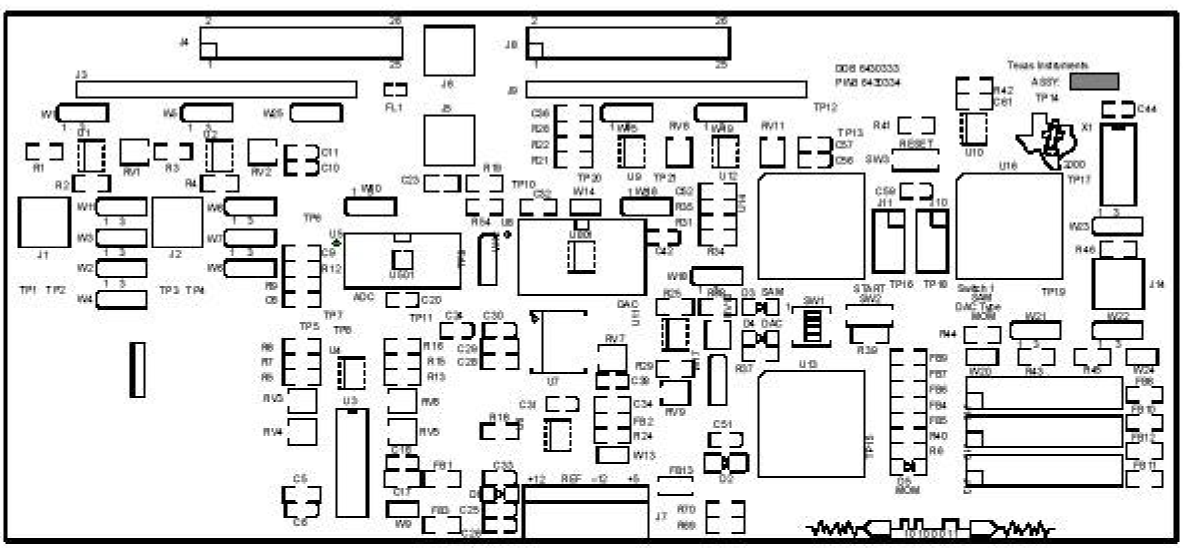

**Figure 3: EVM Daughterboard**

The output signal from our Power Converter stage is also tapped as feedback into our Control Logic Stage. It is defined as a +/- 1 V analogue audio signal, such as would be sufficient to drive a set of headphones. In the final product, of course, the output power levels would need to be significantly higher in order to drive speakers, however this is out of the scope of the current project as defined in the Functional Specification.

The analogue output signal, as feedback, will tie into an input port on the MULTI-CNVTR-EVM daughter card (shown in Figure 3), which is directly connected to the DSP using a standard Texas Instruments bus interface. The daughter card is a DAC/ADC evaluation tool that allows the user to trial a variety of DACs and ADCs with a minimum of interface redesign.

For our initial prototype, we will use the TLV2541 ADC converter to receive the audio feedback signal, as it is the default component that ships with the board and it suits our needs for the primary prototype nicely. Having a sampling rate of 200 kHz, the TLV2541 will not be sufficient for our second prototype or our final product, however there are several alternative ADCs packaged with the daughter board, such as the TLC2551, which switches at 400 kHz. Note that our initial specification was for the final product to switch at 500 kHz. At this point in time it is difficult to predict whether 400 kHz will be sufficient, however this should become considerably more clear after results of been analyzed from the first two prototyping stages.

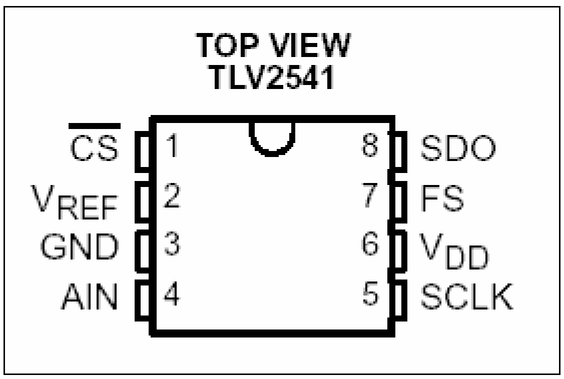


**Figure 4: Pin-outs for TLV2541 ADC IC**

Figure 4 shows the TLV 2541 Analogue-Digital-Converter IC, which has a single channel input with a sample rate of 200 kHz.

### 3.1.3) Post-ADC

All signal processing after the ADC is internal to the DSP and daughter board and is therefore limited by the structure of the TI devices. This interface is essentially software in nature. It will not be discussed here other than this brief mention.

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### 3.1.4) Control Signal

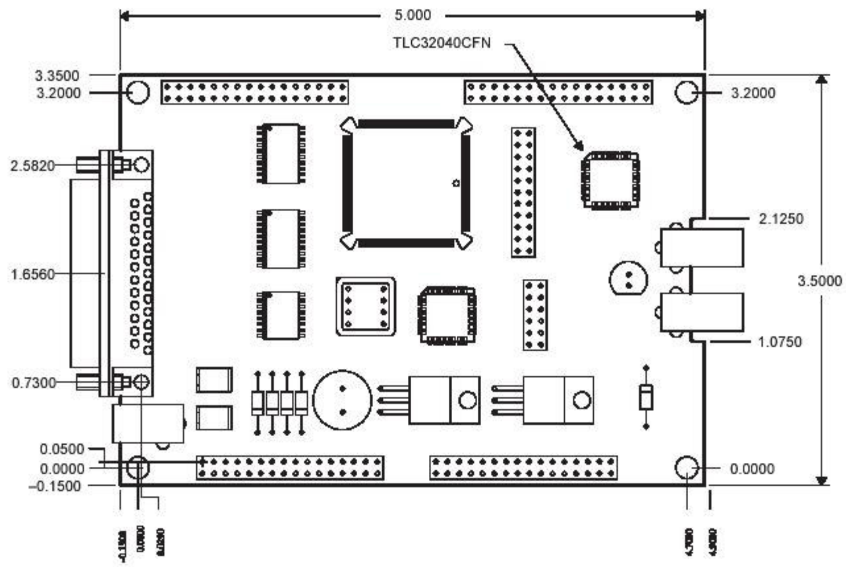


**Figure 5: TMS320 DSP board**

The Control Signal is perhaps the most key component of our system. Using a Timer Output from the TMS320 DSP board shown in Figure 5, the Control Logic influences the voltage output levels of the Power Converter by varying the duty cycle of this square wave signal. For the initial prototype, this signal will be a 100 kHz square wave, however in future revisions we expect to require a much faster signal in the range of 400 kHz or above.

This document will not attempt to delve into the theory behind switch mode power supplies, however it is key for the reader to understand that the output voltage of the Buck power supply (indeed all switch mode power supplies) configuration is proportional to both the frequency and the duty cycle of the control signal. We have chosen to keep the frequency constant, while varying the duty cycle to produce the required effect.

It is important to note that for any application other than extremely low power scenarios, a driver circuit as well as an isolation circuit is required between the output of the DSP and the switching semiconductor component of the Power Converter. The reason for the isolation circuit is obvious: to protect the DSP from power surges and general prototyping errors, as it is the most expensive component of our system. The driver circuit is needed in order to supply the current necessary to open or close the “gate” that controls the state of the Power Converter.

In the case of our first prototype, a driver circuit is not necessary due to the extremely low voltages being used. In fact, the isolators themselves should be sufficient to drive the switching transistor (model 2N222A). In later revisions, the 2N222A transistor will be used to source current for a high power switching FET.

Unfortunately, at the time of writing this document we are still unable to properly utilize the timer output of the DSP board in such a way as to produce the required signal. This is indeed a very large roadblock in our design, however we are optimistic that it will be overcome before the first demonstration date.

### 3.1.5) Power Rail

The simplest, though arguably the most crucial interface of our system is to the power supply. For all initial prototyping phases we will use a 9 V power supply, such as might be provided by a standard battery. The final version will require a rectified and smoothed out 120 V 60 Hz AC signal so as to maximize usability within the common household.

Of course the DSP board and daughter board have specific power requirements of their own, specifically: A 120 V 60 Hz AC signal passed through a proprietary TI transformer and then into the TMS 320 DSP as well as a 5 V and 12 V DC signal to power certain functions on the daughter card. How these needs are accommodated for in the final off-the-shelf product version is beyond the scope of this project, however the reader is reminded that the final version will most likely not make use of the DSP kit to begin with.

In all cases, the power supply will be directly soldered (or clipped) onto the circuit wherever possible, as it should be entirely internal to the final product. No fancy connectors short of a two-prong plug will be required.

## 3.2) External Interfaces

The external interface requirements of our product, as defined in the Functional Specification, relate only to the final product version, and not to the prototypes. Never the less, it is important that we address them at this early time in the design phase so as to keep our long term goals clear from the beginning. The next three sections refer to requirements **R[24]**, **R[25]**, and **R[26]** respectively, as defined in the Functional Specification[2].

[2] http://www.sfu.ca/~bmpun/teampower/documents/TeamPower_FunctionalSpec.pdf.

### 3.2.1) On / Off Button

Each instance of our product (speaker enclosure) will have an on/off button with which the user can control the power supply's connection to the circuit. This button will be depressed when in the "on" state and raised in the "off" state so as to make clear the status of the device. It will be wired in series with a replaceable (non-reset-able) fuse and directly interrupt the AC supply line to the circuit. When the button is in the "off" state, all power will be disconnected from the device.

### 3.2.2) "On" LED

Each instance of our product (speaker enclosure) will have an LED to indicate the power status of the device. Unlike the On/Off Button, the LED will be implemented at the other logical end of the device, right at the input to the Power Converter stage, so as to light only when the entire system is known to have power. A dark LED could indicate lack of power to the system as well as power interruption somewhere along the initial rectification stage. We believe this maximizes the information that is presented to the user given only a single indicator light.

### 3.2.3) Volume Control

To maximize power efficiency, the volume control will present a low-power digital signal to the DSP, which will affect the output volume via software rather than simply a resistor or other power-dissipating method. This is an "extra" feature that we hope to implement in order to improve the overall power efficiency of the device. It should be noted that in the final product this might prove not to be cost-efficient in terms of production.

From the user's point of view, each unit (individual speaker case) will have an individual volume control knob, which will attenuate the audible output signal to a greater degree as it is turned counter-clockwise. This should be no different from the standard volume control interface of any household appliance.

## 4) Standards and Certifications

The proof of concept prototype will not be required to pass any certifications or adhere to standards.

## 5) Testing Requirements

Each individual component will need to be tested as well as the overall system.

The Buck power stage will need to be tested to output +5V when switched using a 100 kHz square wave input from a function generator. The control algorithm needs to be tested to see if it is reading in the correct values from the analog input and the Buck power stage output. It also needs to be tested to verify it is outputting the appropriate analogue signal.

The entire system needs to be tested to verify it can output a +/- 5V, 0.5 Watt output signal over a frequency range of 100 Hz-20 kHz.

## 6) Documentation Requirements

The proof of concept prototype will have no formal user manual, as its functionality will be explained during the demo.

## 7) Conclusion

Due to the experimental nature of our project, we expect a high probability of unforeseen roadblocks to arise during our construction of the first prototype. With this in mind, requirements and goals for the first prototyping stages may have to be slightly adjusted "on the fly". We have high confidence, however, in the overall design specifications as they are defined in this document.

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# 8) References

## 8.1) General References

[1] "Texas Instruments" February 2004, http://www.ti.com

[2] "Magnetics" February 2004, http://www.mag-inc.com

[3] "TI Daughterboard …" February 2004, http://www.sfu.ca/~bmpun/teampower/datasheets/spra478.pdf

[4] "TLV2541 ADC" February 2004, http://focus.ti.com/lit/ds/symlink/tlv2541.pdf

[5] "Simple Switching Topologies" February 2004, http://www.smpstech.com/tutorial/t03top.htm

[6] "SPDIF" February 2004 http://sancho.hu/SBLive!/spdif.htm