by Carlos Verdonck

USB 16-bit AD/DA Converter

Build a USB Soundcard for your Desk PC or Laptop

I have always been fascinated by computers interfacing to the real world. During the last years, all kinds of interfaces have popped up: serial (RS-232, RS-485, ...), parallel, different standards, several speeds, USB 1.0, 1.1, and 2.0, SATA, ... USB or 'Universal Serial Bus' gave an answer to some of the problems encountered like speed issues and bi-directional communication (ever tried to input data on a printer port?).

This project describes the construction of a mini USB soundcard, which can be used to add a soundcard to your desktop PC or portable computer. Voice or sound recording is possible simultaneously, as well as hooking up external sound speakers for quality music playing or gaming. A very compact design (2" by 3") and low cost makes this an ideal project for the practical electronics hobbyist/professional. Just take this circuit, hook it up to a free USB port on a PC or a portable (without opening the case), attach a headphone, and start listening to your favorite CDs. It's as simple as that.

No bigger than your credit cards or wallet, it is self-powered from the USB bus. For the audio lover, it excels in audio performance for a low price, too. You can use this circuit as an audio player, as well as capturing sounds, using a microphone or an audio source. You can record voice messages and send these 16-bit sound recordings via email to friends and relatives. Ever thought of organizing a karaoke evening? Big fun!

You can easily build this project yourself or a high-quality circuit board, as well as the component set, is available from the author (see references). A completely built and tested module is available, as well.

Chip Overview: PCM2900

The heart of the circuit consists of a single chip USB codec from Texas Instruments, the PCM2900. Being USB 1.1 compliant (full speed protocol converter), the chip acts as a bi-directional USB to analog audio converter, including 16-bit AD/DA converters. There is no need for programming the device or booting parameters from an E2PROM, which makes the design efficient and compact. On-chip voltage regulators make up the necessary voltages for all internal cores, sourced from the 5V USB bus power (VBUS pin). External powering is not necessary. The on-chip analog PLLs enable independent playback and record sampling rates with low clock jitters. Due to its compact 28-pin SSOP package, the chip excels in density, looking at all features that are on-board. Complete details on this chip can be found in References (1) and (4).

Block Diagram Description

A 12-MHz crystal provides the reference clock source required by the on-chip clock generation circuitry. Internal analog PLLs are used to generate low-jitter AD/DA clocks for handling the stereo audio signals. After termination of the USB bus by the USB engine, audio samples are interfaced to the on-board 16-bit AD/DA converters. A red LED gives an indication on the state of the USB data bus. When data on the USB is in a constant idle state, the LED illuminates.

The stereo audio interfaces are 3.5 mm stereo mini jacks for connection to a microphone, powered speakers, or audio test equipment. The analog output drives a sec-

Figure 1. Block diagram AD/DA converter.

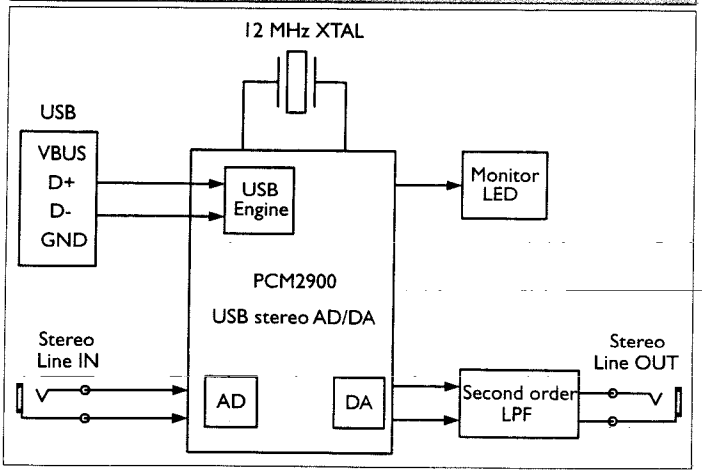
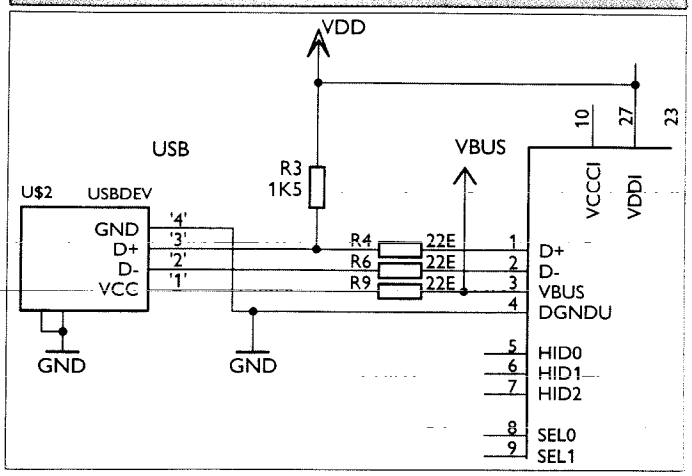


Figure 2. USB interface circuit.



ond-order low-pass filter, with a cut-off frequency around 20 kHz. This eliminates all unwanted harmonic residues from the DA conversion process.

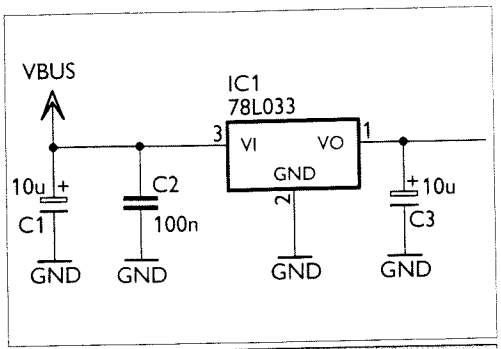


Figure 3. Power conversion circuit.

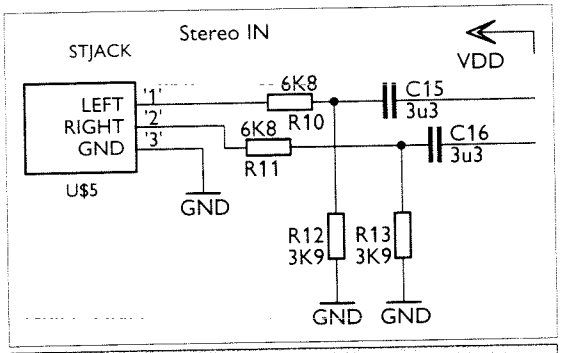


Figure 4. Analog stereo input circuit.

Circuit Details

The schematic diagram is built around the TI PCM2900 and reflects a minimum of active components. The schematic can be subdivided into five areas: the USB interface, power conversion, the stereo input stage, the USB codec, and the stereo output stage (including filtering). Again, the AD/DA converter is bus-powered, meaning that the power supply is sourced from the +5V pin from the USB bus. Let's take a look at each sub block and go into detail.

USB Interface

The PCM2900 directly connects to the USB plug, where D+, D- is the digital USB data and VBUS is the bus sourced supply. R3 is a pull-up to VDD, being 3V3, in order to define the USB data connections at transient. The USB ground pin is connected to the single ground plane on the board. Series resistors of 22 ohms suppress overshoot/undershoot on the USB bus.

Power Conversion

To achieve the highest quality with the AD-conversion process, the manufacturer of the chip highly recommends to power the PCM2900 with an external voltage regulator, which is the LE33CZ (comes in a TO-92 housing). This causes the harmonic distortion of the AD converter to be lower than 10 dB, compared to the situation where the internal voltage regulator is used. C1, C2, and C3 serve as a standard low-frequency filtering of the power rails. VBUS is the +5V input.

Measurement Results (Measured at 0dB, 44.1 kHz unless otherwise mentioned)	
Input signal	USB audio data
Nominal output signal	62% VCC (1,096 Veff @ 5V)
Frequency range (output loaded with 10K)	5 Hz ... Fs/2 (Fs = sampling frequency)
Amplitude @ 20 kHz	-0,25dB
BW analog filter	30 kHz (MFB)
Output impedance	100 ohm
Signal-to-noise ratio	> 101 dBA
THD+N (1 kHz, B = 80 kHz)	< 0,0035 %
THD+N (20 kHz, B = 80 kHz)	< 0,025 %
IMD	< 0,006 %
Channel separation	> 116 dB
Stopband attenuation digital filter	> 82 dB
Current consumption	< 60 mA

Stereo Input Stage

The analog input section of the PCM2900 chip has a fixed input sensitivity. After installation of the AD USB hardware, no regulation (in the driver) on the AD converter can be found as such. The input window of the PCM2900 is dimensioned at 0.6xVCCI, with VCCI 3.3V equal to 1.98V peak-to-peak. The resistive divider R10 and R12 (or R11 and R13) is set at 3k9/(3k9+6k8) or 0.36, which gives a maximum window at the input of the stereo jack of 5.5V peak-to-peak. C15 and C16 are DC decouplers and the choice of MKT types of capacitors is for quality reasons. The input impedance of the section is 10.7 K ohms.

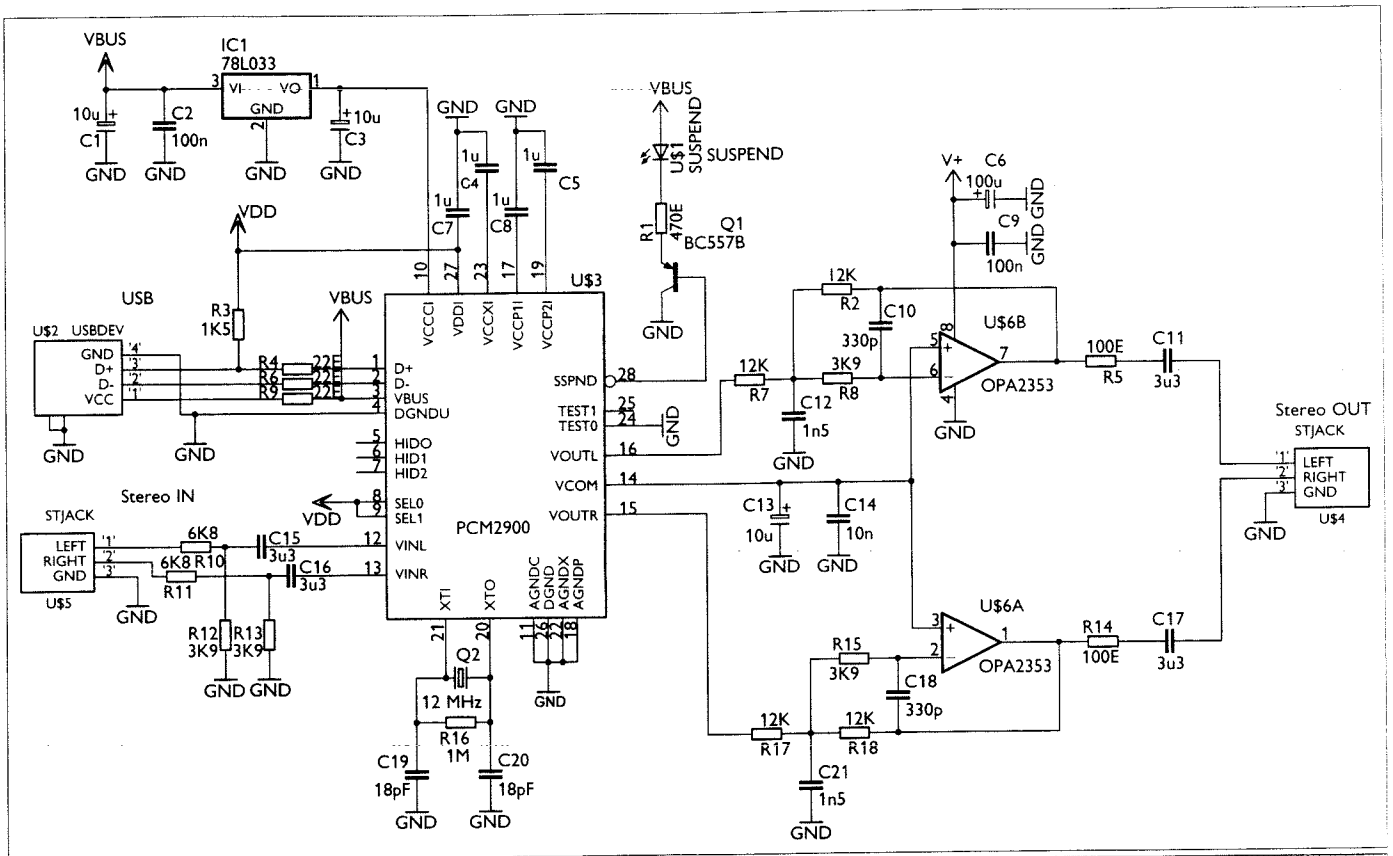


Figure 5. Complete schematic diagram.

USB Codec

The USB codec is a single chip PCM2900, very compact in a SSOP 28-pin housing. The SSPND signal indicates valid audio USB data. An external clock of 12 MHz is generated from an external XTAL, with two ceramic capacitors for loading.

Parts List

Parts	Quantity	Value	Device
C1, C3, C13	3	10u	ELC-2,5L
C10, C18	2	330p	MKT or polyprop
C11, C15, C16, C17	4	3u3	MKT or polyprop
C12, C21	2	1n5	MKT or polyprop
C14	1	10n	Multipurpose decoupl
C19, C20	2	18pF	Ceramic
C2, C9	2	100n	Multipurpose decoupl
C4, C5, C7, C8	4	1u	C-EUC1206K
C6	1	100u	ELC-2,5L
IC1	1	78L033	LDO,TO92 package
Q1	1	BC557B	TO-92-EBC
Q2	1	12 MHz	CRYTALHC49S
R1	1	470E	RES 0.25W
R10, R11	2	6K8	RES 0.25W
R16	1	1M	RES 0.25W
R2, R7, R17, R18	4	12K	RES 0.25W
R3	1	1K5	RES 0.25W
R4, R6, R9	3	22E	RES 0.25W
R5, R14	2	100E	RES 0.25W
R8, R12, R13, R15	4	3K9	RES 0.25W
U$1	1	LED	LED3MM
U$2	1	USBDEV	USB B angled/board
U$3	1	PCM2900	SSOP28
U$4, U$5	2	STJACK	Stereo Jack
U$6	1	OPA2353	SO08

Stereo Output Stage

The PCM2900's internal DAC has a cut-off frequency of 250 kHz. As it is a delta-sigma DAC type, noise shaping causes a lot of noise above 20 kHz. For the analog output section, a third order, low pass filter is chosen (Butterworth type, fc at 28 kHz). The active component in this filter is also from Texas Instruments – the OPA2353 (SMD type SO-8). This opamp is a high speed, low noise, low distortion, and (most important) rail-to-rail input and output. All capacitors are MKT, for quality of the signal processing, and extra filtering is put on the power supply of the opamp, to reduce any HF influence.

Construction

The double-layer board layout holds the USB connector on one side and the stereo mini jacks for both input and output on the opposite side. The SSOP package of the PCM2900 chip forces the routing of the board to 10 mil. Start the construction of the board by soldering the PCM chip, using a fine-pitch solder iron (18-20 Watts). Soldering flux is helpful, as well. Position U3 and first solder two opposite pins. Re-check the pin positioning relative to the pads.

Soldering the SSOP package pins sometimes causes joints between pins, which can be removed by de-soldering litze. After soldering the fine-pitch leads of the SSOP package, carefully check all individual pins to avoid possible shorts at start-up. Finish the SMD parts before moving to the through hole components (C4,5,7,8, and U6). The second chip is a regular SO08 package, with a lower density than the SSOP.

After the SMD parts are mounted, you may want to use a larger size soldering iron for the through hole components. Once all parts are stuffed, installation of the USB hardware on a PC is the next step.

Installation and Testing

Hooking up the unit to a PC's USB port triggers an automatic installation process (Win98 or higher). Under the category 'USB audio device,' the board is recognized and becomes accessible under 'Control panel'->'Audio devices.' Parameters such as volume, balance, etc., ... can be set and audio playback or recording should be possible.

Once attached onto the PC's USB board, the red LED lights for a couple of seconds and goes out after recognition, enabling the PC. If the LED stays on, there is something wrong. Check the VBUS voltage (+5V) and VCCI (+3.3V) first and make sure the PCM2900 is receiving the correct DC voltages. Also, check the individual pins of the SSOP package (soldering okay, shorts?). The PCM2900 needs the right DC voltages and USB data to become operational. The DA section can be tested by generating test sequences on the PC and analyzing the analog signal on an audio tester (analog stereo output). The AD section can be analyzed by generating a reference signal on the analog input of the unit and utilizing audio analysis software on a PC. More info on audio testers and test sequences can be found on the following websites:

www.sumuller.de/audiotester
www.blazeaudio.com/downloads/index.html
www.tracertek.com/audio_testing.htm

Karaoke, anyone? **NV**

References

(1) Texas Instruments, *PCM2900 Stereo audio codec with USB interface*, May 2002, www.ti.com

(2) Texas Instruments, *OPA2353 High-speed, single supply, rail-to-rail operational amplifiers*, March 1999, www.ti.com

(3) FilterPro design program, www.ti.com

(4) Author's website, http://users.skynet.be/bestelectrix