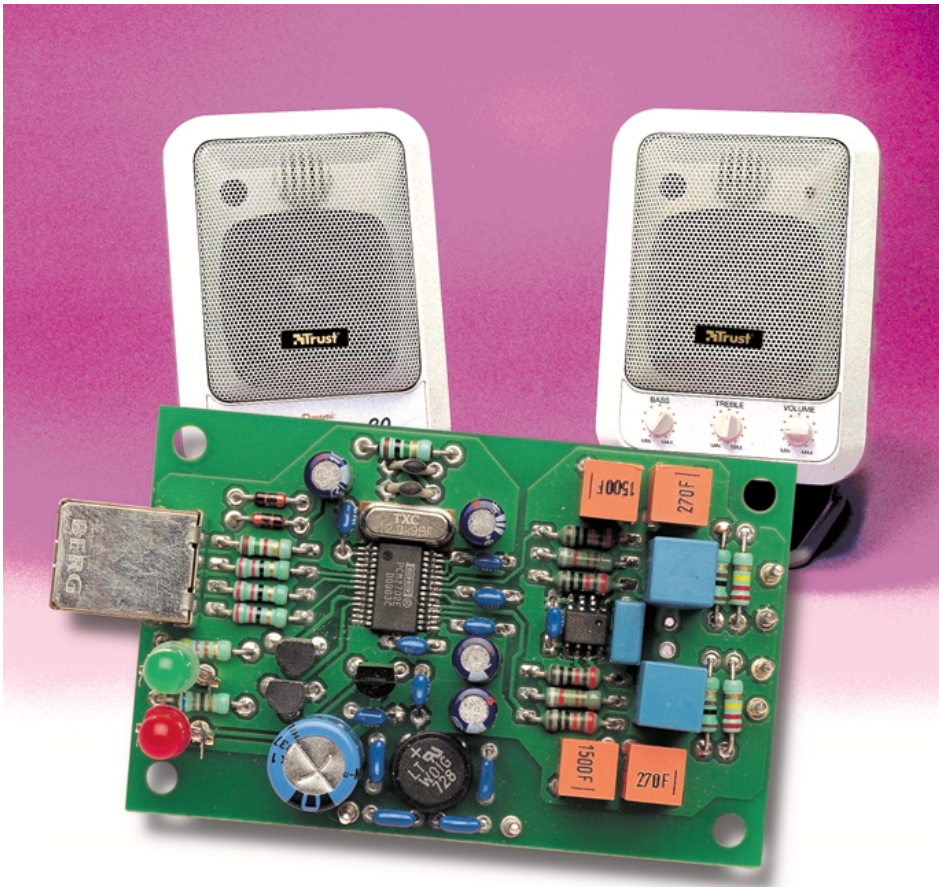


# USB Audio-DAC

## A mini PC Sound Card

Design by T. Giesberts

This circuit is pre-eminently suitable for PCs and laptops that are not equipped with a built-in sound card but do have a USB interface. However, the 'mini PC sound card' can also be useful for other applications and various experiments.



The introduction above provides a nearly complete character outline for the circuit under consideration. In brief, it is a 16-bit stereo version of a digital to analogue converter with USB interface. The converter may be used for a range of audio applications. But the first thing that comes to mind is an external sound card for PCs and laptops without

such a card, or as an expansion card in the event a second one is desired.

The circuit is conspicuously compact and simple by design, because it consists mainly of an integrated D/A-converter supplemented by two opamps. This simplicity however, does not imply that the quality of

this 'USB audio-DAC' has been compromised. On the contrary, we would like to say. A short profile:

The DAC possesses an integrated USB interface that complies with version 1.0 of the standard. It accepts 16-bit stereo and monaural USB data streams and is equipped with an 8× oversampling digital filter. The circuit contains an 'Enhanced multi-level delta-sigma modulator' and is compatible with sampling rates of 32, 44.1 and 48 kHz. In addition, it has a digital attenuator, a soft-mute function as well as optical Suspend- and Playback-indicators. And finally, there is no need for additional drivers when used with Windows 98 (and later).

The description above sounds all very nice, but it is the end result that this all leads to, that is more important. Well then, in a separate table, all the measuring results are summarised. Examining the results with more than a cursory glance, you will have to reach the conclusion that the performance is very reasonable.

### PCM2702

The heart of the circuit consists of a PCM2702, a two-channel single-chip D/A-converter with integrated USB interface controller. **Figure 1** shows the block diagram detailing the internals of the IC. For more information you may refer to the (condensed) datasheet printed else-

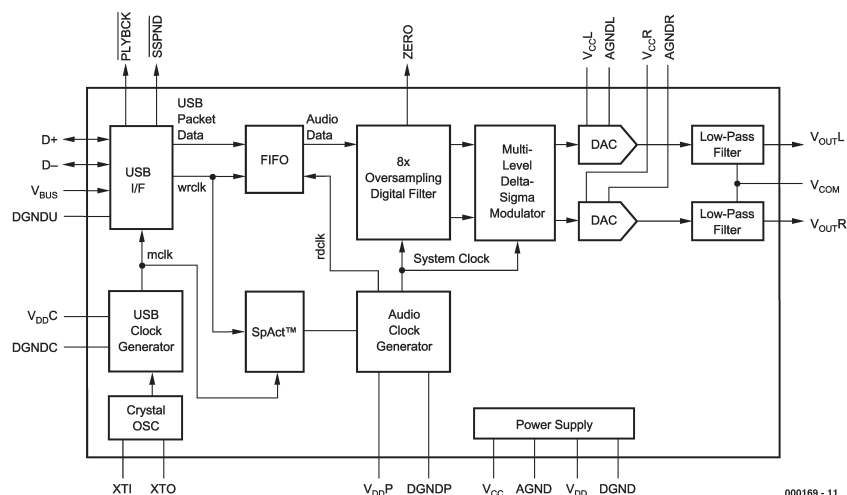


Figure 1. Block diagram of the single-chip D/A-converter PCM2702.

where in this issue.

Control and audio data are both transferred to the PCM2702 via pins D+ and D-. All data to and from the IC are transferred at full speed.  $V_{BUS}$  (pin 8) and DGNDU (pin 9) are also connected to the USB bus.  $V_{BUS}$  does not consume any power and is used only to detect the connection to the

USB bus.

The PCM2702 has two interfaces. Each interface is constructed by some specific setting. Interface #0 has only one setting. This setting describes the standard audio interface

The most important three connections are the input and output termi-

nals, and the, so-called Feature Unit.

The input terminal is defined as 'USB stream'. This input accepts two channel audio data streams. The output terminal is defined as a 'speaker'. The Feature Unit supports volume and mute control.

The built-in digital volume control can be adjusted from 0.0 dB to -64.0 dB in steps of 1 dB. Each channel can be set independently, but master control of both channels simultaneously is also possible. Mute is only available in master control.

Interface #1 has three alternative settings. Setting #0 is the 'Zero Bandwidth' setting (a kind of mute function). Setting #1 selects 16-bit stereo and #2 is the 16-bit monaural setting.

The PCM2702 requires a 12 MHz clock for USB and audio functions.

The on-chip oscillator with an external crystal (which is how it is used here) may generate this clock. Or, if desired, an external clock signal may be applied to pin XTI instead.

The IC includes an internal power-on reset circuit, which automatically initialises the digital logic when the power supply is switched on. The PCM2702 is ready to receive audio data after completion of the reset sequence and a connection to the USB bus.

## The Circuit

The circuit (Figure 2) has largely been copied from the evaluation board DEM-PCM2702 from Burr-Brown. As can be observed, besides the PCM2702, the active components are limited to a dual opamp, a couple of general-purpose transistors and a voltage regulator. A handful of standard parts completes the circuit.

We refrained from fitting a power supply connector and mini-jack on the PCB. As a consequence, either a mains power adapter or a small PCB transformer (voltage >8 V, power >0.5 VA) may be used. A mains power adapter with regulated output is preferred, because the ripple suppression ratio of the 5 V regulator 78L05 (IC3) on the PCB is only 50 dB.

To connect active PC speakers, for example, a mini-jack or cinch connectors may be used. Cinch connectors permit the connection of a normal power amplifier without the need for a special adapter cable.

Because of the relatively large supply current (approximately 60 mA) it was not considered appropriate to power the circuit from the USB bus (since the maximum current permitted is only 100 mA, a second device would increase the current consumption to unacceptable levels). The PCM2702 has good power supply rejection which makes addi-

## Measurement Results

(measured at 0 dB, 44.1 kHz unless otherwise indicated)

input signal	USB audio data
nominal output voltage	62 % $V_{CC}$ (1.096 $V_{eff}$ bij
5.000 V)	
bandwidth (10 k $\Omega$ load)	5 Hz to $f_s/2$ ( $f_s =$
32/44.1/48 kHz)	
amplitude at 20 kHz	-0.25 dB
analogue filter bandwidth	30 kHz (2 <sup>nd</sup> order 0.25dB-
Chebyshev)	
output impedance	100 $\Omega$
signal to noise ratio	> 101 dBA
THD+N	(1 kHz, B = 80 kHz) < 0.0035 %
	(20 kHz, B = 80 kHz) < 0.025 %
IMD	(60 Hz/7 kHz = 4:1) < 0.006 %
channel separation	> 116 dB
stopband attenuation digital filter	> 82 dB
current consumption	< 60 mA

The distortion figures are, without exception, very good. The numbers for signal to noise and channel separation are no worse. The frequency response (measured using a test CD) of the sound card is remarkably flat. For the benefit of the purists, this graph has been reproduced here. The only irregularity consists of a small amplitude increase that is caused by the Chebyshev output filter. It appears like a large 'bump', but when closely examining the scale of the graph it is realised that the ripple is less than 0.25 dB!

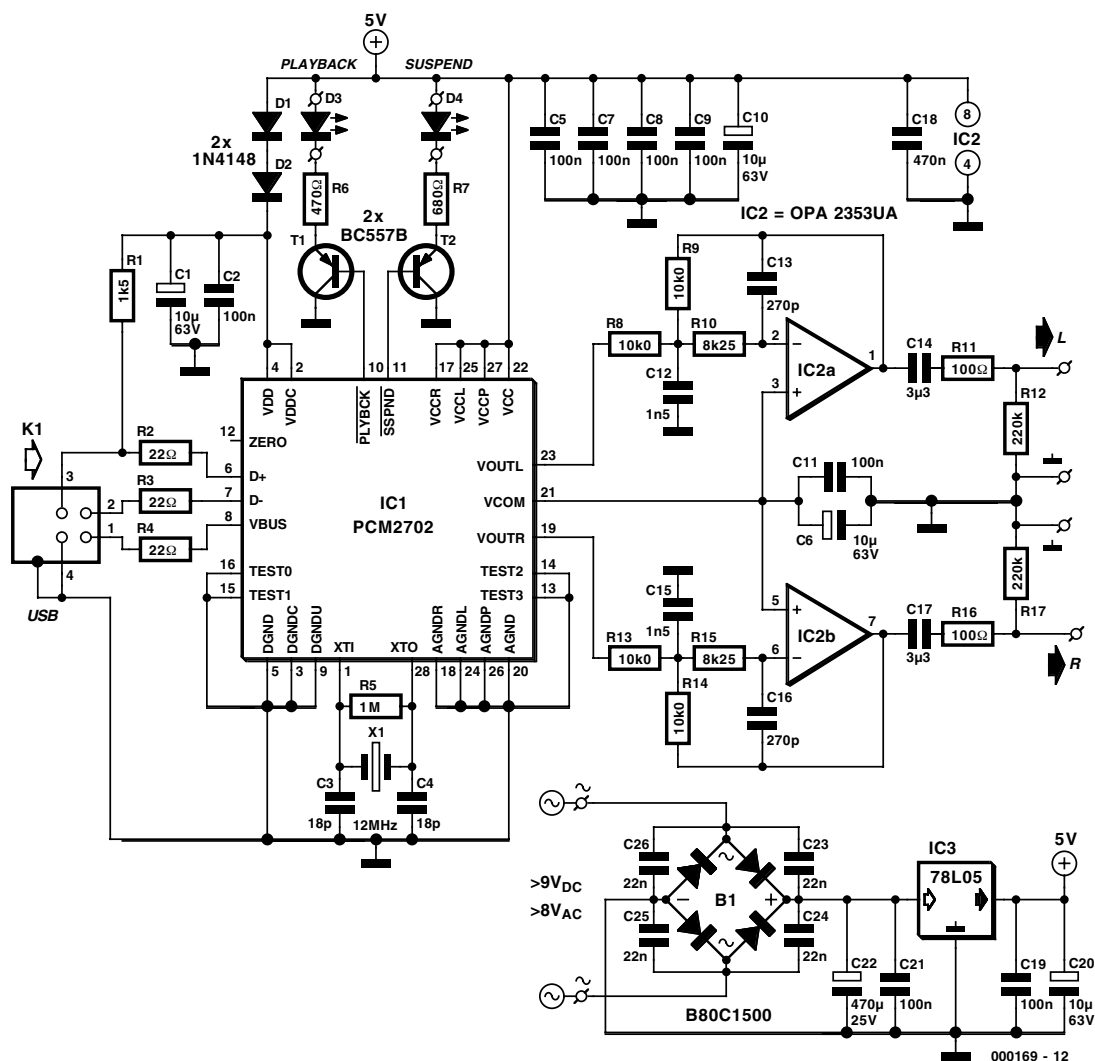


Figure 2. The complete schematic of the USB audio-DAC is remarkably simple.

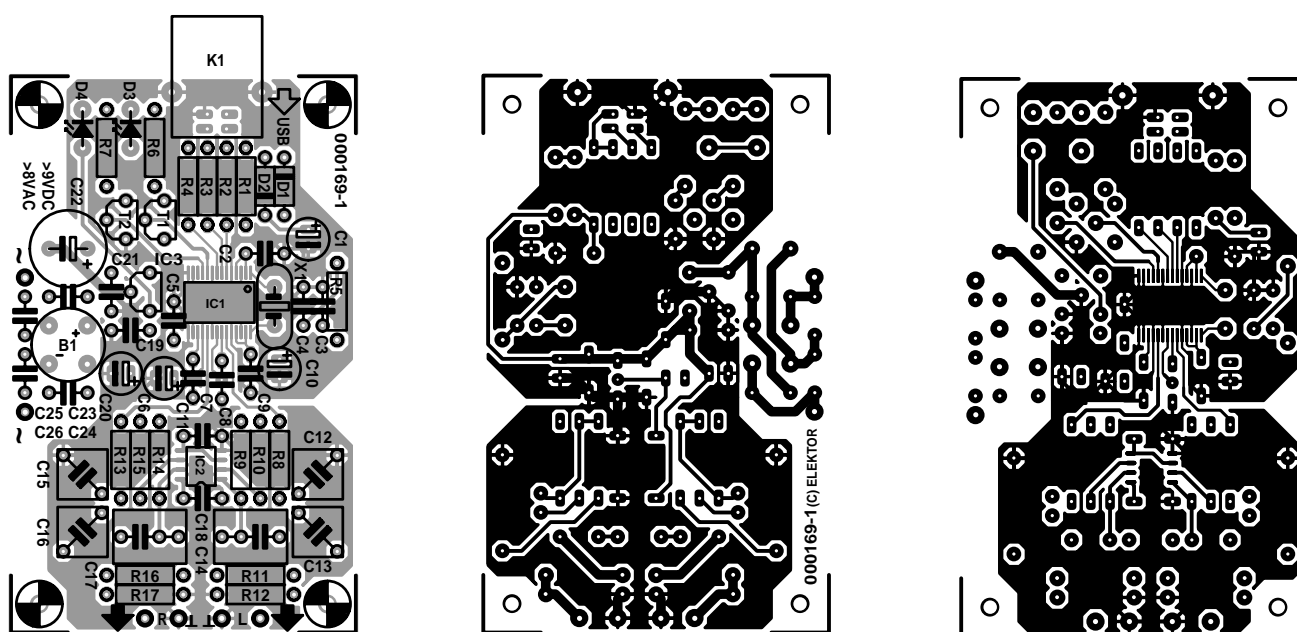


Figure 3. The PCB is very compact, in part because IC1 and IC2 are SMD devices.



tional SMD capacitors unnecessary. RF decoupling is provided by standard 100 nF ceramic capacitors (with 5 mm lead pitch).

With the crystal oscillator, keep in mind that C3 and C4 act as  $C_{load}$  for the attached crystal (here  $C_{load} = C3/2 + C_{parasitic}$  (when  $C3=C4$ ); if necessary, the frequency may be measured at the XTO pin and is allowed to deviate by at most 500 ppm).

This audio DAC, for a change,

## COMPONENTS LIST

### Resistors:

R1 = 1k $\Omega$   
 R2,R3,R4 = 22 $\Omega$   
 R5 = 1M $\Omega$   
 R6 = 470 $\Omega$   
 R7 = 680 $\Omega$   
 R8,R9,R13,R14 = 10k $\Omega$  1%  
 R10,R15 = 8k $\Omega$  25 1%  
 R11,R16 = 100 $\Omega$   
 R12,R17 = 220k $\Omega$

### Capacitors:

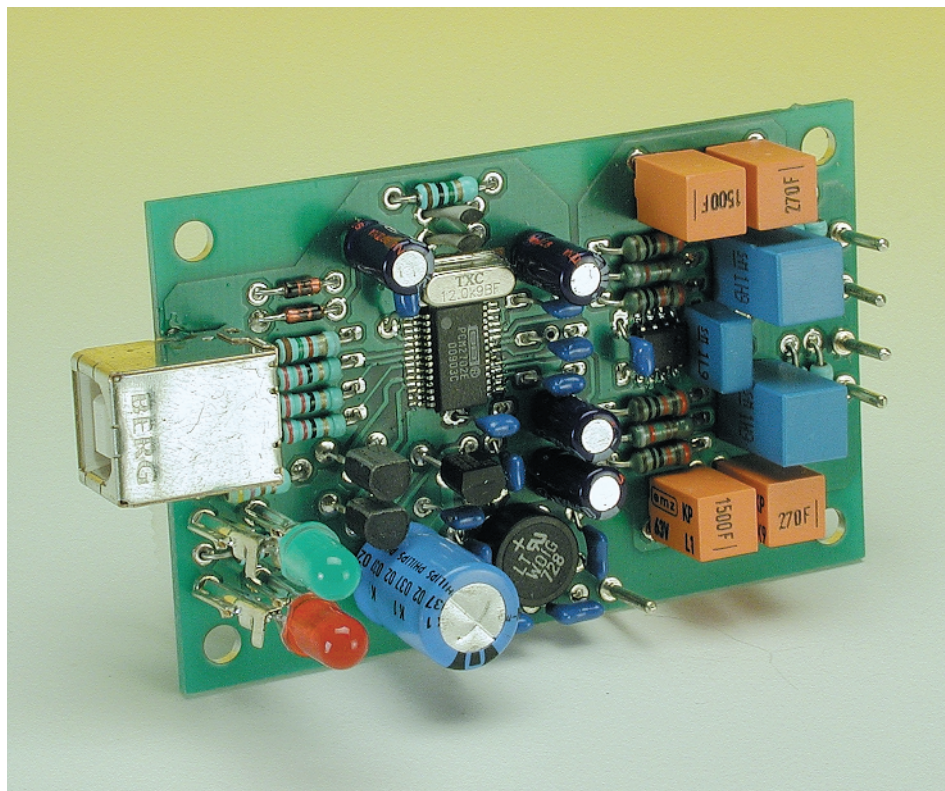
C1,C6,C10,C20 = 10 $\mu$ F 63V radial  
 C2,C5,C7,C8,C9,C11,C19,C21 = 100nF ceramic, lead pitch 5mm  
 C3,C4 = 18pF  
 C12,C15 = 1nF 5 1% polystyrene/polypropylene  
 C13,C16 = 270pF 1% polystyrene/polypropylene  
 C14,C17 = 3 $\mu$ F 3 MKT (Siemens), lead pitch 5 or 7.5mm  
 C18 = 470nF, lead pitch 5mm  
 C22 = 470 $\mu$ F 25V radial  
 C23-C26 = 22nF ceramic, lead pitch 5mm

### Semiconductors:

D1,D2 = 1N4148  
 D3 = green high-efficiency LED  
 D4 = red high-efficiency LED  
 B1 = B80C1500 (80V piv, 1.5A peak), round case  
 T1,T2 = BC557B  
 IC1 = PCM2702E (SSOP-28 case) (Burr-Brown)  
 IC2 = OPA2353UA (SO-8 case) (Burr-Brown)  
 IC3 = 78L05

### Miscellaneous:

K1 = USB connector, receptacle style B (PCB mount)  
 X1 = 12MHz quartz crystal  
 PCB, order code **000169-I** (see Readers Services)



does not use Sallen-Key filters, but uses Multiple Feedback filters (MFB) instead. The output filters are DC coupled. This is possible because the Vcom output biases the opamps to exactly half of the power supply rail. An additional advantage of the MFB filters is the relative insensitivity to component tolerances. C11 provides RF decoupling of the bias voltage. Because these are only 2<sup>nd</sup> order filters, the Chebyshev type with 0.25 dB ripple was selected. This is a compromise between the smaller bandwidth of the analogue output filter (better suppression of the mixing products in the audio band) and quality.

The amplifier selected for the output filter is an OPA2353UA. This is a high speed, single supply, rail to rail, low noise CMOS opamp with a maximum output current of 40 mA. As a result of using this amplifier, an additional power supply is avoided and the output filter can simply be powered from the same 5 V that is already present.

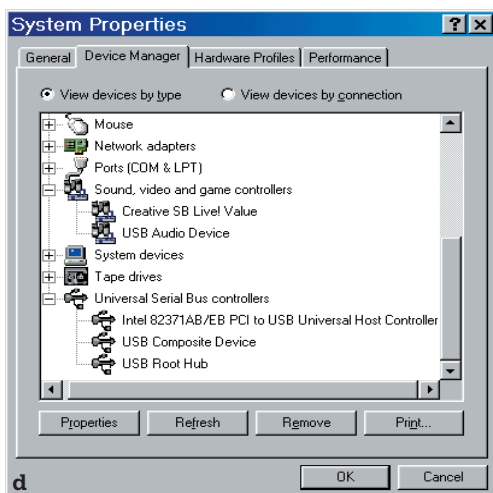
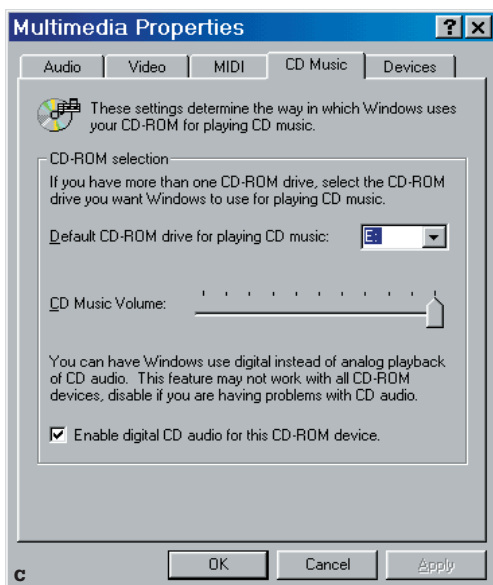
The outputs have to be DC decoupled, of course. This is achieved with C14/C17 (3.3 $\mu$ F MKT; check that the pitch is either 5 or 7.5 mm!), R11/R16 ensure that capacitive loads will never be able to cause trouble.

R12/R17 make sure that C14/C17 are always charged. This prevents a loud 'pop' if the loudspeakers are connected to the circuit after this has already been powered up.

Two LEDs indicate the status of the circuit.

## Filter software

On the Internet, at the Burr-Brown website (<http://www.burrbrown.com/applications>) the program FilterPro may be found. The program that may be downloaded is called filter.zip, which contains, among other things, filter2.exe. This is a DOS program that enables the calculation of the well-known Sallen-Key filters as well as the MFB filters that are used here. Several parameters may be adjusted and the exact values of the E-96 series resistors can be calculated. The capacitors are automatically adjusted for the selected scaling resistors (E-12 values), but it is also possible to choose your own values, this is particularly useful when using previously measured capacitors. Those who disagree with the choice of the Chebyshev filter for this circuit, may modify the filter themselves to, for example, a Butterworth or a Bessel type.



D3 is lit up when the PCM2702 is playing back audio data (Playback). D4 is lit up when the USB interrupts the audio data stream to the PCM2702 (Suspend).

## Construction

The PCB layout for the USB audio DAC is shown in **Figure 3**. It is remarkably compact, having dimensions of only  $46 \times 74$  mm.

Both the PCM2702 and the dual opamp OPA2353VA are surface mount devices. A considerable amount of soldering skill is required. The problems are only minor when soldering IC2, but for IC1 a soldering iron with very small tip is absolutely necessary (the pins have only a 0.65 mm pitch!). Use desoldering wick to remove any excess solder. To prevent overheating of the IC, allow it to cool down from time to time. This also applies to the soldering operation.

Once both SMD ICs have been carefully soldered to the PCB, the remainder of the parts may be fitted. These are, without exception, standard components of which there are only a very small number, so no problems are anticipated here.

## Installation

We installed the circuit on a PC with Windows98SE. Windows98 (and later) contains drivers for USB audio playback as standard.

For testing purposes it is possible to power the circuit using a 9 V battery. The red LED (D4) should light. Once the connection to the USB cable is made (cable type A to B), the red LED should extinguish immediately and a window should pop up with the message 'Burr-Brown Japan PCM2702'. This is followed by the window 'Add New Hardware Wizard' which will want to install the drivers for a 'USB Composite Device' (refer to **Figure 4a**). Once the drivers are installed, the Wizard window will reappear which now will want to install a 'USB audio Device' (**Figure 4b**). Having com-

pleted all of this, there should be, in Control Panel, under System Properties in the Device Manager under 'Sound, video and game controllers' a 'USB audio device' and under 'Universal Serial Bus controllers' a 'USB composite device' (**Figure 4c**). If another sound card is already installed, then using Control Panel under Multimedia Properties in the Audio tab it is now also possible to select 'USB Audio Device' as the Preferred device for Playback.

We assume that every PC these days is equipped with a CD-ROM drive. With a regular sound card, the analogue output from the CD player is normally directly connected to this card. This permits the listening to, or the processing of, audio-CDs using the PC. If you would like to listen to audio CDs using the USB audio DAC, then, in Multimedia Properties in the 'CD Music' tab tick 'Enable digital CD audio for this CD ROM device' (refer **Figure 4d**). There are now four controls in the 'Volume Controls' window: one for 'speaker' (master), one for 'CD Player', one for 'Wave' and one for 'SW Synth' (for MIDI, a Software Wavetable Synthesiser).

## Practical Hints

There are older generations of PC motherboard (not ATX) that do possess a USB controller but do not have the appropriate connectors fitted. Separate USB-dual-brackets are available (standard with two USB connectors type A) with an 8 or 10 way socket that may replace an unused expansion slot cover. If no expansion slots are available, then it may be possible to remove the bracket with the 25 way printer port and 9 way serial port and move these to the break-out openings in the computer case instead. The USB bracket may then be fitted in the newly created space.

There are three variations (there could be more) of the socket for this bracket, so pay close attention to the header pinout. The connections in the socket are usually easily swapped around. By carefully lifting up the plastic locking tabs and simultaneously pulling on the wires, the individual connectors can be removed from the socket.

Figure 4. The installation on the PC is not particularly difficult. The text provides a number of useful hints.

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