MP3 Pre

Stereo microphone

Marcel Cremmel

There are still a lot of hobbyists who enjoy making high-quality live audio recordings of concerts, interviews, radio broadcasts, natural sounds, and so on. Professional equipment such as Nagra and the like is simply too expensive. We can thus be thankful that many MP3 players are equipped with an analogue input and a high-performance MP3 or WMA encoder.

You need portable equipment if you want to make recordings in the field. Professional equipment for this purpose is very expensive, and many affordable alternatives (such as MP3 players) cannot handle microphone signals. Microphones require some sort of assistance to supply the high signal levels that must be provided on the line inputs. Although some players have built-in microphones, the quality is often barely adequate for use as a dictating machine. This means you need a microphone preamplifier to adapt the microphone output to the line input.

The characteristics listed in the 'MP3 preamplifier features' inset can be obtained without using any special components. Transistors and opamps that you have tucked away in a drawer somewhere should do just fine. Aside from the potentiometers and connectors, all the components are SMD types. But there's no need to be afraid – even beginners can assemble the circuit board if they are blessed with a grain of patience, an ounce of dexterity and a pinch of precision.

Microphones

Even the best preamplifier won't perform well with a mediocre microphone or a poor cable. A wide variety of systems are available, with prices ranging from a few euros to several hundred. The preamplifier described here is optimised for dynamic microphones. The characteristics of the microphone (see the 'Principal characteristics of a microphone' inset) are a major factor in selecting a microphone.

The Sennheiser MD21 is a genuine reporter's microphone that has been on the market for several decades already. It has a sensitivity of 1.8 mV/Pa and generates an output signal of 0.36 μV in a quiet room, or 3.6 mV if you aim it toward a pneumatic hammer.
It has a very large dynamic range: 3.6 mV ÷ 0.36 μV is a healthy 80 dB. Based on this information, we can specify the following properties of an ideal preamplifier:

- An input noise level that is significantly less than 0.36 μV, in order to obtain a satisfactory signal-to noise-ratio (SNR).
- No overdrive or signal distortion at 3.6 mV.

A good SNR can be achieved by using a well-considered design and choice of components for the preamplifier. The second property requires using a potentiometer so the output level can be adjusted to suit the maximum acoustic pressure.
The distance between the microphone and the preamplifier is often more than 10 metres. The cable used for this link is thus exposed to interference from magnetic fields, in particular AC mains fields at a frequency of 50 Hz. The signal carried by the cable has a low amplitude and must be protected against this interference, since otherwise the interference will be audible as the well-known 'mains hum'. This protection is

amp

preamplifier

provided by the screen of a screened cable. For proper operation, the screen must be connected to ground, and it cannot be used to carry the signal. Despite this protection, some interference signals still manage to reach the active conductors. If these conductors have the same impedance relative to ground, the induced signals will also be the same. Their effect can then be neutralized by the differential input stage of the preamplifier. In addition, the low impedance of a dynamic microphone reduces the effect of external interference.
In short, use a screened cable with two conductors and solder the cable together as shown in **Figure 1**.

Features

- Stereo
- Compatible with dynamic and electret microphones
- Maximum input sensitivity: 50, 60 or 70 dB, selectable
- Level control using two potentiometers
- Bandwidth: 50 Hz to 50 kHz at maximum gain (70 dB)
- Distortion: 0.04% at –10 dBV (316 mV_{eff})
  0.12% at 0 dBV (1 V_{eff})
- Input noise: –124 dBV (0.63 μV_{eff})
- Power source: 9-V battery
- Current consumption: 3 mA per channel
- Designed to fit in a commercially available enclosure with a battery compartment.

Schematic diagram

The schematic diagram consist of two identical amplifier channels. Here we describe one of the two channels.
The circuit is powered by a 9-V battery. An LED wired in series indicates that preamplifier is switched on. The voltage drop of the LED (1.6 V to 2 V for a red LED) does not affect the performance of the preamp. The supply voltage is switched via the contacts of the audio socket. In the quiescent state, two contacts prevent T9 and T10 from conducting. The TMOS transistor is thus cut off, so no voltage is applied to the other components. When a microphone cable is plugged in, the contact in the socket is opened. The supply voltage is now applied to the gate of T9 or T10 via R3 or R33. The TMOS transistor is thus switched on and provides power

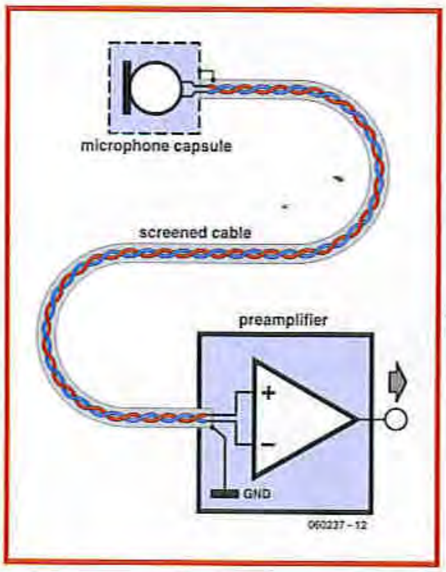


Figure 1. Construction of the screened cable link between the microphone and the preamplifier.

to the amplifier channel. The high resistance of R3 and R33 limits the current consumption to 1.6 µA per channel in the 'off' state.

Amplifier design

Why is it necessary to amplify the signal? The line input of an MP3 player requires a peak signal level of approximately 1 V, which means 2 V peak-to-peak. This range is converted to 16-bit digital values in the device, which thus provides a resolution of 30 µV. However, the signal produced by the MD21 at a normal conversation level is only 3.6 µV, which is much to low for the analogue-to-digital converter (ADC) of the MP3 player. If you connect the microphone directly to the player, you will make a recording without any sound. For a satisfactory SNR, the level of the signal applied to the input of the player must be at least 100 times as large as the value of the least significant bit, which means at least 3 mV. The signal from the microphone must be amplified by a factor of 833 to achieve this level. This is the job of the preamplifier.

The preamplifier described here provides a choice of three gains: 315 (50 dB), 1000 (60 dB), or 3150 (70 dB). Such high gains cannot be obtained in a single stage in combination with an acceptable bandwidth, so this task is split over two stages. The first stage is built using discrete transistors, while the second stage is implemented using an operational amplifier.

In the first stage (shaded grey in **Figure 2**), you can see the classic structure of a differential transistor amplifier (T1 and T2). The microphone signals arrive via IN1 and IN2, with the capaci-

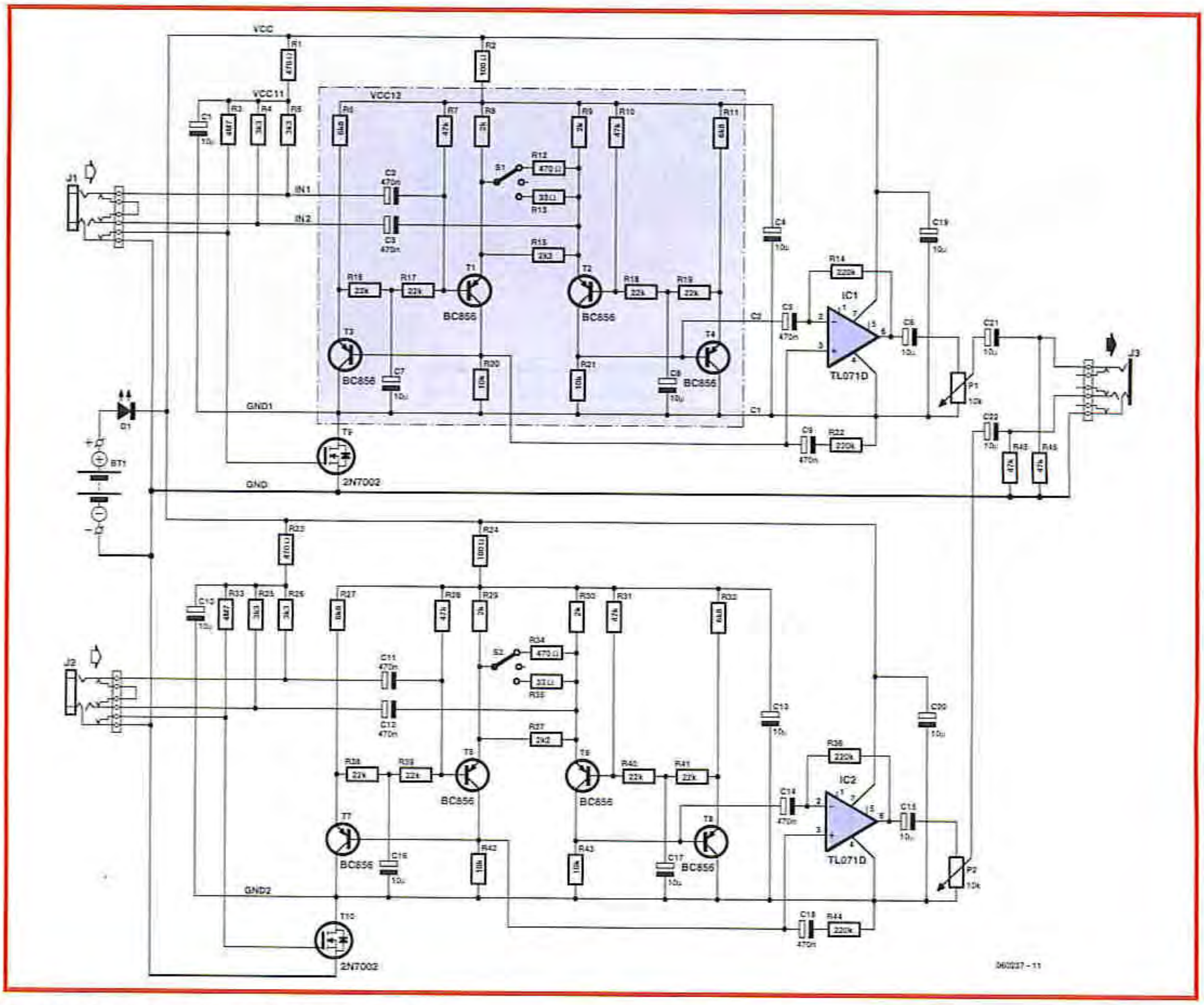


Figure 2. Full schematic diagram of the microphone preamplifier for MP3 players.

tors providing DC blocking to avoid upsetting the DC bias setting. The output of the first stage is taken across the collectors of T1 and T2.
The gain is determined by the equivalent resistance between the two emitters:

- 2.2 kΩ: 13.6× (23 dB)
- 2.2 kΩ || 470 Ω: 43× (33 dB)
- 2.2 kΩ || 33 Ω: 135× (43 dB)

Transistors T3 and T4 stabilise the operating point of the stage, which makes it unnecessary to use a matched pair for T1 and T2.

Why use transistors?

Could be first stage be built using an opamp and a few passive components instead of transistors? The answer is yes with regard to the gain, but no with regard to noise. This can be shown using a simple comparison. We compared the behaviour of two amplifier designs with the same input sensitivity: the transistor stage described above (with S1 set to R12 for a gain of 33 dB) and an amplifier built using a TL071, which is known for its low noise level. The frequency characteristics are shown in **Figure 3**. Both circuits meet the requirements, but the transistor stage does it better.
We can use a PSPICE simulation to determine the effective input noise voltage. This calculation takes all noise sources into account. It yields the following results:
- *Design using a TL071*: noise level 500×10^{-18} V²/Hz over the frequency range of 100 Hz to 20 kHz (white noise). This yields

$V_{eff} = \sqrt{[(500 \times 10^{-18}) \times (20{,}000)]} = 3.2\ \mu V$.

- *Design using transistors*: noise level 11.5×10^{-18} V²/Hz over the frequency range of 100 Hz to 20 kHz. This yields

$V_{eff} = \sqrt{[(11.5 \times 10^{-18}) \times (20{,}000)]} = 0.48\ \mu V$.

The noise level is thus a factor of 6.6 lower, so the transistor stage wins hands down. This noise level is of the same order as the signal produced by the microphone in a quiet room. This means you can hear a fly buzzing around in the room.
Strictly speaking, you also have to take into account the thermal noise generated by the internal resistance of the microphone. The MD21 has an internal resistance of 200 Ω, which yields an effective noise voltage of $8.6 \times 10^{-9} \times \sqrt{R} = 0.12\ \mu V$ (at 25 °C and a bandwidth of 20 kHz).

Examples of acoustic pressures

Condition	P [Pa]	P [dBSPL]
Auditory threshold	20 µ	0
Quiet room	200 µ	20
Conversation	2 m	40
Lively conversation	20 m	60
Busy street	0.2	80
Pneumatic hammer	2	100
Pain threshold	20	120

Due to the gain of the first stage, an opamp can be used for the second stage with satisfactory results. A TL081 can also be used in place of the TL071 without any appreciable degradation of performance.
The differential structure is maintained to avoid losing 6 dB in input sensitivity. The gain is fixed at 22 (27 dB) as determined by resistors R14, R20, R21 and R22 for the one channel or R42, R43, R36 and R44 for the other channel.
Potentiometers P1 and P2 can be used to independently adjust the output levels as desired. Capacitors C6 and C15 block the DC component to prevent crackling from the potentiometers.

Construction

All components except the battery are fitted to a printed circuit board. This

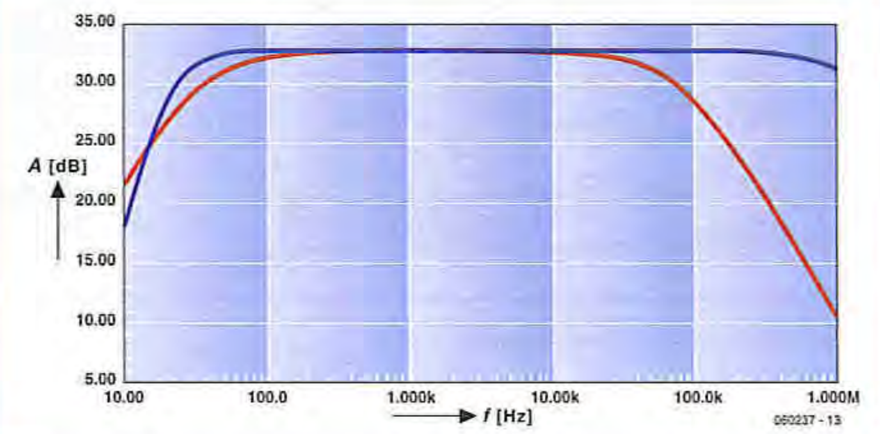


Figure 3. Bandwidth of the first stage. Blue: transistor version. Red: TL071 version.

Principal characteristics of a microphone

- Sensitivity in mV/Pa
- Output impedance
- Bandwidth
- Directional sensitivity
- Maximum acoustic pressure

An electronics specialist is interested in the first three characteristics, while a recording specialist is interested in the last three.

The signal voltage provided by a microphone is proportional to the acoustic pressure and the sensitivity of the microphone:

- $V_{MIC} = S \times P$
- S: sensitivity in V/Pa
- P: acoustic pressure deviation in Pa

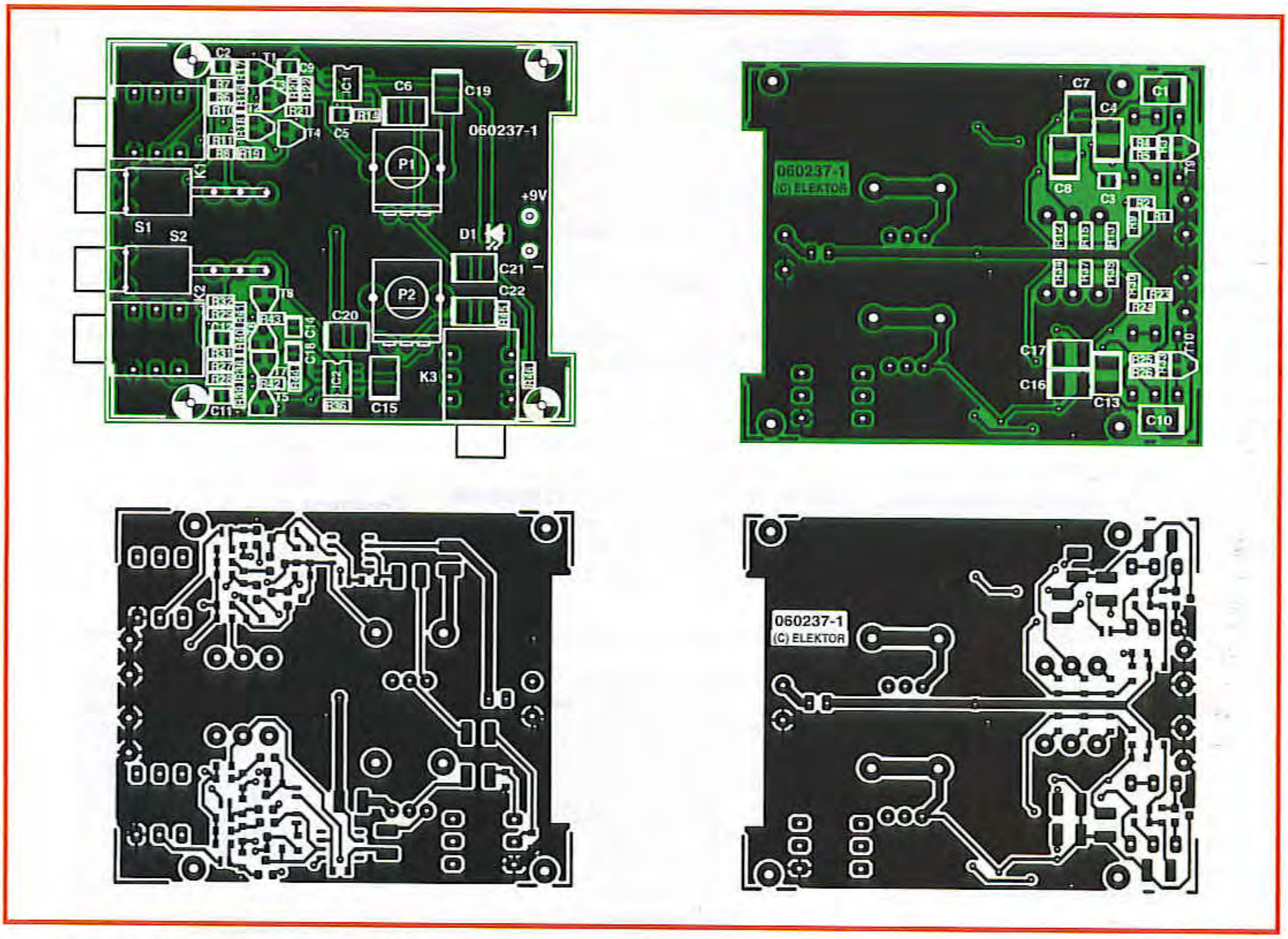


Figure 4. Layout of the double-sided PCB designed for this project.

is a double-sided, through-hole plated PCB. If you make the board yourself, you will have to make the through-hole connections by hand. The shape of the board is specifically designed to fit an enclosure distributed by Farnell with a compartment for a 9-V battery. We selected PCB-mount chassis connectors for the audio sockets to ensure optimum contact. **Note:** these are not standard versions.

We advise using a soldering iron with a very fine tip. Start by soldering the SMD parts, since they will difficult to reach later on due to the other components. Pay good attention to the polarity of the electrolytic capacitors, which are present in generous numbers on the bottom of the board.

The SMDs are distributed over both sides. Handle the MOS transistors carefully to avoid exposing them to electrostatic charges. Be careful when solder-

COMPONENTS LIST

Resistors

R1,R12,R23,R34 = 470 Ω
R2,R24 = 100Ω
R3,R33 = 4MΩ7
R4,R5,R25,R26 = 3kΩ3
R6,R11,R27,R32 = 6kΩ8
R7,R10,R28,R31,R45,R46 = 47kΩ
R8,R9,R29,R30 = 2kΩ
R13,R35 = 33Ω
R14,R22,R36,R44 = 220kΩ
R15,R37 = 2kΩ2
R16-R19,R38-R41 = 22Ω
R20,R21,R42,R43 = 10kΩ
P1,P2 = potentiometer 10kΩ, B, Alps type RK09K11310KB (Farnell # 119-1725)

Capacitors

(all SMD)
C1,C4,C6,C7,C8,C10,C13,C15,C16,C17,C19-C22 = 10µF 16 V tantalum, Vishay Sprague 595D106X9016B2T (Farnell # 392-8895)
C2,C3,C5,C9,C11,C12,C14,C18 = 470nF/25 V tantalum, Vishay Sprague 595D474X9025T2T (Farnell # 116-6814)

Semiconductors

D1 = LED, 3mm, red
T1-T8 = BC856ALT1G, SMD, SOT-23, ON Semiconductor (Farnell # 114-7782)
T9,T10 = 2N7002, MOSFET, SMD, SOIC, Texas Instruments (Farnell # 102-1754)
IC1,IC2 = TL071CD, SMD, SOIC, Texas Instruments (Farnell # 958-9449)

Miscellaneous

K1,K2,K3 = 3.5mm jack socket with 3 contacts, Schurter R36310000 (Farnell # 149-933)
S1,S2 = SPST switch, angled pins, PCB mount, height = 12.7mm, C&K 7103MD9 AV2BE (Farnell # 957-5510)
BT1 = 9V battery with clip-on lead
K4 = 2-way PCB pinheader
Case with battery compartment, e.g. BC2, Farnell # 223-554
PCB, ref. 060237-I from ThePCBShop

ing the resistors for switches S1 and S2 (R12, R13, R15, R34, R35, and R37): solder only the ends of these resistors that are not connected to the corresponding switches. The other ends will be soldered when you fit the switches to the board. If you solder them before you fit the switches, the holes may be filled with solder.

Be sure to do a neat job of soldering, since many of the solder pads are close together. If you etch your own PCB, be sure to make the through connections between the top and bottom sides carefully and avoid making any shorts, which would be difficult to find later on.

Enclosure

Once the circuit board is finished and you have checked that it works properly, you can fit it in the enclosure with the battery compartment. Make holes in the bottom part of the enclosure for the input and output connectors and the two switches. The top part must have holes for the two potentiometers and the LED, which adds a bit of flair to the top of the enclosure (a square or rectangular LED is a good choice here, with the leads trimmed to the right length).

Putting it to use

After you're satisfied that the preamplifier is working properly, you can start using it. All you have to do is to connect two microphones to the input connectors (K1 and K2) and connect the output to the line input of your MP3 player, and you're ready to go. Use a length of screened stereo cable for the connection to the MP3 player.
Here's to good recordings!

(060237-1)

Some MP3 players with audio inputs

Creative:
Zen Nano Plus

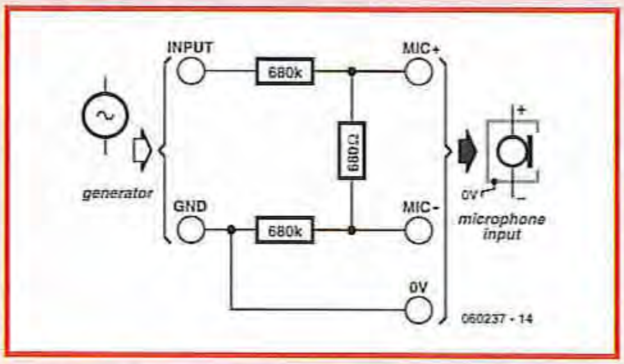
Packard Bell:
Audio Dream Colour

IRiver:
T20 and T30 series

Samsung:
YP-ST5, YP-T6 and YH-925 series

Measured results

Due to the very low input levels and the fact that it was not possible to produce the necessary levels directly using the available signal generators, we made an attenuator cable as shown in ***Figure 5.***



Characteristics:
Attenuation: 2000 (66 dB)
Output impedance: 680 Ω
(nearly the same as a dynamic microphone)
Preamplifier operating in differential mode

Figure 5.
Electrical diagram of the attenuator cable.

Results
The three curves correspond to the three settings of switch S1.

Measured results:

Setting 1: Maximum gain = 1 dB + 66 dB = 67 dB. This is nearly the design value of 70 dB. Lower -3-dB point: 50 Hz

Setting 2: Maximum gain = –8 dB + 66 dB = 58 dB. This is nearly the design value of 60 dB. Lower -3-dB point: 50 Hz

Setting 3: Maximum gain = –18 dB + 66 dB = 48 dB. This is nearly the design value of 50 dB. Lower –3 dB point: 50 Hz

The upper –3 dB point is above 100 kHz (–2 dB at 100 kHz).

Noise and distortion
The noise and distortion figures were measured by the author. The results we obtained with our own analyser (Audio Precision) are nearly the same.

Results

Switch S1	S_{gen} [dBV] at 1 kHz	S_{out} [dBV]	Measured gain	S/N	THD	Output noise level	Input noise level	
Gain max	–1	0	67 dB	57 dB	0.12%	–57 dB	–124 dBV	0.63 μV_{eff}
Gain moyen	+8	0	58 dB	65 dB	0.12%	–65 dB	–123 dBV	0.71 μV_{eff}
Gain mini	+18	0	48 dB	72 dB	0.12%	–72 dB	–120 dBV	1 μV_{eff}

Distorsion 0.12% at V_{out} = 0 dBV
0.04% at V_{out} = 10 dBV

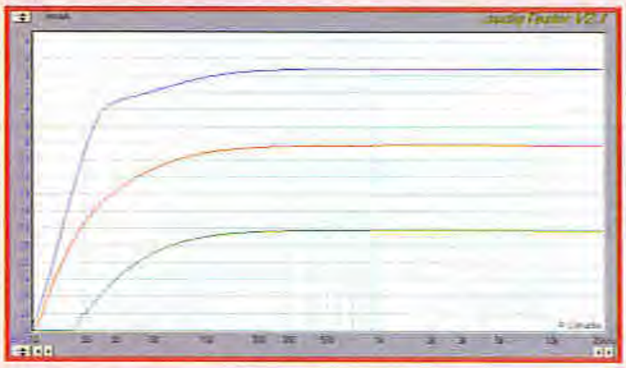


Figure 6.
The results measured by the author are very close to our measured results.

Corrections & Updates

MP3 Preamp

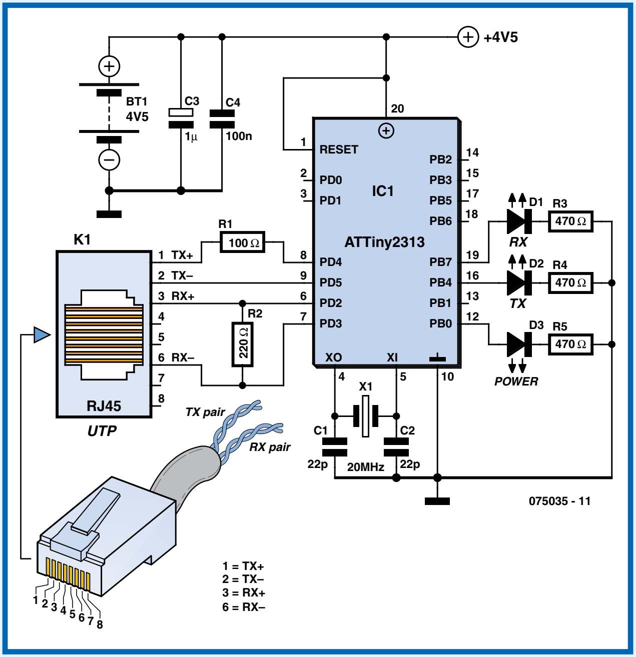
February 2007, p. 40-45, 060237-I

On the PCB component overlay, the labels of SMD resistors R29 and R32 have been transposed. Resistor 29 (2 kΩ) should be the top device in the row of resistors fitted to the right of S1 and S2. R2 (6kΩ8) should be directly below it.

Ethermeter

March 2007, p. 72-74, 075035-I

Due to a crashed hard disk in the author's PC an early version of the circuit diagram was printed. The correct schematic is reproduced here.



Canon EOS Cameras go Wireless

July/August 2004, p. 102, 030432-1.

In the transmitter circuit diagram, pushbutton S1 should be a normally closed (NC) type.