THE ELECTRONICS & COMPUTER MAGAZINE

SEPTEMBER 1998
£2.75

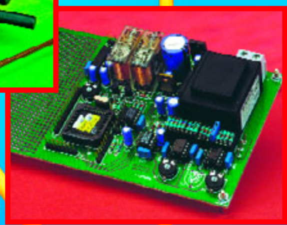
ELEKTOR ELECTRONICS

PC TOPICS:

- the joystick port
- small VGA tester
- experimental power supply for PCs

How does a digital loudspeaker system work ?

active magnetic antenna



multiple test card for microcontrollers

418/433 MHz control system

versatile aid for experimenters

laser-controlled burglary deterrent

September 1998 Number 269

Elektor Electronics
Volume 24
ISSN 0268/4519

CONTENTS

INFORMATIVE ARTICLES

CONSTRUCTION PROJECTS

MISCELLANEOUS

THIS MONTH IN PC-TOPICS:

- Experimental power supply for PCs
- Do more with the gameport
- Accurate time measurement in visual BASIC
- Small VGA tester

The circuit described in this article is primarily intended for installing into a PC, to act as a versatile supply for all kinds of experimental circuits. However, the supply being designed for an input voltage of 12 V, it may also find useful applications in your car, caravan or boat. The actual design is that of an easily built discrete low-drop regulator with short-circuit protection.

Design by R Lucassen

experimental power supply for PCs

adjustable between 1 V and 12 V, and from 50 mA to 1.5 A

Power supplies are among the equipment many electronics enthusiasts love to have lots of, if only for the sake of being able to power each and every circuit on the workbench. The design of the experimental supply for PCs slowly materialised while the author worked on a processor application circuit for the PC. When the control circuit was ready and had to be powered, alas, the author's benchtop power supply was already in use, supplying the equipment to be controlled! Many of you will recognize this type of problem. In the case of the author, the incident prompted him to put an additional, adjustable power supply high on the list of 'things to do'. Preferably, this supply had to be incorporated into the PC, employing the 12-V voltage which is conveniently available inside the case.

Profile

To begin with, a profile was drawn of the desired power supply. After some thought, the following 'must have' points were noted:

- ► input voltage: 12 V;
- ► output voltage adjustable between 1 V and 12 V;

- ► adjustable current limit from 50 mA to 1.5 A;
- ► LED indicator for output current overload;
- ► LED indicator for too high output voltage or too low input voltage;
- ► short-circuit resistant;
- ► simple to build, preferably using commonly available parts.

In order to explain the final design of the circuit, the above aspects will be discussed one by one.

The +12 V input voltage was already mentioned. This is one of the standard voltages available inside any PC. Other standard voltages are –12 V and +5 V, and hardware fans may like the idea of making these externally available as well, say, by way of a fuse. These voltages can be a great help when working on application circuits. The 12-V input voltage used here has the additional advantage of allowing all commonly encountered (vehicle) batteries to be used as the power source.

If you want to be able to power as many different circuits as possible, the supply really has to be adjustable. If, however, we want to be able to turn the output voltage up to 12 V while the input voltage is also 12 V, then there is no way to avoid the use of a low-drop voltage regulator. After all, to operate properly a normal regulator will typically require a voltage difference of at least 2 to 3 V between its input and output.

Adjustable current limiting is a must on any experimenter's power supply, while the LED indicators belong in the class of useful add-ons.

Because a complete voltage/current readout based on an LCD or even a moving-coil instrument would take up a lot of space and considerably add to the cost of the power supply, this facility had to be dropped in the design.

The two last requirements, short-circuit protection and simple construction, should really be considered self-evident features.

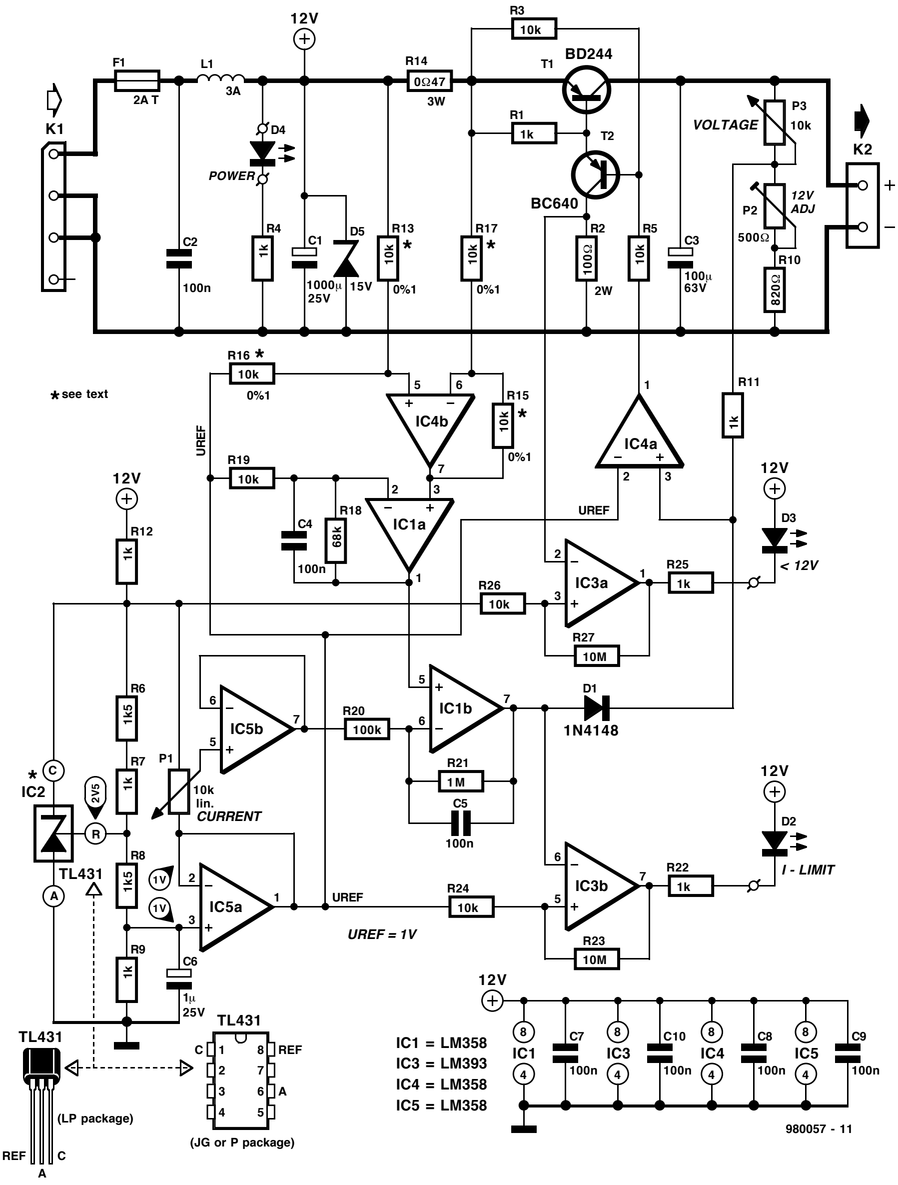


Figure 1. IC2 and IC5a produce the reference voltage, T1 and T2 act as a voltage regulator, and IC3a and IC3b drive the LED indicators. The rest of the circuit handles all of the current limiting and short-circuit protection.

Circuit diagram

Although there is no lack of integrated voltage regulators on today's electronics market, and it is very tempting to use one of these black boxes, they generally introduce so much voltage loss that a circuit consisting of discrete parts is often the best solution. Consequently, the circuit diagram in **Figure 1** shows a good many opamps and a couple of transistors.

At first blush the circuit diagram may appear rather tangled, so we'd better start explaining the various sub-functions.

To begin with, the connections and controls: the 12-V input voltage is connected to K1, while the regulated output voltage is available on K2. Pot P1 is used to set the current limit, and P3 to adjust the output voltage. Preset P2 enables the exact range of the output voltage to be accurately adjusted.

Next, the structure of the circuit. This can be divided into four sub-circuits: reference voltage source, voltage regulator proper, current limiter and LED drivers.

Reference voltage

In principle, it would have been possible to use the PC's internal 5-V supply as the reference source. However, to make sure the power supply can also be used without a PC, a 'precision shunt regulator' type TL431 is applied. In the circuit diagram you find this component identified as IC2. Some confusion may arise from the double appearance of this IC in the circuit diagram, but that is due to the fact that the TL431 is supplied in two different packages, and that both may be used on the PCB. So you only have to

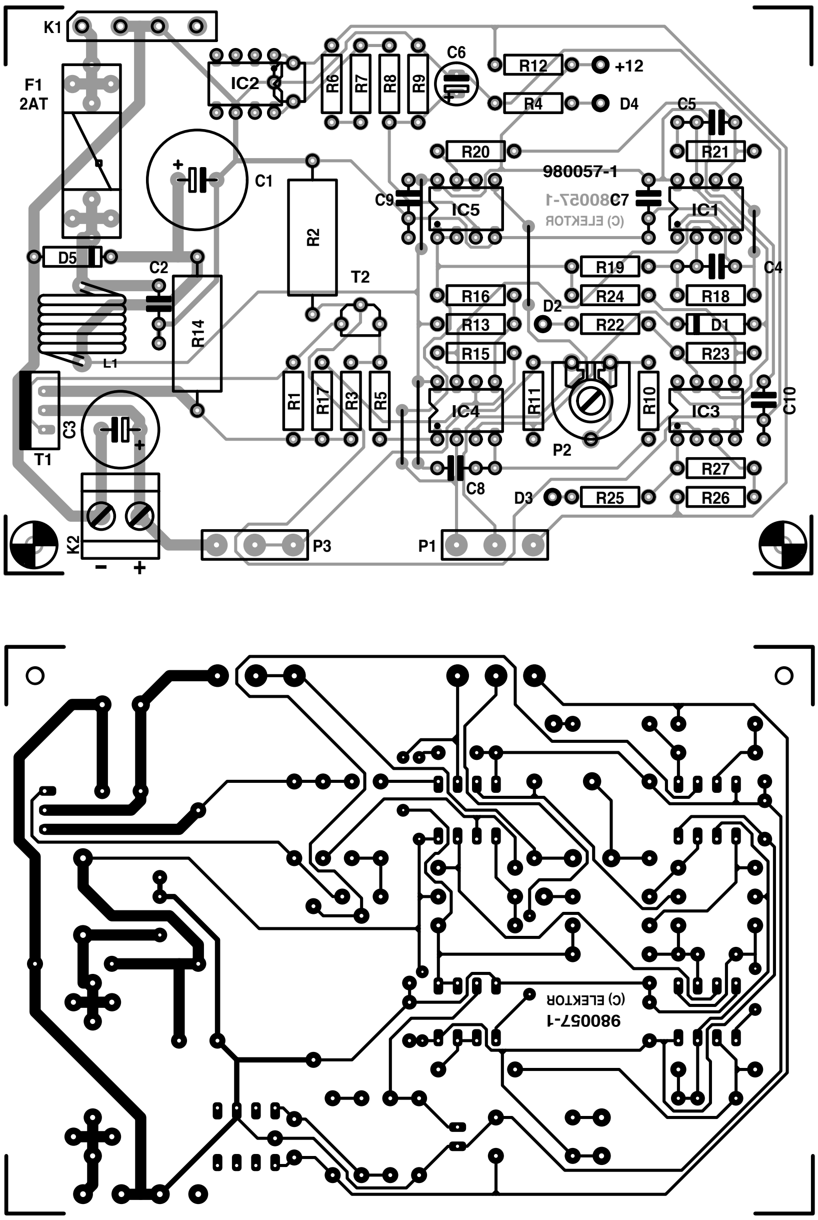


Figure 2. The PCB is clearly laid out, and spacious, so that populating it will not present undue problems.

COMPONENTS LIST

Resistors:
R1,R4,R7,R9,R11,R12,R22,R25 = 1kΩ
R2 = 100Ω 2W
R3,R5,R19,R24,R26 = 10kΩ
R6,R8 = 1kΩ5
R10 = 820Ω
R13,R15,R16,R17 = 10kΩ 0.1%
R14 = 0Ω47 3W
R18 = 68kΩ
R20 = 100kΩ
R21 = 1MΩ
R23,R27 = 10MΩ
P1,P3 = 10kΩ linear potentiometer
P2 = 500Ω preset H

Capacitors:
C1 = 1000µF 25V radial
C2,C4,C5,C7-C10 = 100nF
C3 = 100µF 63V radial
C6 = 1µF 25V radial

Semiconductors:
D1 = 1N4148
D2,D3,D4 = LED
D5 = 15V, 400mW zener diode
T1 = BD244
T2 = BC640
IC1,IC4,IC5 = LM358
IC2 = TL431 or TL431P
IC3 = LM393

Miscellaneous:
L1 = suppressor choke, min. 2A
F1 = fuse, 2A, slow, with PCB holder
K1 = 4-way PC power supply connector
K2 = 2-way PCB terminal block, pin distance 5mm
Heat-sink for T1, e.g. Fischer SK59
PCB, order code 980057-1, see Readers Services page.

mount one TL431 on the board!

The TL431 normally supplies a reference voltage of about 2.5 V. This voltage is reduced to 1 V by potential divider R6-R9, and then buffered by IC5a. The output of this IC, pin 1, supplies a stable and fairly robust voltage, U_{REF}, of 1 V, which is used as a reference for other sub-circuits in the power supply.

Voltage regulator

This part of the circuit is designed to the standard recipe, and excels in simplicity. IC4a compares the reference voltage with the portion of the output voltage supplied by P3. Depending on the outcome of the comparison series transistor T1 receives a proportional amount of base drive via T2. In this way, P3 enables the output voltage to be adjusted. The ‘lower side’ of the voltage divider has been made adjustable with preset P2 to enable the highest value of the output voltage to be set.

Especially when the output voltage set with P3 is relatively low, and a relatively large current is supplied, T1 will turn a lot of power into heat. So, you will not be surprised to learn that that this transistor has to be cooled to allow for its dissipation!

Current limiter

Series resistor R14 acts as a current sensor, and its value actually determines the maximum output current. The value 0.47 Ω indicated in the circuit diagram results in a highest current of 1 A. For 1.5 A, R14 has to be lowered to 0.33 Ω.

The voltage across R14 is applied to opamp IC4b by way of R13 and R17. To this voltage the opamp adds the reference level applied via R16. Using IC1a the resultant, output current dependent, voltage is amplified 7.8 times (ratio R18/R19), so that the IC output supplies 1 V at I = 0 A, and 4.86 V at I = 1.5 A.

Next, the amplified measurement voltage is applied to the + input of IC1b, which acts as a combined comparator, integrator and amplifier. The – input of the said opamp is supplied with a voltage between 1 V and 5 V, emanating from P1 and buffered by IC5b. As long as the amplified measurement voltage (i.e., the value of the output current) remains below the threshold set with P1, the output of IC1b will remain at 0 V. As soon as the set limit is exceeded, however, the voltage level at the + input of IC4a will be pushed up by the output of IC1b.

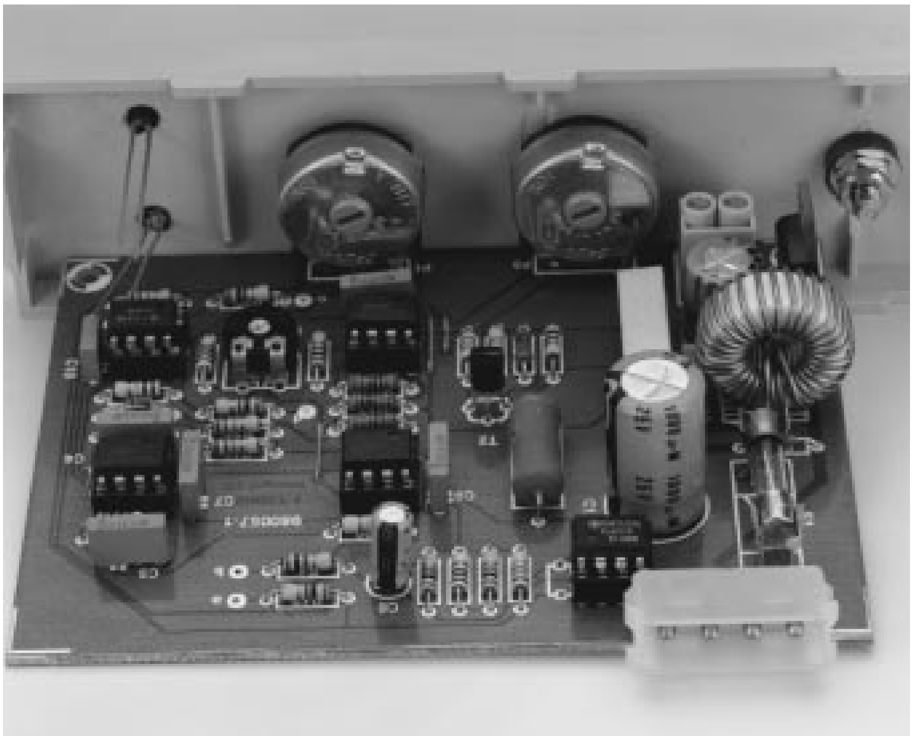


Figure 3. Compare your construction efforts with this prototype. T1 is only temporarily connected — it is to be secured on a heatsink.

The result is that the output voltage is reduced until the measured output current drops below the threshold set with P1. When the supply output is short-circuited, the current through sensor resistor R14 will surge and actuate the current shut-down function almost immediately, irrespective of the setting of P1. Consequently, the output voltage will be reduced to almost zero. In this way, the current-overload protection also acts as an effective short-circuit protection.

LED drivers/indicators

Whenever the instantaneous voltage level at the output of IC1b rises and the current limiter is actuated, the – input of comparator IC3b becomes 'high' with respect to the + input which is held at U_{REF}. Consequently the comparator output swings from high to low, causing LED D2 to light and indicate that the output current has exceeded the threshold set on P1.

The previously mentioned voltage indication is equally simple, and set up around comparator IC3a. One of its inputs is connected to junction R12-R6 which supplies about 5 V derived from the input voltage. The other input is tied to the collector of T2. If, for whatever reason, the input voltage becomes too low for the set output voltage, transistor T2 will be driven hard. As a result, the voltage at the – input of IC3a will become higher than that at the + input, so that the comparator output swings from high to low, causing LED D3 to light and indicate a too low input voltage.

Practical matters

Although all essential aspects of the basic design have been discussed so far, there are a few details left to be looked at. LED D4 acts as an on/off indicator together with its series resistor R4. For the sake of safety, a fuse (F1) is inserted in series with the input voltage. Choke L1 affords noise suppression, while electrolytic capacitor C1 adds some extra smoothing of the input voltage. Zener diode D5 was added to protect the circuit against excessive input voltage levels.

The printed circuit board designed for the power supply is shown in **Figure 2**. The layout is pretty spacious, enabling even less experienced constructors to build the circuit with a fair chance of first-time success. Take your time, work carefully and simply follow the component list and the component overlay. Mind the polarity of the electrolytic capacitors and the diodes, and use IC sockets for the opamps.

Obviously, the LED indicators are soldered directly on the board. The intention is for them to be mounted on the front panel of the enclosure, and connected to the board by way of short, flexible wires.

Series transistor T1 is purposely located near the edge of the board to allow easy fitting of a heat-sink. A heat-sink such as the type SK59 from Dau/Fischer will be adequate here. In case you intend to use a metal enclosure, one of the walls will also do as a heat-sink. Whatever option you use, however, make sure the transistor is properly insulated from the heatsink. For this purpose you use a mica washer and a pair of plastic bushes with associated nuts. Use your ohmmeter or continuity tester to check the insulation between the transistor body and the heat-sink!

The circuit is very simple to adjust. Simply connect it to the 12-V input voltage, turn P3 to maximum, and then adjust P2 until the output voltage no longer rises (the output voltage will then be just below 12 V). That completes the adjustment of the power supply.

Mounting into the PC

There are two options available for finishing the circuit, and your choice will depend mainly on the application you have in mind for the power supply. if you expect to use it mainly as a mobile supply in combination with a (car) battery, then the circuit is best installed in its own case. Alternatively, if the circuit is to be used as a 'real' PC-internal supply, then the obvious choice is to build it into the PC case. Unless you have a notebook, portable or otherwise fully crammed or internally inaccessible PC, that is fairly easy to do by securing the circuit board against one of the pull-out panels at the front of the PC. What's left to be done is drill a few holes in the panel for the two wander sockets (for the output voltage), the pots, P1 and P3, and the LED indicators — not too difficult, we reckon.

To connect up the input voltage, the board has space for a 4-way connector, K1, which should be simple to hook up to the PC's internal power supply cabling.

One last remark. Although a voltage/current readout is not provided as a standard feature on this power supply, you are, of course, free to add your own LCD or moving-coil meter. Note, however, that any type of readout will require an additional front panel to be used on the PC. Fortunately, that will not be a problem in most cases.

(980057-1)

Nearly all of today's PCs have a 15-way connection for a joystick. This port is only used for games, while the serial and parallel ports remain connected to peripheral equipment. So, it makes sense to investigate if and how the gameport can be employed for measurement and control applications.

By B. Kainka

do more with the gameport

some examples of alternative programming

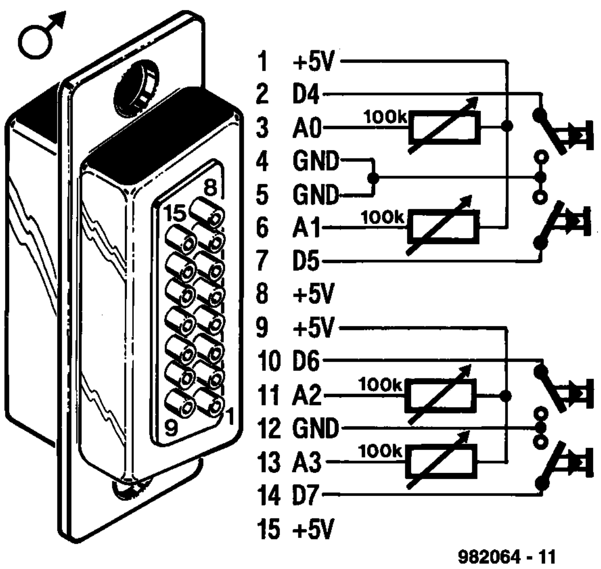


Figure 1. Connection diagram of the gameport found on most, if not all, of today's PCs.

The gameport (a.k.a. joystick port) has four quasi-analogue inputs, A0-A3, that enable the value of a resistive element to be measured using the charge time of a capacitor. Furthermore, the gameport has four digital inputs (D4-D7). It is also the only standard interface on the PC to offer the +5 V supply voltage, allowing external circuits to be powered without problems. The pinout of the gameport is listed below and illustrated in **Figure 1**.

1,8,9,15	+5 V
4,5,12	ground
2	D4
3	A0
6	A1
7	D5
10	D6
11	A2
13	A3
14	D7

The gameport occupies just one port address in the PC's I/O memory range: 201_H. There, all inputs may be read in one go. The structure of this port address is illustrated in **Figure 2**.

Using a dummy write operation to this address, the analogue inputs are reset before every new measurement.

Under normal circumstances, the quasi-analogue inputs are employed to measure the position (value) of the 100-kΩ potentiometers in a joystick. After software initialisation, a 10-nF capacitor is charged via each potentiometer. As soon as the voltage across these capacitors reaches 2/3 of the supply voltage, an internal comparator toggles, and the capacitor is discharged again. The capacitor charge time is directly proportional with the position of the potentiometer spindle. In the PC, a quadruple timer type 558 is typically used for this purpose. The joystick inputs are usually protected by 2.2-Ω series resistors.

Listing 1 shows the principle of reading the pot values. By means of a one-time write operation to address 201_H using an arbitrary databyte, the four timers are reset simultaneously. When this address is read, the lower four bits indicate the timer states for the respective inputs A0-A3. A logic 1 means that the threshold voltage has not been reached at the relevant input. In this way, the charge time may be measured with the aid of a fast 'software' loop. High-value potentiometers (with a value of up to 1 MΩ) result in a relatively long charge period, enabling the measurement to be carried out at sufficient accuracy. To prevent the program entering an infinite loop caused by an open input, a

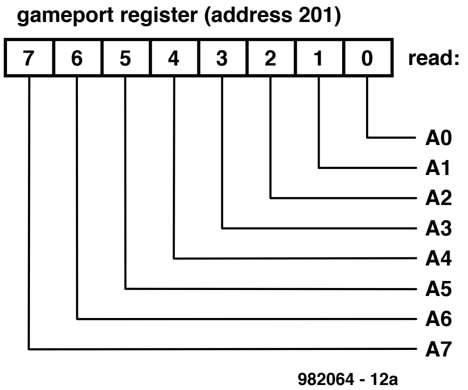


Figure 2. Reading the gameport register at address 201H is crucial to any experimental use of this port.

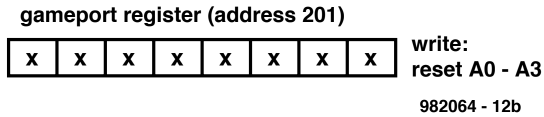


Figure 3. Writing to the jgameport register at I/O address 201H resets the analogue inputs.

time-out function is built into the program.

The analogue inputs are suitable for direct resistance measurement. However, because of the tolerance of the charging capacitors, these measurements are marked by poor accuracy. Consequently, each input has to be calibrated separately. Once that has been done, temperatures may be measured using an NTC resistor with a value of about 100 kΩ.

The four digital inputs are TTL-compatible. They have 1-kΩ pull-up resistors and 47-pF noise suppression capacitors. An open inputs is read as a 'logic 1'. The digital inputs are intended for switches connecting to ground, but they can also be driven by TTL IC outputs, or by transistors. **Listing 2** shows a small program you may want to use to get started with reading the digital inputs. This program looks at the upper four bits of address 201_H.

Because of the pull-up resistors, a fairly large current flows when an input is pulled to ground (approx. 5 mA). Although this amount of current should not be a problem when, say, a switch position is being read, it may be too high when CMOS IC outputs are used. Consequently, some applications do require the use of input drivers.

The digital inputs enable you to do all kinds of experiments. One thing should be kept in mind, however: just like the parallel printer port, the gameport has no overload protection, so that errors and accidents may cause serious damage. The supply voltage outputs in particular are a major headache: a short-circuit here can cause the PC to crash or, worse, the internal power supply to be destroyed.

Voltage measurement

The analogue inputs of the gameport allow us to measure voltages in a very simple way. After all, not only changes in resistance value cause a capacitor's charge time to be modified, but also any change in the input voltage. The charge voltage has to be greater than 3.3 V, however, in all cases. **Figure 3** shows how input A3 may be used to measure voltages. To enable voltages between 0 and 3.3 V to be measured also, the measurement is carried out with respect to the com-

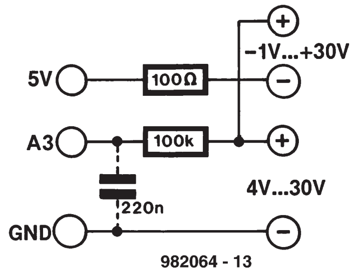


Figure 4. Using this simple circuit it becomes possible to employ the gameport to measure analogue voltages. The additional 0.22-µF capacitor will only be required if you have an old, slow PC.

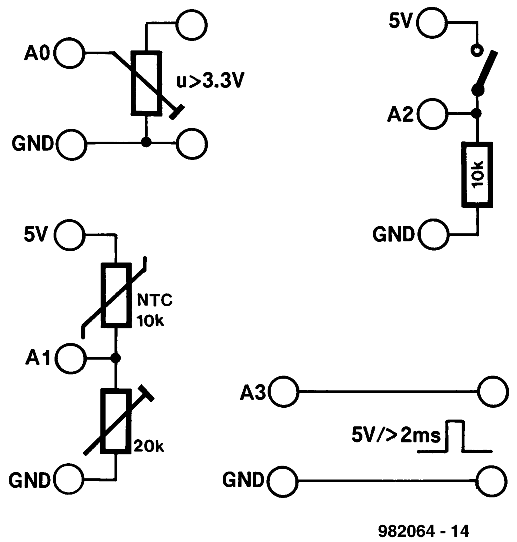


Figure 5. If you want to use a PC to monitor temperature, voltage or status, the gameport can provide excellent services.

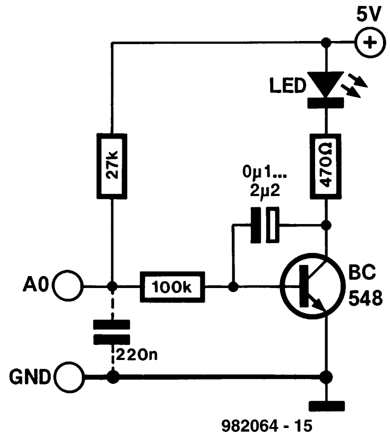


Figure 6. A trick allows the analogue input to double as a digital output.

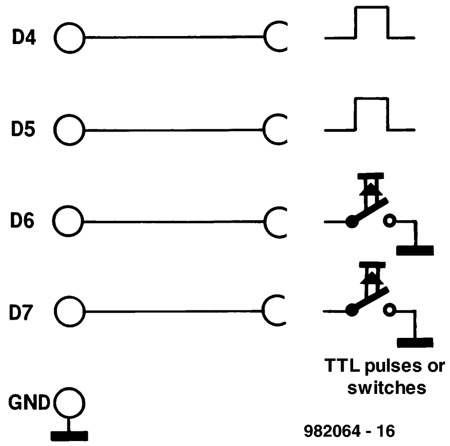


Figure 7. The gameport is capable of reading TTL-level pulses and switch positions without the help of additional hardware.

puter's supply voltage. That is also the reason for splitting the charging resistor, preventing short-circuits when the measurement wire accidentally touches the computer case (ground!). Unfortunately, this setup only allows measurements to be carried out on potential-free objects like batteries and the like.
When, in certain applications, the voltage to be measured area is always greater than 4 V, it is also possible to carry out measurements with respect to ground. The program shown in **Listing 3** offers both possibilities. The variable called 'Nullvalue' (initial value) contains the preloaded counter state at a test measurement using an input voltage of 5 V (or with the input short-circuited, if the measurement is with respect to the supply voltage). This reference value has to be established empirically for any individual computer, using, for example, the counter program from Listing 1. The procedure 'Calibrate' allows this value to be fine-tuned while the program is running. If we want to use more than one input at a time, say, for multiple voltage measurements, each channel has to be calibrated via its very own counter value. The relation between counter value and input voltage is not linear but described by an exponential function. The actual conversion and linearization is performed by the function called 'Uin'.
The measurement method as described here offers only limited accuracy. The main error sources are the computer power supply and the temperature co-efficient of the charge capacitors. None the less, the effective resolution of 0.1 V across the measurement range up to 30 V will be satisfactory for a good many applications.

Listing 1

```
Program Joystick_Resistance;
uses crt;
function Counter (Channel : Integer) : Word;
var n : word;
        Portvalue : Byte;
begin
        Portvalue := 1;                         {A0}
        if Channel=2 then Portvalue := 2;       {A1}
        if Channel=3 then Portvalue := 4;       {A2}
        if Channel=4 then Portvalue := 8;       {A3}
        n:=0;
        Inline ($FA);                           {block interrupt}
        port[$201]:= 0;                         {reset timers}
        repeat
            n:=n+1;                             {count until bit = 0}
        until ((Port [$201] and Portvalue) = 0) or (n>10000);
        Inline ($FB);                           {enable interrupt}
        Counter := n;
end;
begin
        repeat
                writeln (Counter(1),' ',Counter(2),' ',Counter(3),' ',Counter(4));
        delay (200);
        until KeyPressed;

end.
```

Listing 2

```
Program Joystick_Digital;
uses CRT;
function Din: Byte;
begin
       Din := Port [$201] AND 240;         {read bits 4-7}
end;
begin
       ClrScr;
       rpeat
              GotoXY (10,10);
              write (Din AND 16 div 16,'  ');   {D4}
              write (Din AND 32 div 32,'  ');   {D5}
              write (Din AND 64 div 64,'  ');   {D6}
              write (Din AND 128 div 128,'  '); {D7}
       until KeyPressed;
end.
```

Both the resolution and the accuracy may be improved by fitting an additional 0.22-μF capacitor as illustrated in **Figure 3**. This modification results in longer charging periods and, consequently, higher counter values, so that, in the end, the input voltage is measured using smaller steps.

The temperature co-efficient may also be improved by the use of a foil capacitor. Unfortunately, there is nothing you can do about supply

Listing 3

```
Program Joystick_Voltage;
uses CRT;
var Nullvalue: Word;
              Ch : Char;
function Counter (Channel : Integer) : Word;
var n : word;
              Portvalue : Byte;
begin
       Portvalue := 1;                    {A0}
       if Channel=2 then Portvalue := 2;   {A1}
       if Channel=3 then Portvalue := 4;   {A2}
       if Channel=4 then Portvalue := 8;   {A3}
       n:=0;
       Inline ($FA);                     {block interrupt}
       port[$201]:= 0;                   {reset timers}
       repeat
              n:=n+1;                         {count until bit = 0}
       until ((Port [$201] and Portvalue) = 0) or (n>>10000);
       Inline ($FB);                     {enable interrupt}
       Counter := n;
end;
function Uin: Real ;
begin
       Uin := 3.33 * (1/(1-exp(-Counter(4)/Nullvalue))-1/(1-exp(-1)));
end;
procedure Calibrate;
begin
       Nullvalue := Counter (4);         {measurement via A3}
end;
begin
       Nullvalue := 340;
       ClrScr;
       repeat
              repeat
               GotoXY (1,10);
               writeln ('Voltage w.r.t. +5V = ',Uin :3:1, 'V');
               writeln ('Voltage w.r.t. ground = ',Uin+5 :3:1, 'V');
               delay (200);
              until KeyPressed;
              Ch := upcase (ReadKey);
              If Ch = 'K' then Calibrate;
       until Ch = chr(27);
end.
```

```
Listing 4

Program Joystick_Limits;
uses CRT;
var Nullvalue: Word;
       Ch : Char;
procedure Reset;
begin
       Port [$201] := 0;
end;
function Input (Channel: Integer): String;
var State : String;
Portvalue : Byte;
begin
       Portvalue := 1;                                  {A0}
       if Channel=2 then Portvalue := 2;      {A1}
       if Channel=3 then Portvalue := 4;      {A2}
       if Channel=4 then Portvalue := 8;      {A3}
       if (Port [$201] AND Portvalue) = 0 then Input := 'yes'
              else Input := 'no'
end;
begin
       ClrScr;
       writeln (‘Limit Checking        <<Reset>>   <<Esc>>');
       repeat
              repeat
                     GotoXY (1,4);
                     writeln ('Channel 1: ',Input(1));
                     writeln ('Channel 2: ',Input(2));
                     writeln ('Channel 3: ',Input(3));
                     writeln ('Channel 4: ',Input(4));
                     delay (200);
              until KeyPressed;
              Ch := upcase (ReadKey);
              If Ch = 'R' then Reset;
       until Ch = chr(27);
end.
```

voltage fluctuations caused by the PC itself.

Checking the limits

A useful property of the timer used for the gameport is that the condition of the analogue inputs (threshold reached or not) can be stored in flip-flops, completely independent of other applications. So, it is possible to reset the timers at any moment, and then concentrate on other matters. After some time, each input may be checked to see if the input voltage has exceeded the trigger threshold of 3.3. V.

Figure 5 shows some ways of realizing this in practice. Higher voltages may be monitored by means of a voltage divider. An NTC may be employed to check if a certain temperature is exceeded, for instance, in the PC itself! The sensor then has to be mounted on a temperature-critical component (like the CPU) to check if this is adequately cooled.

In addition to analogue quantities, it is also possible to monitor ‘individual’ pulses (having a minimum length of about 2 ms), or switch positions. In this way, it becomes possible to tell for sure whether or not a certain event occurred at least once during a certain period of active monitoring.

Listing 4 provides an example of a program that effectively monitors the extreme values (measurement limits). The inputs may be reset at any time, and the state displayed on the screen. It is possible to leave the program at any time, and start it again later. In this way, it becomes possible to analyse events that occurred in the meantime.

Switching output

The absence of digital outputs unfortunately limits the application range of the gameport. With just a handful of parts, however, it is easy to create at least one digital output. After a software start of the timers, the analogue inputs are supplied with a single ramp-shaped pulse with a peak value of 3.3 V, but only if this output is is pulled to +5 V by a resistor. A large number of

```
Listing 5

1   REM Flashing LED on Gameport
10  FOR N = 1 TO 5000
20  OUT (&H201), 1            :REM reset timer, LED on
30  NEXT N
40  FOR N = 1 TO 10000        :REM LED off
50  NEXT N
60  IF INKEY$ <<>> "" THEN END
70  GOTO 10
```

Listing 6

```
program Four_Channel_Counter;
uses CRT;
var ch : Char;
procedure Counter;
var z1,z2,z3,z4: word;
Input, InputAlt: Byte;
begin
        ClrScr;
write (' Event counter  <<spacebar>> = Reset  <<Esc>>');
Z1:=0; Z2:=0; Z3:=0; Z4:=0;
InputAlt := Port[$201];              {read D4-D7}
gotoXY (10,5); write (Z1);
gotoXY (10,7); write (Z2);
gotoXY (10,9); write (Z3);
gotoXY (10,11); write (Z4);
repeat
        Input := Port[$201];
        if (Input and 16) << (InputAlt and 16) then begin
                Z1 := Z1 + 1;                              {D4}
                gotoXY (10,5); write (Z1);
        end;
        if (Input and 32) << (InputAlt and 32) then begin
                Z2 := Z2 + 1;                              {D5}
                gotoXY (10,7); write (Z2);
        end;
        if (Input and 64) << (InputAlt and 64) then begin
                Z3 := Z3 + 1;                              {D6}
                gotoXY (10,9); write (Z3);
        end;
        if (Input and 128) << (InputAlt and 128) then begin
                Z4 := Z4 + 1;                              {D7}
                gotoXY (10,11); write (Z4);
        end;
        InputAlt := Input;
        until KeyPressed;
        {delay (40);}                    {key debounce}
end;
begin
        repeat
                Counter;
                Ch := ReadKey;
        until Ch = chr(27);
end.
```

such pulses result in an average voltage of about 2 V, which is sufficient to switch on a transistor.

Figure 4 shows a circuit that turns an analogue input into a digital output. Here, the transistor turns on an LED when the joystick timer is reset all the time. The output signal from the joystick connection is smoothed by a 2.2-μF capacitor, which also provides 'soft' turning on and off of the LED.

Listing 5 supplies you with a program for an LED-based flashing light. Because it is not essential for the reset pulses to arrive quickly one after another, a BASIC program will do fine. In line 20, 5000 successive reset commands are given. These are sure to switch on the transistor. If you happen to use a slow PC, the required threshold voltage may not be reached. In that case, it is necessary to lengthen the timer's charging period by mounting the dashed 0.22-μF capacitor. The transistor is automatically switched off when no reset commands are issued.

A digital counter

By reading the digital inputs of the joystick directly, it becomes possible to realize various types of digital counter. As shown in **Figure 6**, the digital inputs may be connected directly to switches or TTL outputs. To illustrate just one of the options that become available, an event counter is described below.

Listing 6 provides the program of a quadruple pulse counter. All four digital inputs are continuously monitored by the procedure 'Counter'. Incoming pulses are independently counted and displayed on the computer screen. Because the latter occurs during the counting operation, the maximum input frequency is limited to about 1 kHz when using a simple and slow PC.

The inputs may be directly connected to switches, push-buttons or reed relays. Obviously, counting errors may be introduced by contact bounce which is inherent to nearly all mechanical switches. An effective debouncing method is to introduce a short pause of a few milliseconds, for example, delay(40). When the pulses are supplied by electronic sources like Geiger-Muller counters or clock oscillators, these pauses must be omitted because they lower the highest possible input frequency.

(982064)

In an earlier article on light intensity measurement using the PC (*Elektor Electronics* February 1998 Supplement) it was claimed that accurate time measurement is very difficult to implement in Visual BASIC. Our reader Mr. Feltes had second thoughts about this, and shows that it can be done!

Software by J. Feltes

accurate time measurement in Visual BASIC

create software delays with 100-μs resolution

True, because of its coarse resolution, the Timer function in Visual BASIC is only suitable for creating relatively long intervals. However, with the API function SLEEP apparently designed for shorter intervals, it should allow higher resolution to be achieved. SLEEP has to be declared as follows:

```
Declare Sub Sleep Lib "Kernel32"
(ByVal Milliseconds As Long)
```

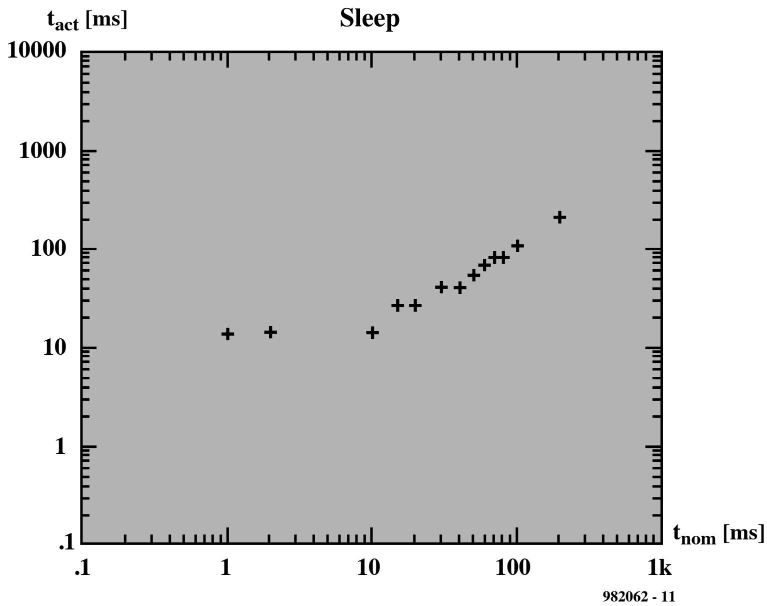
None the less, real measurements using this simple test program

```
Sub Rect(t As Long, t1 As Long)
For i = 1 to t1
    Sleep t
    PortOut &H278, 1
    Sleep t
    PortOut &H278, 0
Next i
End Sub
```

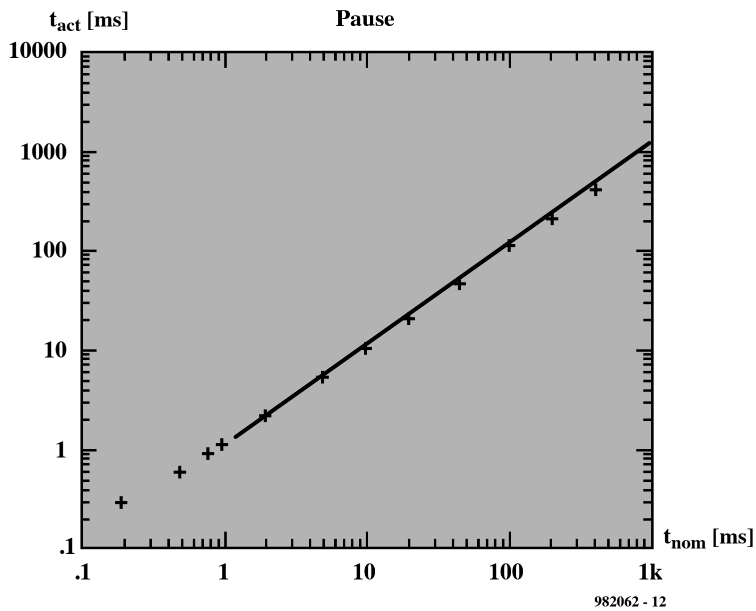
failed to indicate that the SLEEP function provides better resolution than the well-known timer-interrupt ticks. In fact, the accuracy that can be achieved is about equal. The result of the measurement is shown in **Figure 1**. The horizontal axis shows the target value, the vertical axis, the real value. Both are in milliseconds. This particular test was carried out on a Pentium 133 PC running Windows 95. The diagram shows that the duration of the pauses is almost correct only when the length is not less than about 14 ms.

If, however, you want to control, say, stepper motors, you will soon require much shorter, repeatable and CPU-independent delays in the milliseconds range. Neither the Timer nor the

1



2



SLEEP function will get you very far in this respect. A usable short-period timer, on the other hand, employs one of the three counters offered by the 8253/8254 interval timer IC of which any IBM PC or compatible has at least one. After all, while one counter has to be used for memory refresh, and another for the system clock, the third counter is only needed when a tone is to be generated via the PC's internal loudspeaker. Obviously, this timer is available for other purposes, too.

This counter, number 2, is operated in mode 0 and counts down a pre-loaded value to zero. The length of each count is accurately defined, and with it the length of the interval. On finishing the count operation, the counter output goes from zero to one. Unfortunately, continuous reading of the counter output is not possible on all PCs, because the counter is only 8253 compatible, and does not support the Readback command. In this way, the counter state is continuously read rather than the output. When the new value exceeds the old one, the counter produces an overflow. In other words, it has reached the end of the interval.

When this happens, a program like the one shown below branches out of a delay loop:

```
Public Sub Sleepshort(ByVal
Sdelay As Long)
'Sdelay as multiple of 0.838us
Dim x As Long, y As Long, i As
Long, zold As Long, Z As Long

x = Portin(&H61)
x = x Or 1
PortOut &H61, x

PortOut &H43, &HB0
x = SDelay And &HFF
PortOut & H42, y
x = SDelay \ &H100
PortOut &H42, x

zold = 100000
Do
  PortOut &H43, &H80
  x = PortIn(&H42)
  y = PortIn(&H42)
  Z = x + y * &H100
  If Z > zold Then Exit Do
  zold = Z
Loop

End Sub
```

First, bit 0 on Port 61H is set to logic 1 to actuate the gating input of counter 2. Next, the control word $B0_H$ = 10110000_B is output on port 43_H,

10	11	000	0
Select counter 2	Read/Write Mode First low byte, then high byte	Counter Mode 0: Interrupt at counting	BCD/Binary count in binary mode

Then the least significant and most significant bytes of the start value are copied to the counter via port 42H. Because the input frequency of the counter is always 1.19318 MHz (i.e., independent of the CPU clock), the delay to be expected is always a multiple of 0.838 μs. In this way, a maximum pause of 54.9 ms is obtained at SDelay = 65535. The value to be copied is an unsigned integer. Because this type of number does not exist in Visual BASIC, and the highest integer value is 32767, SDelay is transferred as LONG, and internally split in a High and Low byte.

Inside the loop, the counter value is continuously interrogated using the value 80_H = 10000000_B:

10	00	000	0
Select Counter 2	Internally store counter latch state	no meaning	no meaning

As indicated by measurements (**Figure 2**), the pause length of Sleepshort is subject to a tolerance of about ±10% within the range 0.5-50 ms. Further improvement could be in store by replacing the SUBs in the assembler code within the DLL. Because of the counter capacity of 16 bits, the length of the delay is limited to 59.4 ms. Possibly also, Sleep or SleepShort may be employed depending on the desired delay. The subroutine called Pause does this automatically. At longer intervals, DoEvents is called in the meantime to enable a response to Events.

```
Public Sub Pause(Milliseconds As
Single)

DIM Rest As Long, M1 As long, i
As Long

'very short?
if Milliseconds < 50 Then
  Sleepshort Milliseconds *
1000/0.838
  Exit Sub
End If

'longer than 50ms
Breakflag = False
If milliseconds <= 500 Then
  Sleep Milliseconds
Else
  M1 = Milliseconds \ 300
  'Integer Division!
  Rest = Milliseconds – M1 * 500
  For i = 1 to M1
      Sleep 500
      DoEvent
      If Breakflag Then Exit
For
  Next i
  Sleep Rest
End if

End Sub
```

In general, it has to be emphasised that time measurements are not really possible under Windows because the operating system is allowed to break in at any time. The resultant slightly irregular program execution may be demonstrated by using the above program to control a D-A converter and monitor the results of the conversion on an oscilloscope screen. You will not fail to recognize the expected sawtooth shape, although it has a number of interruptions of varying lengths in the form of horizontal dashes. These pauses become longer whenever the mouse or keyboard is used, or the hard disk is accessed. Fortunately, on modern PCs these pauses are in the millisecond range, so that they will not usually be noticed in not-too-fast applications.

(982062-1)

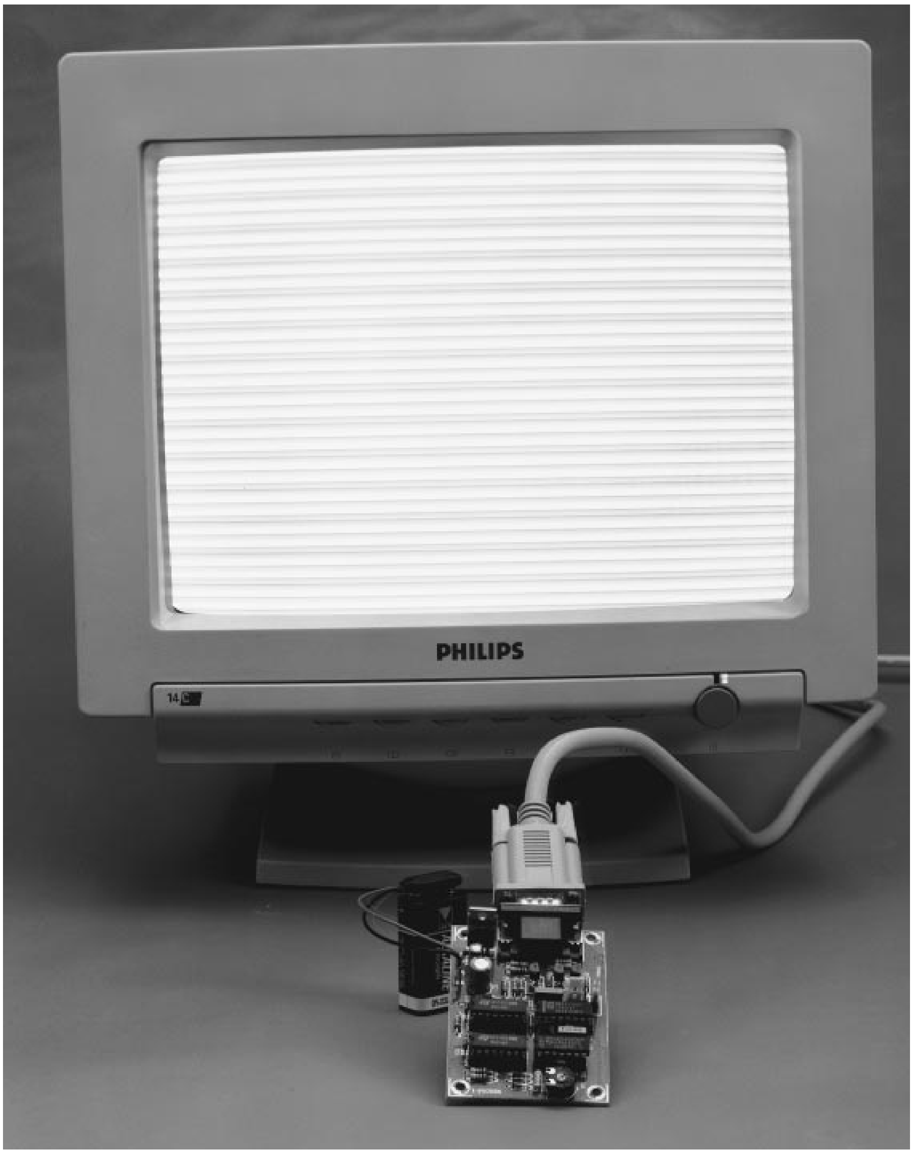
An extensive version of this article appeared in the January 1998 issue of the German Basic Pro *magazine.*

The vast majority of today's computer displays are VGA compatible. To be able to subject such displays to a quick test, a signal source has to be available that supports the rather high frequencies normally associated with the various VGA display modes. The VGA tester described in this article is a compact battery-powered unit that enables you to tell, at a glance, if a computer monitor is working properly or not.

Design by B. de Graaff

small VGA-tester

check computer displays within seconds



The VGA standard (video graphics array) is widely accepted as the current industry standard. Modern VGA-compliant computer monitors are capable of handling line frequencies from 30 kHz up to 100 kHz and more. Consequently, these monitors can only be used in combination with a computer, because the highest line frequency supplied by most TV test pattern generators is about 16 kHz.
One serious risk of connecting a faulty VGA display to a PC is that the fault can also cause damage the PC, and, in particular, the expensive video card.
A small, simple to operate display tester like the one described here may well fill a 'niche' in the market for PC accessories. The fact that the tester is battery-powered makes it ideal for quick and efficient faultfinding and on-site testing.

Before we continue with the description of the circuit, here are the relevant design targets we set out to achieve:

- battery powered;
- simple and reliable
- simple to use
- adjustable frequency
- adjustable line-sync levels;
- recognisable picture on display.

In practice

Although the above list of requirements may cause different assumptions, the present project is simple and easy to reproduce, even without blocking the way to a fairly universal design. The circuit diagram of the tester is shown **Figure 1**. As you can see, the design is based on common-or-garden CMOS logic and a handful of discrete components. Because VGA displays can handle many different line frequencies between (roughly) 30 kHz and 100 kHz, there is a point in making the line frequency adjustable. In this circuit, that has been achieved by means of a sim-

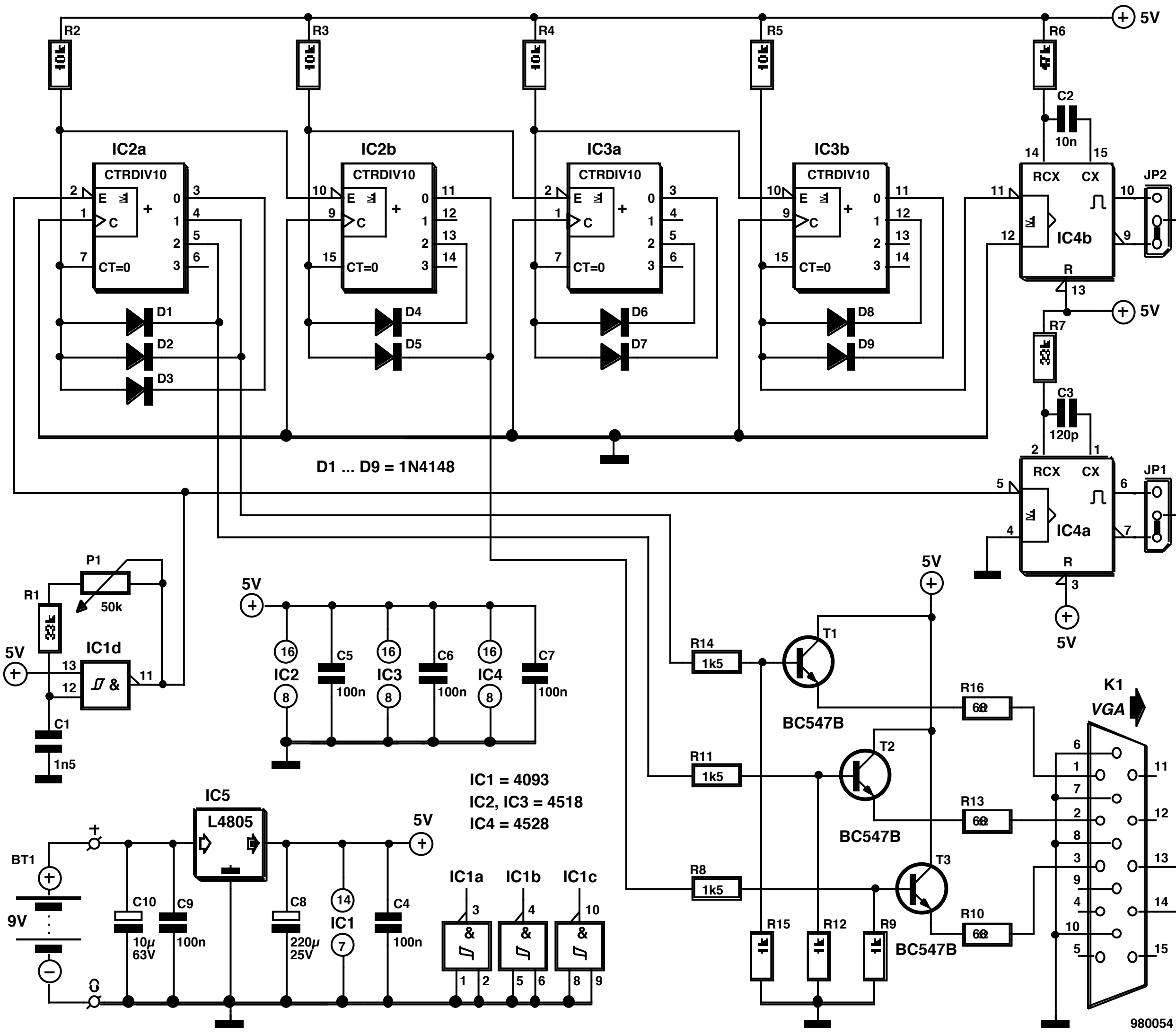


Figure 1. Circuit diagram of the VGA display tester. The circuit is simple and cheap thanks to the use of commonly available parts.

ple R-C oscillator consisting of components IC1d, C1, R1 and P1. In the prototype, the values of the passive parts were found to guarantee a raster frequency range from 47 Hz up to 115 Hz, which should be ample for all applications.

The clock signal is processed by four dividers whose scaling factor is preset by means of diodes. The divider cascade IC2a-IC3b divides by 525. This unusual divisor is achieved by making IC2a divide by 7, IC2b and IC3a by 5, and IC3b by 3. The pulse train supplied by the divider cascade is shown in **Figure 2**. The pulse sequence is used to generate a colour pattern as well as the video sync signals. More about this further on.

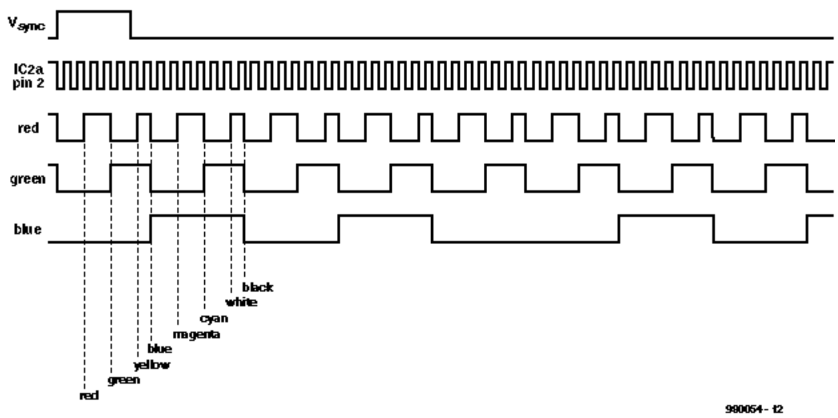


Figure 2. All the necessary signals are derived from central clock signal by means of a divider cascade.

From pulse to picture

Any VGA display requires three essential signals: horizontal sync pulses, vertical sync pulses, and video information. Most VGA displays have three analogue inputs. Unusually, the present tester drives these inputs with digital signals, so that the screen will only show fully saturated colours. Based on 3-bit colour information up to eight different colours can be displayed: red, green, blue, magenta, cyan, yellow, white and black.

The circuit diagram shows that each of the three video inputs on the monitor is driven by a separate buffer transistor. Each of these output drivers is protected by a 68-Ω series resistor to make it short-circuit resistant and at the same time define the desired output source impedance.

That leaves us with the sync pulses to

of the circuit board designed for the VGA display tester may be found in **Figure 3**. The single-sided board is compact, contains all parts and is simple to fit in a small plastic case.

Connector K1 is a PCB-style 15-pin 'high-density' VGA socket. If so desired, the two jumpers for the sync polarity selection may be replaced by toggle switches. This is, in fact, recommended whenever the circuit is to be used 'on the road'.

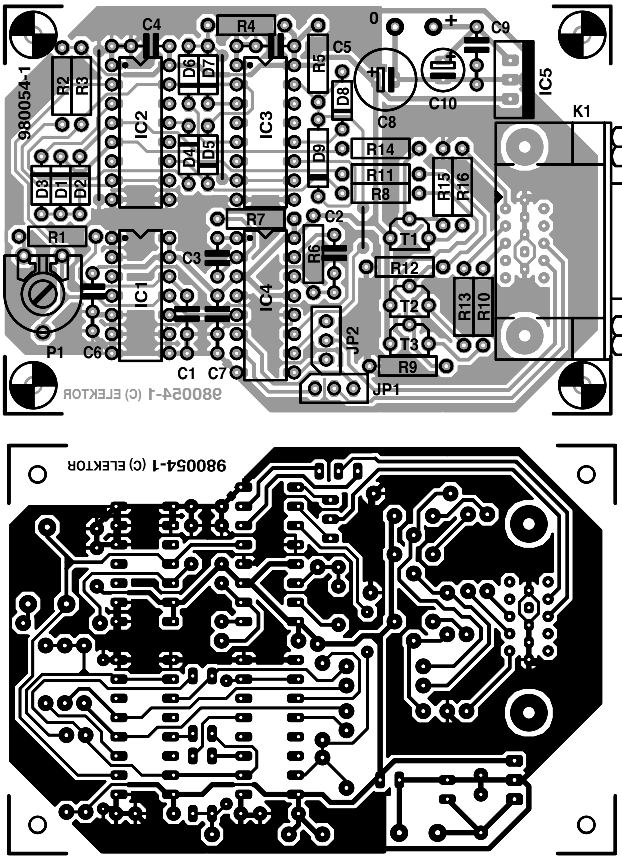


Figure 3. Copper track layout and component mounting plan of the PCB designed for the tester (board not available ready-made).

COMPONENTS LIST

Resistors:
R1,R7 = 33kΩ
R2-R5 = 10kΩ
R6 = 47kΩ
R8,R11,R14, = 1kΩ5
R9,R12,R15 = 1kΩ
R10,R13,R16 = 68Ω
P1 = 50kΩ preset H

Capacitors:
C1 = 1nF5
C2 = 10nF
C3 = 120pF
C4-C7,C9 = 100nF
C8 = 220µF 25V radial
C10 = 10µF 63V radial

Semiconductors:
D1-D9 = 1N4148
T1-T3 = BC547B
IC1 = 4093
IC2,IC3 = 4518
IC4 = 4528
IC5 = L4805

Miscellaneous:
JP1,JP2 = 3-way pinheader with jumper
K1 = 15-way high-density VGA socket, PCB mount, angled pins
Bt1 = 9V PP3 battery with clip and leads.

be generated by the circuit. These pulses are generated using two monostable multivibrators (MMVs). The clock signal of IC1d duplicates as the horizontal sync pulse, triggering monostable IC4a. The output of this IC supplies a pulse with a length of 2.8 µs. Since either the Q and the $\overline{Q}$ output may be taken to the output by way of a jumper, the output signal is available in 'true' or 'inverted' form. A similar approach has been adopted for the vertical sync, although in that case the clock frequency divided by 525 is used as supplied by the divider cascade. The vertical sync pulse is generated by IC4b, and has a length of 175 µs. The other three pulse signals are combined in the video buffers (T1-T2-T3) to provide a line pattern with random colours.

Although the sync and video signals are generated in a very simple manner, the result is perfectly suitable for a vast number of VGA displays.

The rest of the circuit remains limited to a compact power supply. To ensure the circuit works reliably on a 9-volt battery, a low-drop 5-V regulator (IC5) has been added. The upshot is that the tester continues to work reliably even if the battery is almost 'flat'.

Construction

The component mounting plan, a.k.a. 'overlay' and the copper track layout of the circuit board designed for the VGA display tester may be found in **Figure 3**.

Practical use and adjustment

There is not much to be said about these matters. The line frequency is adjusted with the aid of preset P1. All displays should be able to trigger on the signal from about 30 kHz onwards. The display will show a pattern consisting of coloured lines. In case it is essential to test for the reproduction of individual colours, the preset may be replaced by a potentiometer or a rotary switch with a number of fixed resistors at its contacts. In this way it becomes possible to select specific line frequencies like 30 kHz, 50 kHz, 80 kHz or 100 kHz. If you find it easier to work with raster frequencies (sometimes referred to as 'display refresh rates'), then the switch may be calibrated so that you can select between, say, 50 Hz, 60 Hz, 70 Hz, 72 Hz and 75 Hz. Of course, this requires determining the requisite resistor values. Using a frequency meter, a potentiometer and a multimeter, these values should not be too difficult to establish. Alternatively, you may use a couple of fixed 10-kΩ resistors. The frequencies will then be reasonably close to the target values.

Testing is very simple: use a display cable to connect up the VGA display to the tester. If necessary invert the sync signals and see if a horizontal line pattern appears on the screen. As soon as the picture is synchronized, you know for sure that the timing of the display works at the frequency set on the tester. When the bars appear in all eight different colours, the video (RGB) amplifiers may safely be assumed to work all right. If colours are missing, it is easy to determine which of the basic colour circuits (R, G or B) is defective. If a defect is discovered in this way, the best thing to do is take the display to an authorized repair shop. Attempts at home repair are not recommended because of the high voltages that exist inside the display, and the fact that the necessary circuit diagrams will rarely be available!

(980054-1)

the super audio CD

better sound, more facilities, and backward compatibility

When the compact disc, CD, was introduced by Philips of the Netherlands and Sony of Japan in the early 1980s, pulse-code modulation (in practical use), on which CD technology depends, was still young (introduced by the Japan Broadcasting Corporation, NHK, in 1967). In essence, the CD is the medium that introduced most people to digital audio reproduction. Since the introduction of the CD, various aspects of digital audio engineering have been enhanced considerably and have made possible the Super Audio Compact Disc.

Disc data

	Standard CD	Super Audio CD
Diameter	120 mm (4.75”)	120 mm (4.75”)
Thickness	1.2 mm (.05”)	1.2 mm (0.05”)
Programme start radius	25 mm	25 mm
Programme finish radius	116 mm	116 mm
Rotation	Anticlockwise to laser	Anticlockwise to laser
Speed of rotation	500–200 rev/min	500–200 rev/min
Signal layers	1	2
Reflectivity	reflective	semi-transmissive
Capacity	780 MByte	4.7 GByte
Pit width	0.6 μm	
Pit length	0.833–3.054 μm	0.40 μm (min)
Land* length	0.833–3.054 μm	0.40 μm (min)
Pit depth	0.12 μm	0.12 μm
Track pitch	1.6 μm	0.74 μm
Laser wavelength	780 nm	650 nm
Numerical aperture (NA) of pick up lens	0.45	0.60
Encoding:		
Standard reflective layer	16-bit PCM 44.1 kHz sampling	16-bit PCM 44.1 kHz sampling
High-density layer		1-bit DSD 2.8224 MHz sampling
Multi-channel		6 channels (DSD)
Frequency range	5–20,000 Hz	0–100,000 Hz (DSD)
Dynamic range	94 dB	120 dB
Playback time	74 min	74 min
Extra facilities	CD text	Text, graphics, video

* land = spacing between two adjacent pits

By our Editorial Staff

The Super Audio CD looks exactly like a standard CD. What cannot be seen is that the new type of disc consists of a multi-layer hybrid construction that enables a number of new capabilities to be incorporated (see **Figure 1**).

The conventional Standard Reflective Layer (used on conventional CDs) is fully compatible with the CD ‘Red Book’ specifications. The CD player’s laser reads this layer through a semi-transmissive layer.

The 4.7 GByte Semi-Transmissive Layer of the Super Audio CD can hold two complete, 74-minute versions of the music: DSD 2-channel stereo and DSD 6-channel sound. This is made possible by Direct Stream Transfer, a lossless coding developed by Philips.

Figure 1 shows that the two layers are read from the same side. A standard CD player, which uses a 780 nm laser diode reads the Standard Reflective Layer through the high-density layer since this is transparent for 780 nm lasers. A Super Audio CD player, which uses a 650 nm laser diode, reads the high-density layer, since this is reflective at that wavelength. This hybrid-disc technology is all that’s needed to avoid the issue of dual inventory—separate retail stocks of conventional CDs and Super Audio CDs for each title.

1

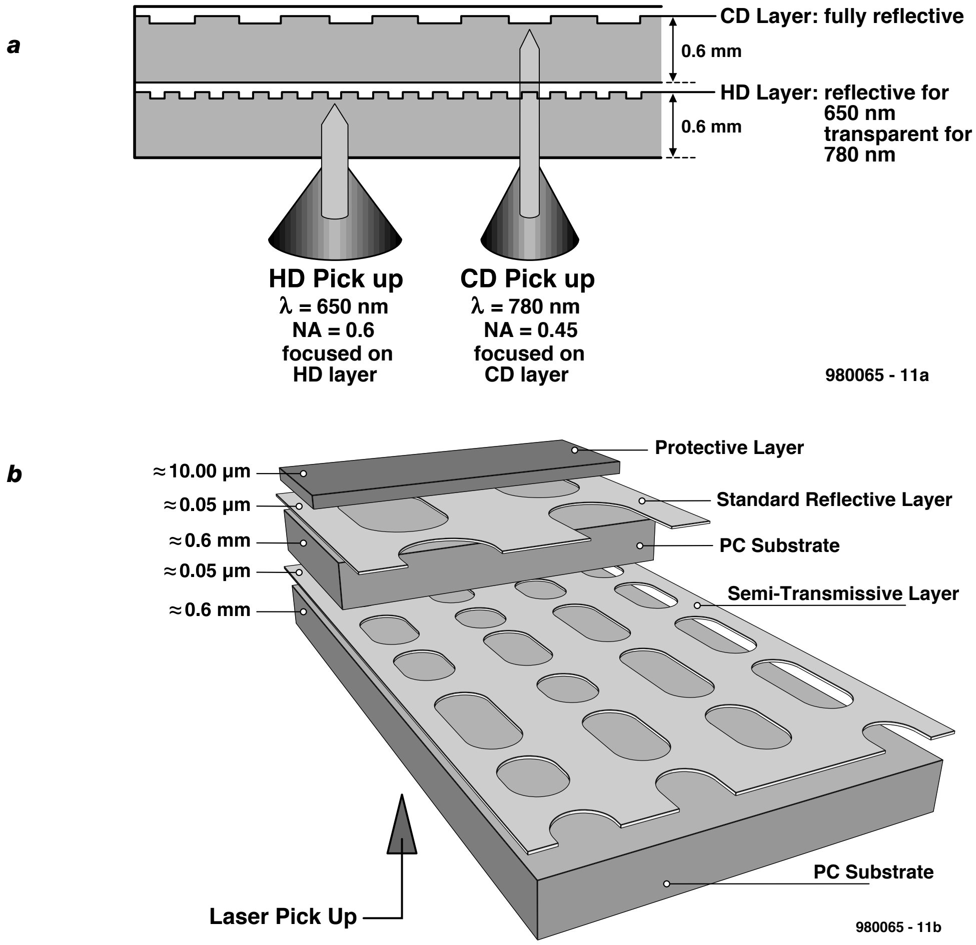


Figure 1. The Super Audio CD is similar in concept to the standard CD, but has an additional high-density layer. The two layers are read from the same side. The CD laser reads the Standard Reflective Layer through the Semi-Transmissive Layer.

NEW CAPABILITIES

The Super Audio CD provides a number of new capabilities compared with a standard CD.

- It uses a hybrid technique in which two independent data layers are sandwiched. This approach results in a CD that is fully compatible with existing, standard CD players. This is important to the retail trade and consumers alike, since it avoids the necessity of doubling up on CDs ccontaining the same recording.
- One layer is processed in Super Bit Mapping Direct, a technology that results in a DSD (direct stream digital) encoded audio signal being reproduced with better quality even on a standard CD player. This is because the 16-bit resolution of the PCM (pulse-code modulation) signal is used optimally. Without the technique, the value of the last bit is not reliable.
- The additional data on the second layer are processed in DSD, an encoding technique in which a digital audio signal is sampled at a rate of 2.8224 MHz and then processed as a 1-bit digital signal. Conventional CDs use a 16-bit PCM code.
- The digital code on the second layer is compressed in Direct Stream Transfer, a Philips lossless coding method. This applies to normal stereo playback, 6-channel playback, text and graphics. In practice a compression ratio of about 50 per cent is obtained.
- Digital watermark. The illegal copying of CDs is made much more difficult with the aid of visible and invisible markings.

DIRECT STREAM DIGITAL TECHNOLOGY

Since the introduction of the CD, the rate at which signals can be sampled has increased appreciably and the resolution has been refined. Yet, the quality of the reproduced sound has hardly improved. This is because the basic concept of the standard CD cannot be changed. One of the serious limitations is formed by the filters used. These filters are required to pass signals up to 20 kHz (which 98% of people cannot hear) and suppress all signals above 22.05 kHz. A number of methods have been devised to accomplish this, such as oversampling. The effect of these is minimal.

In most PCM recording systems, the analogue data are oversampled ×64 with a sigma-delta converter. This means that the system operates with a sampling rate of 2.8224 MHz, which results in a 1-bit digital signal that is converted into a PCM code.

In Direct Stream Digital (DSD) technology, the 1-bit signal is used directly, that is, not converted into PCM code. Since the sigma-delta converter has a relatively high noise floor, a fifth order filter is used to eliminate most of the noise.

Whereas modern tape recording machines used in broadcasting have a bandwidth of 50 kHz at a tape speed of 30 in/sec, DSD technology provides a frequency response from d.c. to over 100 kHz, plus a dynamic range greater than 120 dB across the audio band. Moreover, independent critics and record producers rate DSD sound as ‘relaxed, musical, detailed and transparent, with a far greater sense of space around each instrument and voice’.

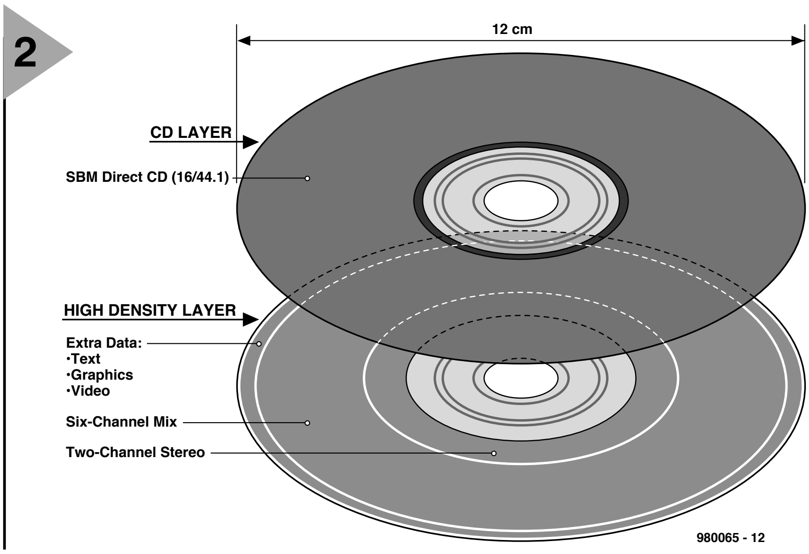


Figure 2. Construction of the Super Audio CD. Note that the laser looks upward from below the disc. A standard CD player's laser does not 'see' the high-density layer.

DIRECT STREAM TRANSFER

Both DSD 2-channel stereo and DSD 6-channel sound depend on the lossless coding method Direct Stream Transfer. Such reduction technologies are also used in computers, for instance, the ZIP protocol. They compress (reduce) the original data stream without the loss of a single bit. The algorithm used for the Super Audio CD gives a reduction of about 50 per cent. Other bit rate reduction technologies which ignore redundant data, such as MPEG-2 or Dolby Digital (AC-3) provide a much higher degree of compression. The price paid for this is that decompression provides a signal that looks like the original, but is slightly different.

SUPER BIT MAPPING

Since the Super Audio CD is mastered in DSD technology, the CD layer, compatible with the CD 'Red Book' standard, is transferred from DSD in a so-called Super Bit Mapping (SBM) direct down-conversion. This means that the 1-bit wide, ×64 oversampled DSD datastream is converted to 16-bit and the usual sampling rate. It is, of course, important that as little information gets lost in this as possible. Sony has developed special SBM processors that enable 20–24-bit accuracy to be obtained with 16-bit signals.

THE NEXT GENERATION

The next generation of CD players, the Super Audio CD players, are fitted with 650 nm lasers to which the high-density layer is reflective. The user of such a new player will have access to 2-channel stereo sound of the highest quality, a 6-channel version of the same sound plus additional text (disc name, artist name, track name, lyrics and liner notes) and graphics.

The available bandwidth for both music versions is 0–100 kHz (compared with 20 Hz to 20 kHz in a standard CD player) with a dynamic range of 120 dB over the audio range (currently 94 dB maximum).

PROTECTION AGAINST PIRATES

It is of the greatest importance to producers and consumers alike that the illegal copying of CDs is stopped. Although the Copy Management System (CSM) restricts the amateur criminal, it does not stop 'professional' felons from producing vast numbers of illegal copies.

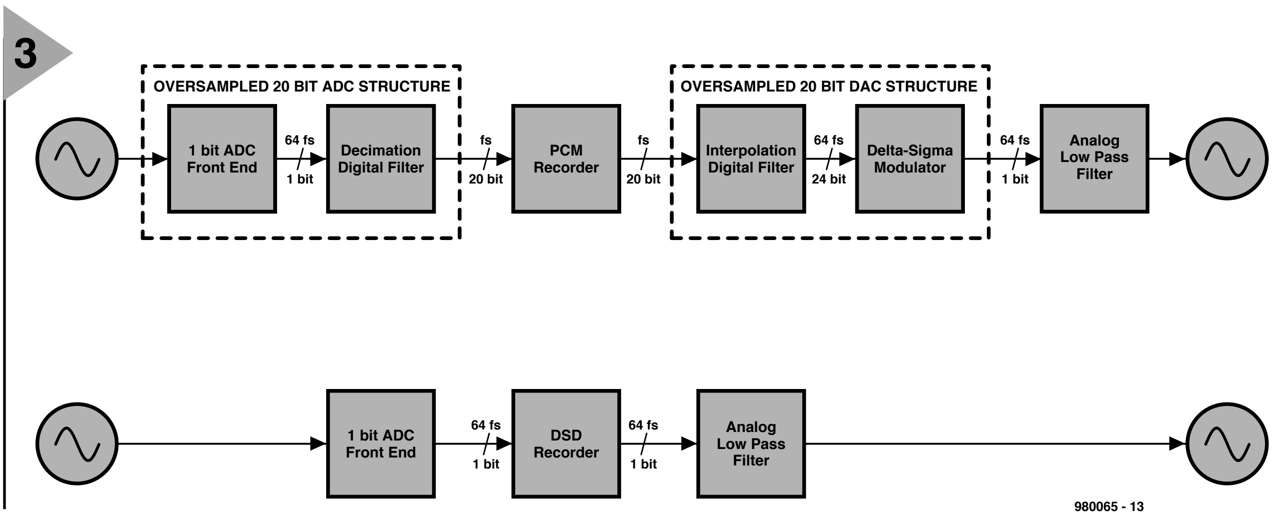
More stringent protection measures are incorporated in the Super Audio CD. First, with the aid of Digital Watermark, the disc is given a water mark in the form of a pattern of pits on the signal side with Pit Signal Processing (PSP). The pattern is highly recognizable by the user, but can only be produced by the manufacturer of the disc using complex technologies. Needless to say, the pattern cannot be removed, even by the original producer.

Also, there are less easily seen markings, such as barcodes and invisible, irremovable data on the CD.

All these precautions do not make it impossible for criminals to copy the CD, but they should at least make it possible for us, the consumer, to ensure that we are not defrauded by these felons by checking that the CDs we buy carry these markings.

[980065]

Figure 3. In standard CD (PCM) processing, filters are required for recording and playback. In super audio CD (DSD) processing, the input filters are not needed and the original 1-bit date are used.



laser-controlled burglar deterrent

simple, effective and inexpensive

Since the 1960s, light-emitting diodes (LEDs) have come into use for many applications. Many people may not know that these diodes, used in low-cost laser-pens and laser pointers, were developed for CD players. Today, lasers are used in architecture, in automobile engineering to measure all sorts of part, and in high-precision spirit levels, to name but a few. Lasers are also used in crime fighting, for instance, in high-precision speed traps to catch the unwary, speeding motorist. These are but a few examples of the many applications of lasers. This article describes how a simple laser diode can be used to build an inexpensive burglar deterrent/alarm.

Design by L. Lemmens

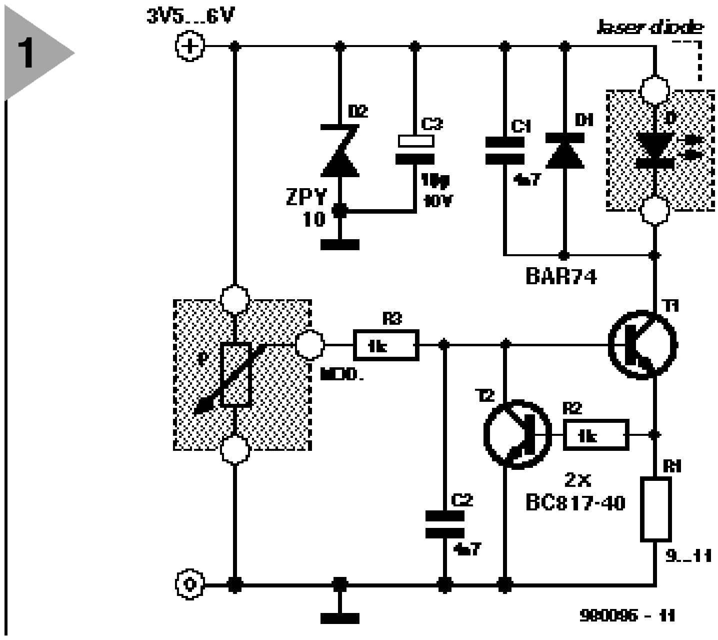


Figure 1. Circuit diagram of a laser unit which may use a discrete laser diode or a laser pointer. The brightness of the laser beam may be varied with a potentiometer or external signal.

SAFETY FIRST!

Any laser, even the smallest, forms a danger for the human eye. In laser technology there is one rule that must be obeyed at all times: Never, ever look into a laser beam or even into its reflection! In this context, it should be borne in mind that even a 1 mW laser is about 1000 times as bright as summer sunlight. Before you start any work on a laser project, take off any rings, watches, bracelets and other shiny personal ornaments that may reflect the laser beam. Also, make sure at all times that there is nobody else in the path of the beam. Children are particularly curious and will want to find out what happens in the beam.

INTRODUCTION

Lasers generate a light beam that, owing to its coherent character, can be used to span large distances. Most lasers available in the retail market are semiconductor types. One version that recently has been in the news (owing to its nefarious use by some unthinking youths) is the laser pointer. This is a small semiconductor laser mounted in a slender, light and easy-to-hold case intended for presentation purposes. The law in most countries limits its output to 1 mW.

Since the light beam emitted by a laser can span relatively large distances, a laser can be used to set up a simple but effective burglar alarm. For instance, a laser and a few mirrors placed in appropriate positions can form an invisible barrier around a building or a valuable object.

A drawback of a laser diode is that it generates a constant beam of light. For the present purpose, it would be much better if the light were modulated so that the intensity of the light beam can be adjusted. Fortunately, this

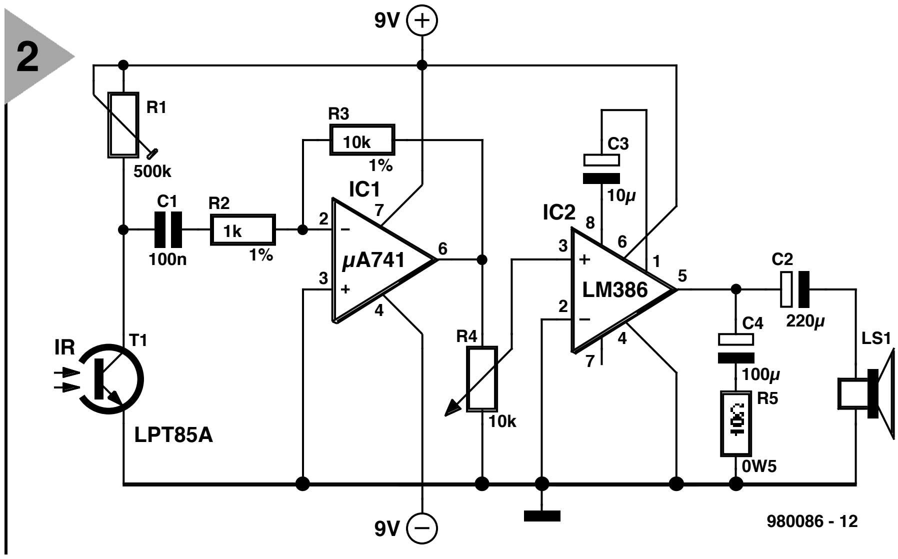


Figure 2. Circuit diagram of general-purpose AM receiver with which modulated laser signals can be received and decoded. The demodulated signal may be used to drive a loudspeaker or a relay.

Classification of laser pointers

Laser pointers, laser pens, and laser diodes available in the retail market are classified in three categories according to NEN (Euro) Norm 60825-1 (available from the British Standards Institute or your particular country's Standards Authority. In the United Kingdom, it may be inspected at many Public Libraries. There is a fourth category, but this deals with lasers for professional applications (which are subject to a licence) only.

Category III

This pertains to lasers with output powers up to 5 mW, which are not safe to use without adequate provisions. At small distances, exposure of eyes for less than a quarter of a second (the eye reflex is longer) leads to irremediable damage to the eye. Its sale to unlicensed private citizens is prohibited.

Category II

Applicable to lasers with output powers < 1 mW. In spite of their low power, such lasers cannot be used in gadgets such as keyrings. Ar distances of ≤ 1 m (3 ft), exposure of 0.25 s can lead to serious damage to the eyes.

Category I

This category applies to laser diodes with an output power < 0.5 mW, which are reasonably safe in use. They can be used in gadgest auch as keyrings. Even so, great care is needed when using these lasers.

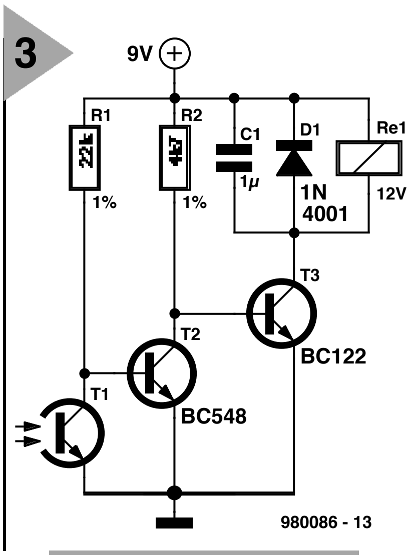


Figure 3. Circuit diagram of light-operated switch. When photo transistor T_1 receives light from the laser, the relay is energized.

can be achieved readily by powering the circuit by a modulated voltage.

Although it is fairly simple to construct a laser diode module (see Reference 1), some readers may prefer to use a ready-made laser pointer.

THE LASER: DESCRIPTION

The circuit of the laser is shown in Figure 1. Diode D_1, in anti-parallel with the laser diode, provides a simple but effective protection against connecting the supply lines with wrong polarity. Should this occur for a brief moment, no harm is done. If, however, the wrong polarity is retained, tantalum capacitor C_3 will explode, but the laser diode will not be damaged.

Depending on the type of laser diode or laser pointer, the value of series resistor R_1 must be adapted, although for most diodes a value of 9–11 Ω is fine.

The circuit is built on a small piece of stripboard. If you have the skills and patience, you may well decide to etch a small printed-circuit board to which the components may be soldered at both sides. Note that the rating of zener diode D_2 is 5 V, 500 mW.

The module can then be taken into use. Using a regulated power supply of 3.5–6V (at which power losses are smallest) and linking the modulation input to the +ve supply line, the diode should emit light.

A proper modulating voltage may be applied to the modulator input. Thanks to the direct coupling, the potentiometer at the input provides the means for accurate power control. The modulation stage handles sinusoidal signals up to 2MHz before the depth of modulation begins to diminish. It is noteworthy that a depth of modulation of 100% is achieved at frequencies of up to 2MHz, which is not bad for a simple circuit.

RECEIVER

The circuit in Figure 2 shows an amplitude-modulation (AM) receiver that uses a photo-transistor, T_1, as detector. It is followed by an amplifier, IC_1, which is very stable and immune to interference. The sensitivity of the receiver proper is set with multiturn preset R_1.

Note that resistors R_2 and R_3 should be metal film, 1% types. The rating of R_5 is 0.5 W.

A second amplifier, IC_2, drives a small loudspeaker, LS_1. The volume is controlled with R_4. The loudspeaker may, of course, be replaced by a small relay to operate another kind of alarm, perhaps at some distance from the installation.

The overall receiver is decoupled by a number of capacitors. Note that C_1 should be a ceramic type.

The detector may be any type of infra-red photo transistor or diode available. Suitable transistors are, for instance, BPW40 or, better, LPT85A; diodes: SFH205 or BPW34.

The receiver is powered by a symmetric supply, which may be provided by two 9-V batteries.

The receiver may be housed in a small plastic case. It is not really necessary to design a printed-circuit board for it: it is easily built on a piece of stripboard. Clearly, the construction should be carried out with care and neat soldering to prevent spurious oscillations occurring that may spoil or distort the measurements and would give rise to false alarms.

The phototransistor should be mounted in a small tube of appropriate inner diameter. This prevents not only interference by ambient light and other sources of light, but also gives the detector some directivity. Mind the polarity of the transistor when soldering it into place: the detector will still work with incorrect polarity, but its sensitivity is then much reduced.

Test

Set sensitivity control R_1 to the centre of its travel, volume control R_4 to nminimum and connect the receiver to the two batteries or other ± 9-V power supply as the case may be. When the volume control is turned gently, a dull hum should become audible: this is the 50 Hz hum emitted by the mains supply via the room lights. When the lights are not on, this hum will not be heard, so do turn them on for this test. If you still do not hear anything, there is a fault somewhere. Check all connections, junctions, components, and so on. If all these are all right, the receiver must work satisfactorily.

ALTERNATIVE

It is not always necessary, or convenient, to use a modulated light beam. Often, a simple light-operated switch such as shown in Figure 3 may be used.

When light falls on to photo transistor T_1, transistors T_2 and T_3 come on, whereupon the relay is energized. If therefore the relay contact opens, either the laser beam is interrupted or the power supply has failed. Two good reasons to take action!

Note that R_1 is a multiturn type and resistors R_2 and R_3 are metal film, 1% types. The relay is a small-signal type, 12 V, ≤50 mA.

The detector may be any type of infra-red photo transistor or diode available. Suitable transistors are, for instance, BPW40 or, better, LPT85A; diodes: SFH205 or BPW34.

References:
Lasers: Theory and Practice by Dirk R. Baur; ISBN 0 90570552 1; Elektor Electronics (Publishing), 1997

The Laser Guidebook by Jeff Hecht, ISBN 0 07 0277370; McGraw-Hill, 1992

[980086]

Note that, if you as a private person use a laser in your own home or garage (as long as unauthorized people have no access) you may do with it what you wish, as long as it does not harm life or property of third parties (including burglars!).

Insurance
If you are an employer, you have, of course, the necessary insurance(s) to cover your liabilities. Beware, however, because most policies explicitly exclude any damage, direct or indirect, caused by laser beams. You must, therefore, make absolutely certain that a relevant clause regarding liability for such damage is included. Many people are not aware of the exclusion.

active magnetic antennas

have general coverage receiver, will travel

The combination of a wire loop with the size of an A4 sheet, coupled to a carefully matched and easily tuned amplifier offers high-quality MW/LW/SW radio reception in your living room. The excellent performance of the two ‘all-portable’ directional active antennas described in this article makes them direct rivals of many extensive outdoor antennas. Meet the Omega-2 and Omega-3!

Designs by
Dipl. Ing. Jo Becker, DJ8IL

The active antenna designs discussed in this article are the result of many years of comparative signal level monitoring using various long-wave, medium-wave and short-wave antennas for indoor and outdoor use. The antennas available for this research work were a 5-m high vertical ground plane, a magnetic loop with a diameter of 1.2 m, an active ‘rod’ antenna [1] and various small magnetic antennas including round and square loops, and ferrite rods coupled to suitably dimensioned amplifiers.

General antenna theory tells us that long wires and rod antennas are only sensitive to the electric component of the received signal. When used indoors, they loose 70-90% of the received voltage as compared with a mounting position on the roof. By contrast, small loop-antennas exhibit a totally different behaviour, mainly because they are sensitive to the magnetic component of the RF signal produced by the transmitter. As long as the thickness of the ‘wall’ or other obstacle to be traversed is much smaller than the wavelength, a magnetic field is hardly reduced in strength. Consequently, the level differences between magnetic antennas mounted indoors and outdoors were found to range from negligible to 50% at the highest

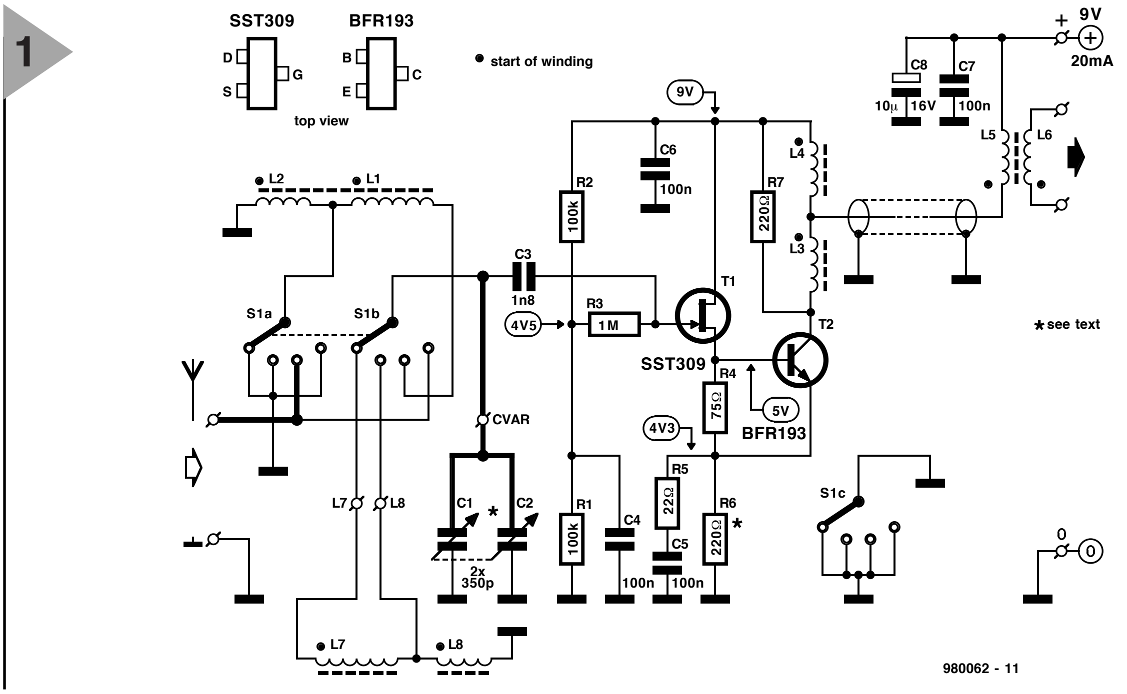


Figure 1. Circuit diagram of the Omega-2 active magnetic antenna for LW/MW/SW reception from 150 kHz to 30 MHz in four ranges. Note that the amplifier is only suitable for the indicated loop antenna. The heavy lines in the diagram indicate connections made in solid wire to preserve the Q factor of the antenna.

$$\frac{U_{out}}{E} = \frac{2\pi f}{c} \cdot \frac{n_{(L2)} + n_{(L1)}}{n_{(L1)}} \cdot A_{loop} \cdot Q \cdot G$$

where $c = 3 \cdot 10^8 \text{ m/s}$

$A = 0.05 \text{ m}^2$

$$G \approx \frac{1}{2} \cdot \frac{R7 \,//\, 4 \cdot 50\Omega}{R5 + r_D \cdot \left[1 + \dfrac{R5 + 1/g_f}{\beta \cdot r_D \,//\, R4} \right]}$$

With $r_D \approx 25\text{mV}/I_c = 2.5\Omega$ at $I_c = 10\text{mA}$, $\beta = 100$, and FET transconductance $g_f = 17\text{mS}$, we get $G \approx 1.9$

With $Q = 50$ (at 10MHz) the effective antenna height is $\frac{U_{out}}{E} = 1.0\text{m}$

on one occasion.

There are still other marked differences between antennas responding to the ‘electric’ field, and their counterparts designed to convert the magnetic component into an electric voltage. Whereas the currently popular active electric antenna (say, the combination of the small telescopic rod with a matching amplifier) typically exhibits wideband behaviour, magnetic antennas generate competitive voltage levels only in resonance, that is, when accurately tuned to the desired receive frequency. Wideband systems unfortunately suffer from susceptibility to intermodulation in the vicinity of strong transmitters, a problem that calls for rather special remedy [2]. Another advantage of magnetic active antennas is that they supply an RF signal with an unusually low background noise level.

W-2 ANTENNA FOR LW/MW/SW

The first antenna discussed here provides seamless coverage of the LW/MW/SW frequency range from 150 kHz to 30 MHz. It is powered by either the receiver or its own power supply, via the RF output cable and a simple RF/DC splitter. Current consumption will be of the order of 20 mA at a supply voltage of 9 V or 12 V. The amplifier accepts a number of inductive loops and coils, including experimental ones, which are simply ‘plugged in’.

The electronics

Although the two-stage amplifier shown in **Figure 1** is based on the design presented in [1], a short discussion on its opera-

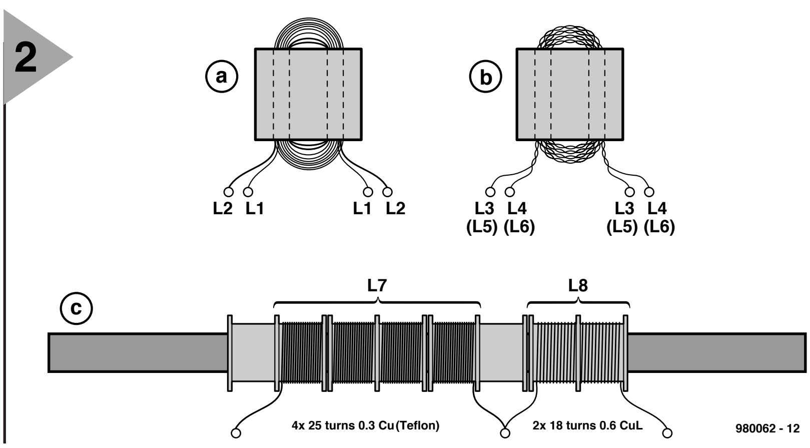


Figure 2. Construction details of the transformers and the LW/MW rod antenna used in the Omega-2.

3

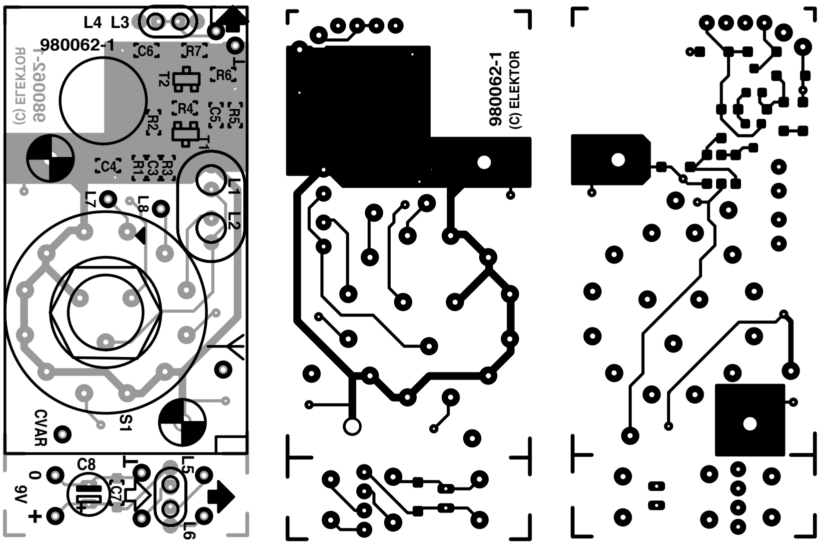


Figure 3. Copper track layouts and component mounting plan of the double-sided, not through-plated PCB. Board available ready-made from the Publishers.

COMPONENTS LIST

Resistors:
R1,R2 = 100kΩ SMA
R3 = 1MΩ SMA
R4 = 75Ω SMA
R5 = 22Ω SMA
R6 = 220Ω (9V supply) or 330Ω (12V supply)
R7 = 220Ω

Capacitors:
C1+ C2 = one 700-pF tuning capacitor, made from two 350-pF AM sections.
C3 = 1nF8 or 2nF2 SMA
C4-C7 = 100nF SMA
C8 = 10μF 16V radial

Inductors:
(CuL = enamelled copper wire)
L1 = 14 turns 0.4mm dia. CuL on binocular core 14x8x8mm, material K1, purple (Siemens)
L2 = 4 turns 0.6mm dia. CuL on above core.
L3 = 10 turns 0.15mm CuL on binocular core 7x6x4mm, material N30, white (Siemens)
L4 = 10 turns 0.15mm CuL on above core (bifilar)
L5 = 10 turns 0.15mm CuL on binocular core 7x6x4mm, material N30, white (Siemens)
L6 = 10 turns 0.15mm CuL on above core (bifilar)
L7 = 100 (4x25) turns 0.3mm dia. AWG30 Teflon-coated wire (Tefzel) on two 2-compartment formers for pot cores 26dia.x16mm.
L8 = 36 (2x18) turns 0.6mm CuL on 2-compartment former for pot cores 26dia.x16mm.
Ferrite rod, 10x200mm, material 4B1 (Philips Components, order code 43300303071)
4 off 2-compartment formers for 26dia.x16mm pot cores.

Semiconductors:
T1 = SST309 (Siliconix, Temic)
T2 = BFR193 (Siemens)

Miscellaneous:
S1 = rotary switch, 3 poles, 4 positions, PCB mount (Lorlin).
Case, plastic, 120x65x40mm.
PCB, order code 980062-1 (see Readers Services page).

Miscellaneous, mechanical
1 non-isolated wander socket.
1 isolated wander socket.
Brass or copper tubing, 4mm dia.
Coax cable, 50Ω, RG174, length 1m.
2 spring washers, dia. 10mm and 6mm.
8 washers, int. dia. 2.5mm, 0.5mm thick.
1 Nylon/Polyamide clamp for 9.5mm cable.
1 bolt, M3x7.
1 spindle extension 6/4mm o.d./i.d, 22-29mm long.
1 Collar knob 31mm dia., with marker (OKW).
1 Collar knob, 31mm dia, w/o marker (OKW).
1 Cap for OKW knob, with marker.
1 Cap for OKW knob. w/o marker.
2 Wander plugs with side hole (Hirschmann).
Aluminium sheet, 1.5mm thick, unprocessed size 71x115mm.
1 BNC plug.

Suggested suppliers:
Conrad Electronic, Klaus-Conrad-Strasse 1, D-92240 Hirschau, Germany. Tel. + 49 180 531 2111, fax + 49 180 531 2110. Internet: www.conrad.de.
Bürklin, Schillerstr. 41, D-80836 München, Germany, Tel. + 49 89 558 75-0, fax + 49 89 558 75-421. Email info@buerklin.de. Internet: www.buerklin.de

tion may be useful at this point. This amplifier exhibits very low noise across its entire frequency range, and offers excellent large-signal behaviour considering its modest current consumption. This is achieved by operating the FET as a source follower passing a high and practically constant drain current: its operating resistance of 75 Ω exists in parallel with the base and emitter of the next transistor rather than with respect to ground. The BFR193 is an SMA bipolar RF transistor whose frequency response is 'linearised' by means of strong feedback ($R_5 \gg r_D$). In contrast with the FET, it is easily dimensioned to supply the necessary (but still quite low) voltage gain. Remember that the main purpose of the amplifier is to provide the best possible impedance match to the loop antenna, while ensuring that severe intermodulation owing to nearby multi-kilowatt transmitters (utility or broadcast) does not occur easily. High gains are not generally required or indeed desirable ahead of any SW receiver input!

Depending on the frequency range selected using rotary switch S1A-S1B (0.15-0.7 MHz, 0.5-1.7 MHz, 1.7-8.2 MHz or 7-30 MHz), different magnetic antennas are connected to the amplifier input. In the highest range, only the 1-turn loop is connected, while in the lowest range, the amplifier receives the voltage produced by two series-connected coils on a ferrite rod. A 700-pF (350+ 350) variable capacitor, C1-C2, enables the antenna circuit to be tuned across a frequency range with a high/low ratio of about 4.8. For the lower SW bands, a loop with 4 turns would appear to be the best choice. The solution adopted here is, however, more elegant, using a transformer (L1-L2) with a step-up ratio of 1:4.5. Interestingly, the combination of a 1-turn loop and the transformer yields roughly the same quality factor (Q) and output signal level as the classic 4-turn loop. In practice, the use of a single 1-turn loop for two SW ranges is simply convenient!

For medium-wave (MW) and long-wave (LW) reception, the traditional ferrite rod still offers good performance. Using a rod with a diameter of 10 mm and a length of 200 mm, made from 4B1 material (μ_i = 250, Philips Components) an effective permeability, μ_e, of about 115 is obtained, which is equal to an air-cored inductor having a surface area of about 90 cm^2, or a diameter of 10.7 cm. If the self-resonance frequency of the ferrite rod is below 2 MHz, the upper limit of the MW band (approx. 1.7 MHz) can not be reached without appreciable attenuation. That is why the MW/LW ferrite antenna is not wound using ordinary enamelled copper wire, but a Teflon-

4

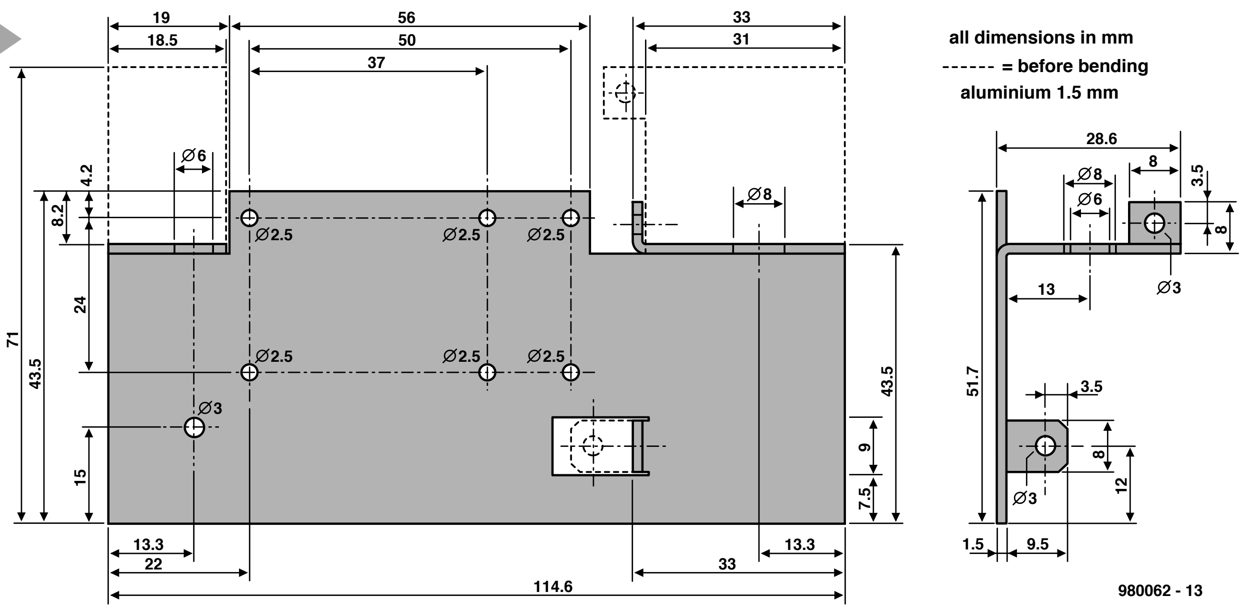


Figure 4. Drilling, cutting and bending details of the internal aluminium chassis.

coated alternative called Tefzel.

The amplifier's output signal appears across L6 at an impedance of about 50 Ω. As you can see, it is coupled out inductively, the amplifier's supply voltage being applied to the primary of the 1:1 output transformer (L5-L6). This is coupled to the amplifier using an arbitrary length of 50-Ω coax cable and a BNC or similar plug.

The value of R6 depends on the supply voltage used: use 220 Ω for 7.5-9 V, or 330 Ω if your supply (or receiver) delivers 10-15 V.

Coil winding, soldering & mechanical work

The construction of the Ω-2 active antenna involves a fair bit of drilling, filing, cutting and winding of inductors. We'll start with the latter.

Three transformers, L1-L2, L3-L4 and L5-L6, are wound using two-hole ('binocular') ferrite cores as illustrated in **Figures 2a and 2b**. L3-L4 and L5-L6 are wound using bifilar wire which is easily made by twisting together two lengths of wire until a pitch of 3 to 5 turns per cm is obtained. After winding, the wire ends have to be identified with the aid of a multimeter. Winding data and materials used are stated in the Components List.

The coils on the ferrite rod (L7-L8) are wound in 'compartments' of formers normally used for pot cores (**Figure 2c**). L7 has four compartments with 25 turns each of 0.3 mm dia. (30AWG) Teflon-coated copper wire. The smaller coil, L8, has a total of 36 turns of ordinary 0.6-mm copper lacquer wire divided equally over two compartments. Note that two compartments remain empty.

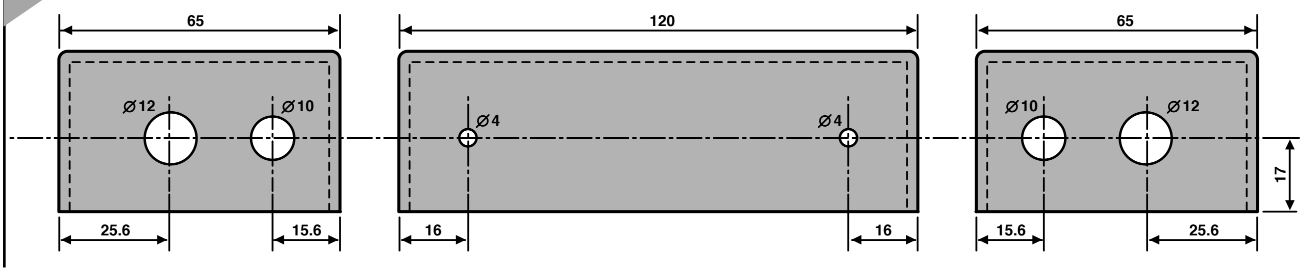
Having made these inductors you are ready to tackle the circuit board. The copper track layouts and component mounting plan of the double-sided PCB are given in **Figure 3**. This PCB is available ready-made from the Publishers. The amplifier proper is largely built from SMA (surface mount assembly) parts. To facilitate soldering by hand, the relevant copper spots are purposely made a little larger than usual for SMA components. To keep its cost within reason, **the PCB is not through-plated**, and a total of seven component wires, plus the wire ends of L3-L4, have to be soldered **at both sides of the board**.

Using aluminium sheet with a thickness of 1.5 mm, a chassis is cut, drilled and bent as illustrated in **Figure 4**. Six holes with a diameter of 2.5 mm allow one of two types of 'Hopt' variable (tuning) capacitor to be firmly secured. Similar tuning capacitors from other manufacturers may require different mountings. One of the Hopt types the author picked up at a rally has only two AM sections, the other, two AM sections and two FM sections. Both are equally suitable. The AM sections are connected in parallel to produce a maximum tuning capacitance of about 700 pF, to be connected between ground and the PCB terminal marked 'CVAR'. A large knob makes for precise tuning, hence two 0.5 mm thick washers are used to make sure the centre of the tuning capacitor spindle is exactly half-way the height of the enclosure. The drilling details for the plastic case itself are shown in **Figure 5**. Seven holes have to be drilled, including one to pass the output coax cable. One additional, larger, hole may be required for a pivot assembly, a turntable or ball-bearing that enables the antenna to be rotated.

The internal construction of the Omega-2 amplifier is further illustrated in **Figure 6**. The two wander sockets are cut to a total length of 14 mm. The

Figure 5. Drilling details for the plastic case.

5



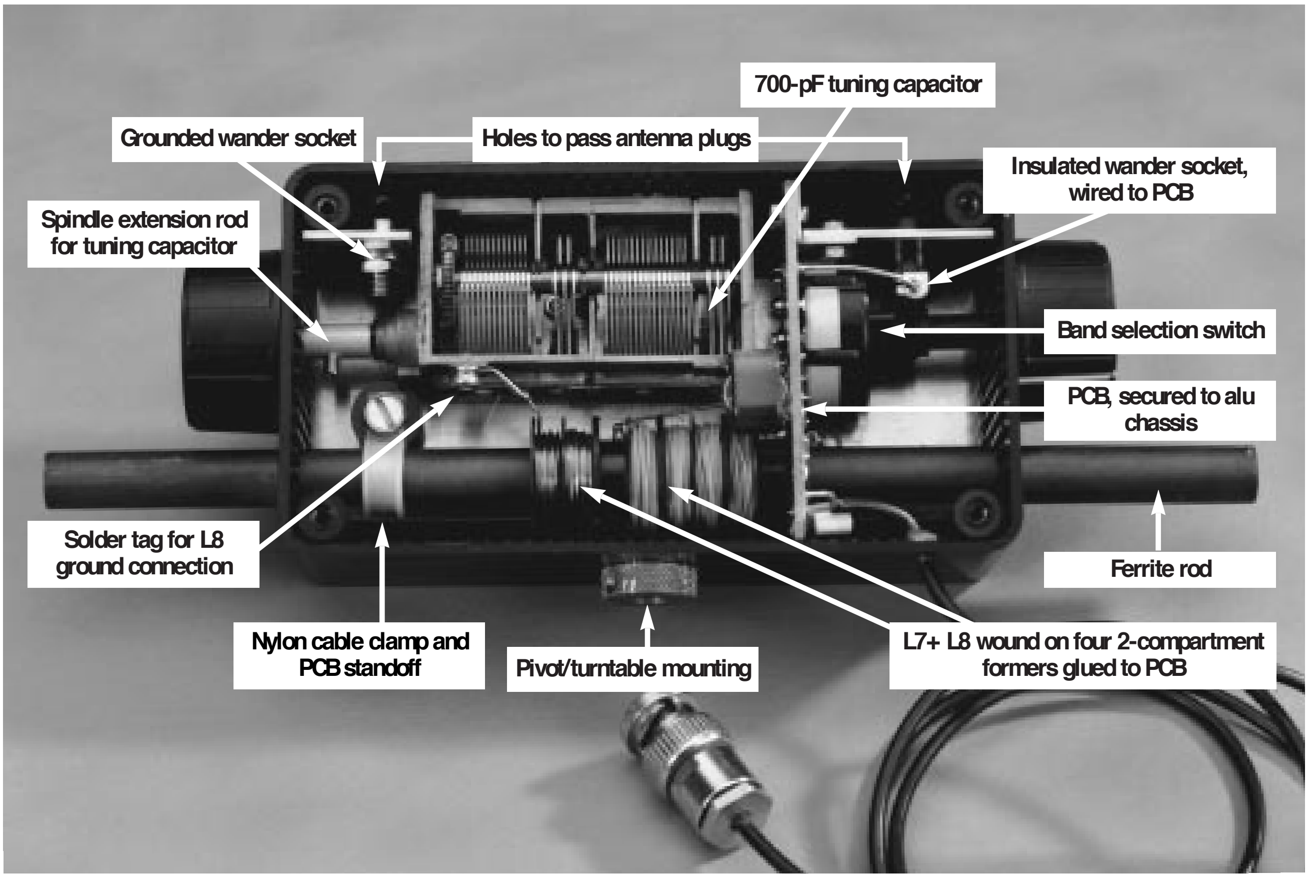


Figure 6. Internal view of the author's well-tried prototype of the Omega-2.

spindle length of the band selection switch is reduced by 13 mm. The insulated wander socket (to the right in the picture) is fitted with a solder tag for wiring to the PCB. In the suggested construction, there is no room for the M10 nut that comes with the rotary switch. Consequently, the locking ring is either omitted or secured in position '4' using two-component glue. The four 2-compartment formers (for pot cores) are first glued together, and then to the PCB. Two compartments remain empty. Later, the ferrite rod is passed through the formers and the holes in the case panels and the PCB, before it is secured with a nylon cable strap.

The loop antennas

The shortwave antenna for the Omega-2 is made by bending 4-mm dia. brass or copper tubing, or massive copper, using a bottle or similar round object as a 77-mm dia. bending aid. Before you start bending the tube, mark the locations of the corners at ±90 and ±300 mm. The final size of the antenna should be 201x261 mm measured from the tube centres, although a few millimetres tolerance is perfectly acceptable. The tube ends are cut off until they are 82 mm apart. Using an electric cooking plate or similar heating

Figure 7. Circuit diagram of the Omega-3 shortwave active antenna. To preserve the antenna's Q factor, the band selection switch should be a heavy-duty double-pole changeover type, preferably with silver-plated contacts. The suggested power supply circuit is inside the Sony ICF SW-100 receiver.

7

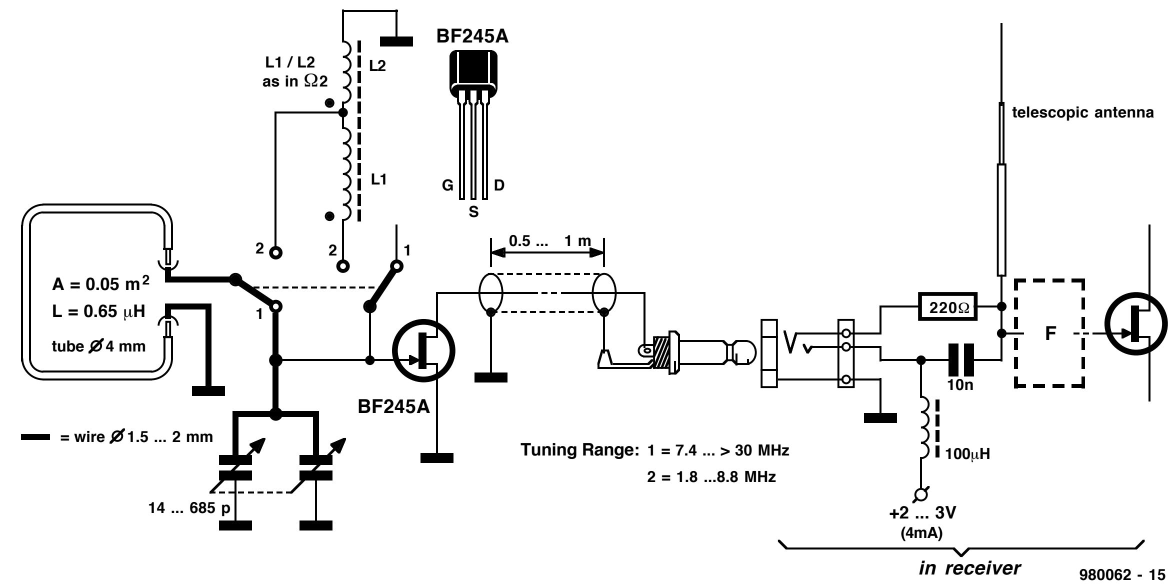


Figure 8. Omega-3 shortwave active magnetic antenna: easily stowed away in your holiday luggage, excellent SW reception guaranteed!

device the antenna and the wander plugs are preheated and then soldered.

An alternative to the ferrite rod is the 'classic' MW loop antenna consisting of 17 turns of 0.6-mm dia. enamelled copper wire wound on a wooden frame of dimensions 22x22x4 cm which is either home-made or obtained from a handicraft shop. The turns should be spaced by about 2 mm, and are best held in position by grooves cut in the four corners of the frame. This antenna will typically produce a signal level which is four times higher than that of the ferrite rod. Like the 1-turn loop for the two SW ranges, the MW window antenna is plugged into the Omega-2 amplifier box by means of two banana plugs. To use this excellent antenna, select the 7-30 MHz range. The finished MW loop is pictured in the introductory photograph, together with the Omega-2 amplifier. Its frequency coverage is 0.51-1.9 MHz.

W-3 ANTENNA FOR SW ONLY

Abroad, in a hotel with awful interference levels caused by airco systems and TV sets, or in a modern office, where computer noise thwarts any attempt at serious shortwave reception, you may expect little from your pocket-size shortwave receiver with its telescopic antenna, or even a wire antenna with a length of 5 m.

If your receiver has a socket for an external active antenna, you should not fail to experiment with very simple magnetic antennas based on FETs. As already mentioned, voltage gain is not required because the small receiver will be designed to handle small signals.

Figure 7 shows the circuit diagram of the Omega-3 active antenna. As you can see, it is simpler than the Omega-2, mainly because the LW and MW bands are not covered. For holiday use, however, the Omega-3 is the perfect choice!

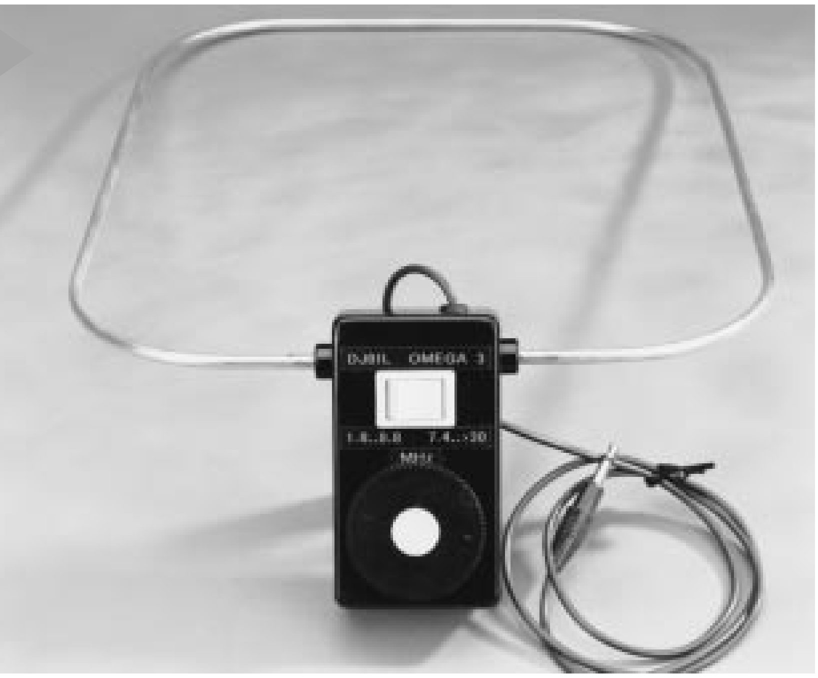
Offering a transconductance of about 0.4 mS the BF245 FET supplies a gain of about 0.8 times at a load impedance of 200 Ω presented by the Sony ICF-SW100 receiver. The internal FET amplifier has a fairly high and frequency-dependent input impedance to match the built-in telescopic antenna. When an external active antenna is connected, its mono jack plug connects the 220-Ω resistor to ground, causing a nearly constant load of 200-220 Ω to be presented to the active antenna output, while reducing the influence of the telescopic antenna. High-pass and VHF trap filters (block F) leave a usable bandwidth of 1.6 to 30 MHz. The CCITT weighted sensitivity of the author's ICF-SW100 is around 0.25 µV at the input jack, for (S+N)/N = 10 dB at 80% amplitude modulation.

Compared with the receiver's telescopic antenna, the Omega-3 guarantees a noticeable volume increase, not even mentioning much reduced background interference levels.

The few parts that make up the Omega-3 are connected 'in the air'. As shown in **Figure 8**, the antenna is plugged in at the sides of the case.

(980062-1)

8



References:

[1]. Wideband active rod antenna, *Elektor Electronics* May 1991.

[2]. RC high-pass filter for active antennas, *Elektor Electronics* February 1992.

More interesting articles on antenna design which appeared in *Elektor Electronics*:

Experimental quadriform ferrite T/R antenna, November 1991

The QTC Loop Antenna, June 1991.

An experimental all-waveband ferrite rod antenna, May 1990.

The miser's T/R Loop Antenna, November 1990.

A compact spiral T/R HF antenna, November 1992.

Mark-Two 80/40 QTC Loop Antenna, July/August 1992.

Wideband active telescopic antenna, July/August 1992.

External ferrite aerial units for SW/MW/SW radios, May 1993.

Small loop antennas for MW AM BCB, LF and VLF reception, June and July/August 1994.

Ultima Loopstick VLF Antenna, July/August 1998.

9

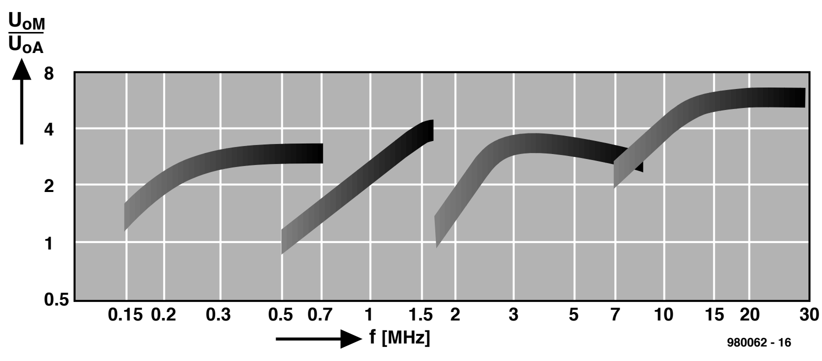


Figure 9. Output voltage (U_{OM}) of the Ω-2 active magnetic antenna installed in a living room, compared with an active rod antenna (U_{OA}) installed on the roof.

how does a digital loudspeaker system work?

Digital loudspeaker system Type DS4 from Visaton

The design of a digital loudspeaker system presents grave difficulties owing to the requirements for low quantization, low spurious noises and good directivity. The key to a good design lies in the digital signal processor, DSP. The electro-acoustic conversion remains traditional, of course, but a DSP unit is added to the digital audio chain in which a digital-to-analogue converter (DAC) precedes the normal amplifier and loudspeaker.

Design by Visaton

Over the past few years, digital signal processing has become more and more important. Compute-intensive filter operations are gradually being replaced by powerful digital signal processors—DSPs. Computing speeds have increased so much that it is now possible with a digital protocol to design crossover networks for active loudspeaker systems which can undertake the error correction for the entire signal chain. Such a network or, rather, controller, is at the heart of the active, digital, four-way loudspeaker system Type DS4 from Visaton (**Figure 1**).

The controller is a combination of a digital preamplifier, digital crossover filter, digital error correction network for the entire chain, and digital protection network. The electronic and acoustic

1

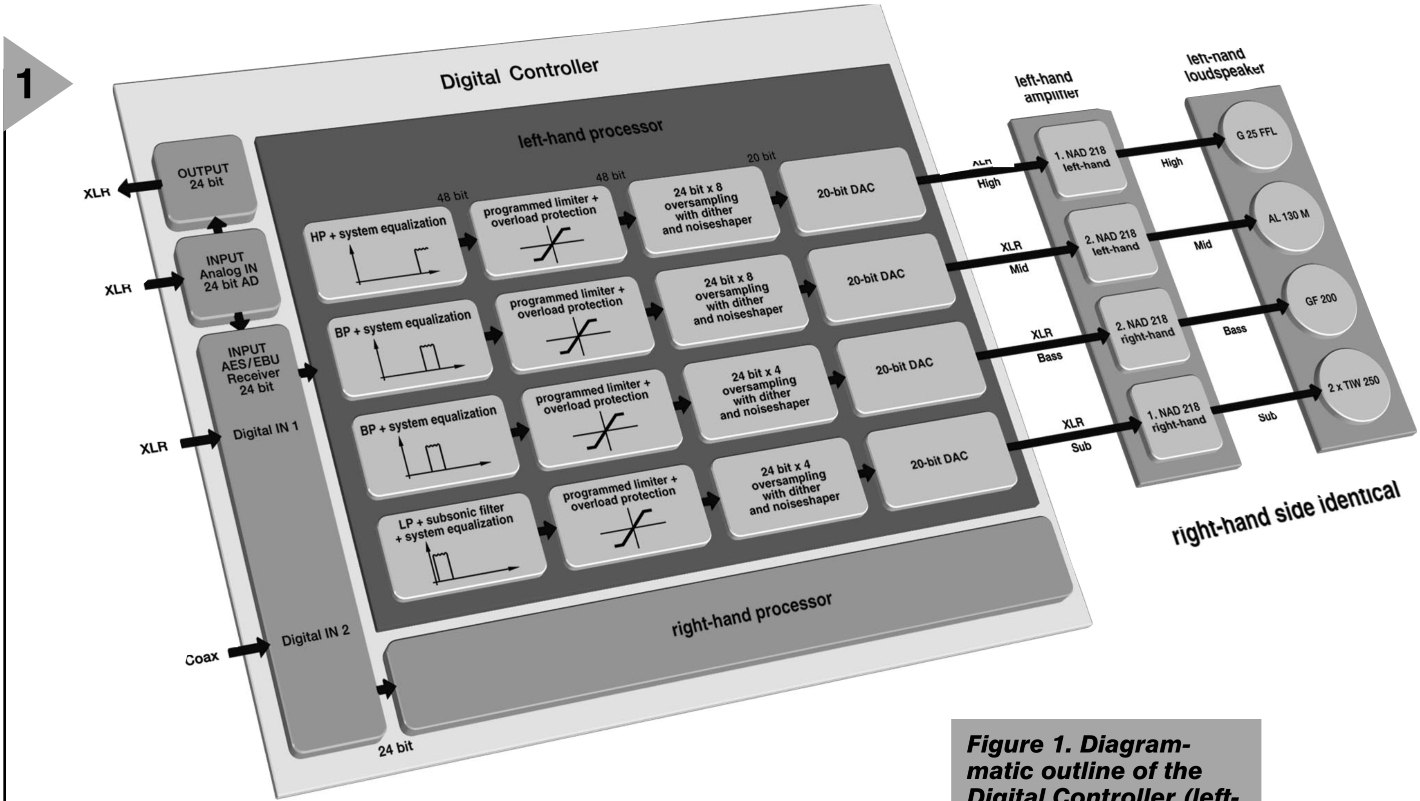
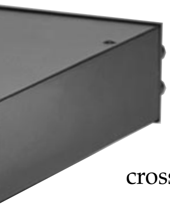


Figure 1. Diagrammatic outline of the Digital Controller (left-hand channel).



capability of the resulting operational unit stands comparison with the best analogue preamplifiers and active crossover networks.

CONTROLLER

The digital controller consists of two digital (1 coaxial, 1 optical) and one analogue (XLR) inputs. The analogue input signals are derived from a 24-bit analogue-to-digital converter—ADC. This data stream or that at the digital inputs (up to 24 bits wide) is fed to the internal signal processing circuits. The controller may be driven at sampling rates of 44.1 kHz or 48 kHz.

The converted signals at the analogue input can be passed to the digital output with a word length of 24 bits. This function (digital insert) is needed for calibration purposes.

FILTERING

The signals in the two stereo channels are processed discretely by two Motorola DSPs: a Type 56009 and a Type 56007. To obtain a bounded impulse response, all filtering is carried out with finite impulse* response (FIR) filters (see **Figure 2**). This is the only type of filter that can determine amplitude and phase response simultaneously.

Operation of an FIR filter may be compared with that of a fast Fourier transform (FFT), since this describes a method for the rapid computation of a digital filter. A drawback of this type of filter is its length, which requires great computer power and results in a (relatively) long signal delay. To prevent overshoot of the leading and trailing edges caused by truncating the number of filter terms (only a filter of infinite length is error-free), special window functions (see box) are built into the filter function.

To make the best possible use of the

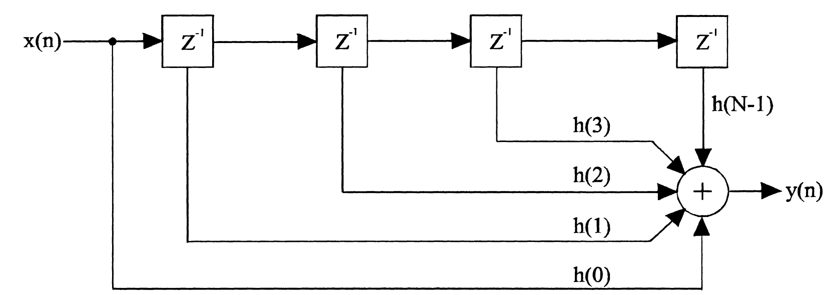
Window functions

The frequency characteristic of a digital filter is a periodic function related to the sampling period, *T*, which can be expanded as a Fourier series. The coefficients of this series represents the impulse response of the filter. When, in a practical case, this infinite series has to be truncated to *n* terms, the sharp cut-off leads to overshoots and oscillations in the characteristic. This is know as the *Gibbs phenomenon* and the effect can be minimized by multiplying the impulse response by a weighting factor described as a *window function w(n)*. This function can easily be incorporated in the design of an FIR. Some of the common window functions have the mathematical form listed below.

Rectangular	$w(n) = 1$	$0 \le n \le (N-1)$
Triangular	$w(n) = 2n/(N-1)$	$0 \le n \le (N-1)/2$
Bartlett	$w(n) = 2-[(2n)/(N-1)]$	$(N-1)/2 \le n \le (N-1)$
Hanning	$w(n) = 0.5-0.5\cos[(2\pi n)/(N-1)]$	$0 \le n \le (N-1)$
Hamming	$w(n) = 0.54-0.46\cos[(2\pi n)/(N-1)]$	$0 \le n \le (N-1)$

Figure 2. Basic design of a finite impulse response (FIR) filter.

2



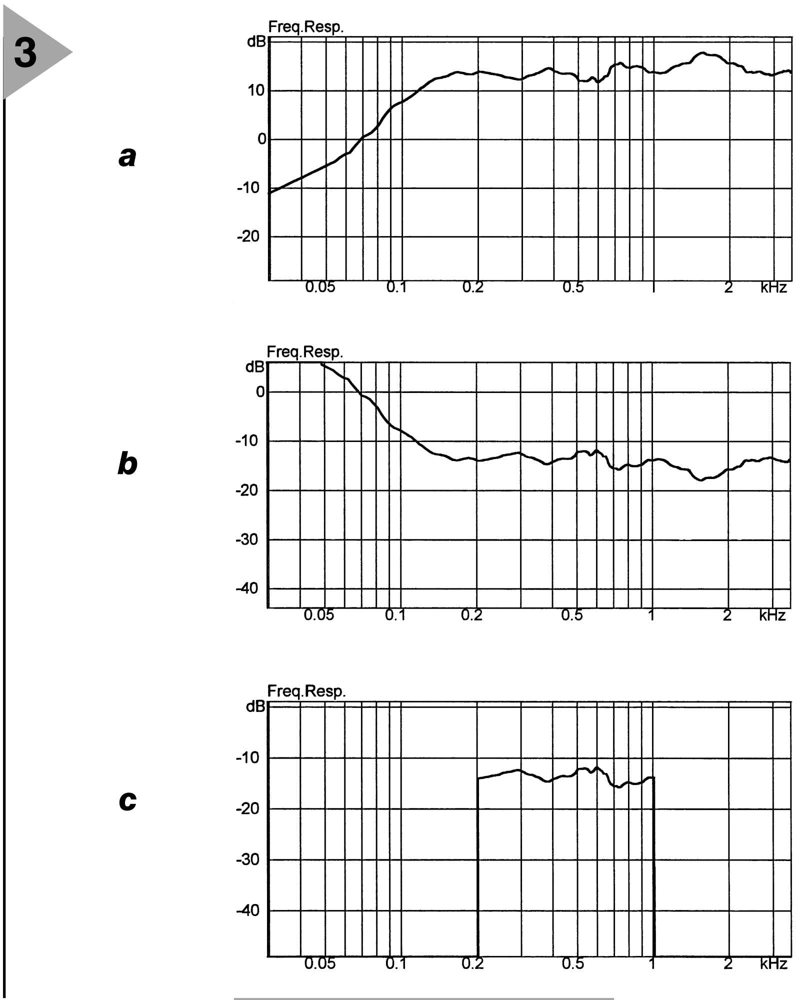


Figure 3. Steps in the signal paths: (a) frequency response; (b) inverted frequency response; (c) band-pass window of the inverted frequency response.

computer power, the frequency domain of each channel is divided into four bands: SUB, BASS, MID and HIGH. Four-times downsampling is used for the MID band, and ×16 for the BASS and SUB bands. This arrangement conforms to subsampling which lowers the upper frequency. In the MID band, the upper frequency is 4 kHz, and in the BASS and SUB bands, 1 kHz. In this way, the requisite computing speed is reduced by factors of about 4 and 16 respectively. This makes it possible to compute 8000 input values for one output value in the SUB band, so that correction of the transfer function is possible even at the lowest frequency.

EQUALIZATION

The system is equalized by evaluating each of the bands once over the entire signal path. This requires special measuring and equalizing software that enables a frequency response as that in **Figure 3a** to be obtained. As a first step in the process, all eight transfer functions are inverted, both as regards amplitude and phase (**Figure 3b**).

When a loudspeaker is driven by its own, complex-inverted transfer function, the theoretical result is error-free transfer. However, as already mentioned, in practice there is always a delay which depends on the quality of equalization.

Of course, high-quality equalization over the frequency range makes sense only if efficient loudspeakers are used. If this were not so, the error correction would need too much amplifying power which the loudspeaker would not be able to handle or the resulting sound pressure delivered by it would be too small.

So as to limit the number of errors resulting from rounding-off (unavoidable with the large number of computing operations), processing is carried out with long internal words. The word length between the functions shown in Figure 1 is 48 bits, but that used internally by the processor is even greater. At the next processing step, the resulting, complex-inverted transfer function is expanded into a filter function (for instance, band-pass – see **Figure 3c**). This process enables phase-locked filters with a skirt steepness of up to 300 dB per octave to be designed.

The bandpass response (see **Figure 4**) meets the demands of the filters needed for equalization, although each band has its own result. The digital output of these filters describes the signal needed to drive the relevant loudspeaker.

MORE FACILITIES

Digital signal processing offers more possibilities than described so far. For instance, from the specification of the relevant components, such as the amplifier or loudspeaker, it is possible to find statements in the digital data stream pertinent to the real load. This is, however, only so if none but linear errors occur in the loudspeaker, amplifier and other components in the system. These may be recognized by the fact that the percentage error remains the same when the signal level is varied. Linear errors are ascertained and corrected during calibration.

Errors caused, for instance, by partial oscillations or too small a maximum linear deflection of the loudspeaker cone are non-linear errors. When the signal level is raised, the percentage of these errors increases. Such errors cannot be corrected by the digital controller. It is, of course, possible to keep them to an absolute minimum by the use of high-quality components. If this is the case, as for instance in the DS4, no active control is used (or needed) in the bass band. Such control would result in system feedback, causing an unbounded impulse response, which is, of course, incompatible with the basic design of an error-free loudspeaker system with finite (bounded) impulse response.

LIMITING VALUES

Provided that the components following the digital controller operate linearly, it is possible to correct all linear errors in the digital data stream. The limiting values of the individual components that program the controller permit an early warning when operation of the system goes outside the linear range, for instance, when one of the components is overloaded. The limiter functions in the program then come into operation.

Limiter functions provide protection for the various components by interrupting the data stream when limiting values are reached. This is not done by a power-off, but by a specified limitation of the output signal of the digital controller. Owing to this limitation, signal components that lie above the limiting values will be distorted but will not cause any damage. If the distortion factor is accepted at peak levels, a loudspeaker reproducing music at mid-frequencies can be operated at higher volume levels. To ensure distortion-free reproduction, the limiter function represents the upper thresh-

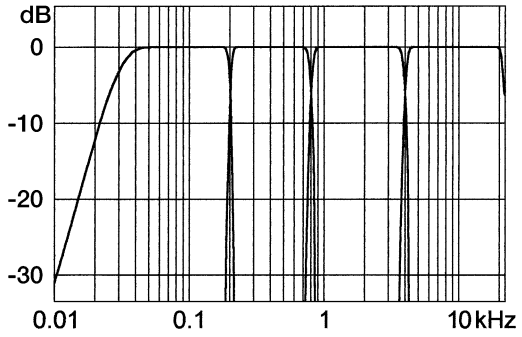


Figure 4. Bandpass characteristic of the DS4 system.

old.

The digital controller of the DS4 system provides three different limiter functions:

- a peak limiter that reacts to peak impulses;
- a thermal limiter, which reacts to thermal loads on the loudspeaker via temperature sensors on the magnet and voice coil;
- an overshoot limiter, which enables better utilization of the power supply of the output amplifier since the short-term pulse power output is normally higher than the continuous power output.

BACK TO ANALOGUE

The final step in the controller process is the reconversion of the digital signal into an analogue one. In this, the word length is reduced to 24 bits, while the SUB/BASS band is computed by real 24-bit ×4 oversampling, and the MID/HIGH band by real 24-bit ×8 oversampling. Oversampling should be seen as an interpolation at equal increases of the sampling rate. This results in a large number of intermediate values which enable much higher quality digital-to-analogue conversion.

The digital data stream is also output in 48-bit words and applied to the dither† and noise shaper. In the dither, a digital noise signal is superimposed on the data stream, so that the rectangular shape of the signal that ensues when low level signals are sampled is resolved.

The noise shaper following the dither stage is a high-pass section that acts only on the superimposed noise signal and shifts the noise floor to an irrelevant high frequency range. At the same time, the 48-bit signal is converted into 20-bit words needed for the digital-to-analogue conversion. This conversion is performed in each band by a 20-bit DAC from Burr-Brown.

The resulting analogue signal is applied to the single output amplifier via balanced XLR links. These links are highly immune to noise. An amplifier, whose output is linked directly to the appropriate driver in the loudspeaker, is needed for each band.

Figure 6. Amplitude response measured along the axis (a), and measured circumferentially (b).

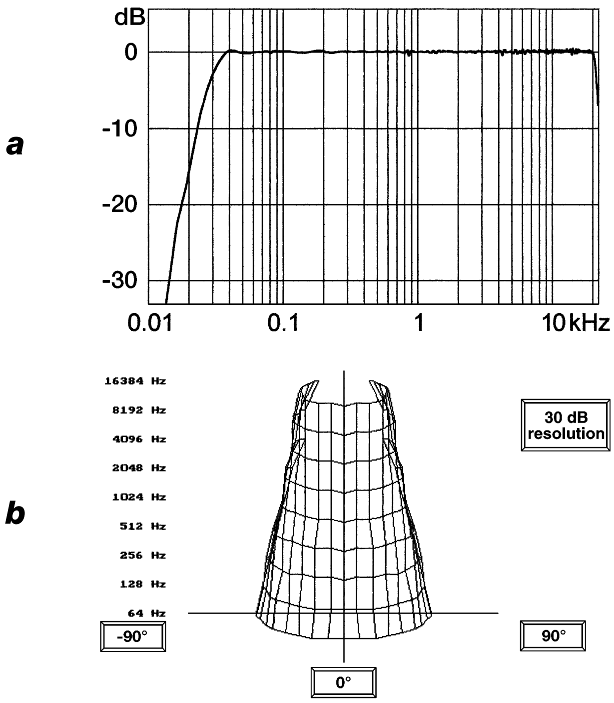


Figure 5. The loudspeaker used in the DS4 system.

LOUDSPEAKER CONSTRUCTION

The radiation pattern of a loudspeaker affects the energy mix in the listening room. This means that loudspeakers with different radiation patterns, even when they have the same transfer function at 0°, produce differently coloured sound in a room. The shape of the DS4 enclosure (**Figure 5**) produces sound focusing that is proportional to the frequency. This is considered the most favourable method by the AES (Audio Engineering Society).

The signal chain is corrected over the entire audio range as regards frequency response, phase response (constant group transit time), and decay time with the aid of a digital controller. With skirt steepnesses up to 300 dB per octave, crossover ranges are virtually non-existent, so that the acoustic drawbacks of traditional multi-way loudspeakers are eliminated.

7

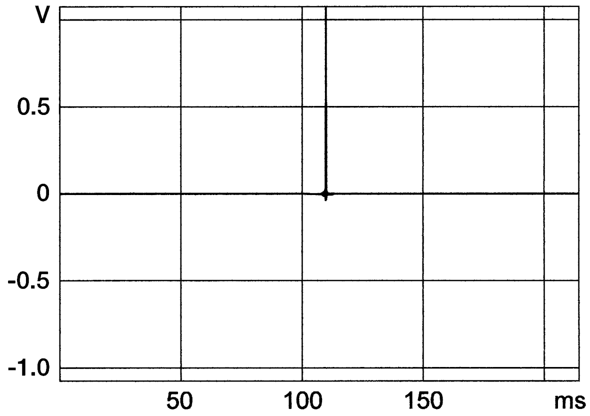
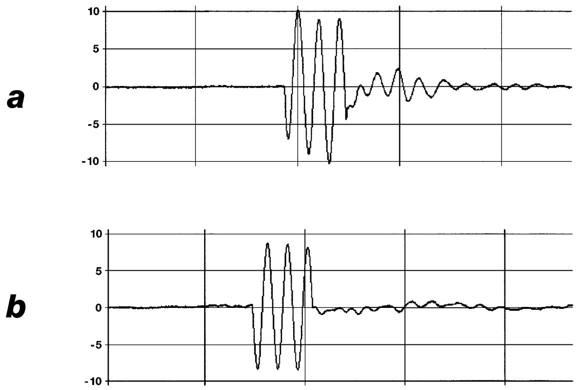


Figure 7. Impulse response of the DS4 measured with a 50 µs long impulse which causes a group delay of 110 ms.

Figure 8. Transient response of a 500 Hz tone burst in (a) an analogue system, and (b) the DS4 system.

8



For an optimum radiation characteristic and maximum sound pressure, the DS4 is designed as a 4-way system. For the very low frequencies, two 25 cm Type TIW250 drivers are used in a d'Appolito arrangement. This ensures even sound distribution in the room and correct positioning of the bass sources up to the mid/high frequency range. The 122- litre bass reflex system has a very large aperture to prevent flow noise.

For the bass frequencies, a 20 cm Type GF200 driver is used, which has a fibreglass cone and rear-vented spider.

The mid-range unit is a 13 cm Type AL130M driver, which has a carbon-coated aluminium diaphragm, rear-vented spider, and an impedance control ring.

The cone drivers have a kapton (high temperature plastic) motor (voice) coil carrier and ventilated pole pieces.

Treble frequencies are reproduced by a 25 mm ferrofluid-cooled textile dome unit Type G25FFL, which uses a spherical horn specially developed for this application.

The DS4 system was tested in an anechoic room, during which the controller 'gets acquainted' with all errors, which are later corrected in real time. The controller is delivered with two correction variants and can be fully adapted to the listening room by a sound engineer.

Each loudspeaker in the DS4 system requires four amplifiers, for instance, two stereo output units Type NAD218. The output in the SUB band is 400 watts into 4 Ω, and that in the other three bands, 250 W into 8 Ω.

Figures 6–9 show some acoustically measured characteristics that represent the results of the digitally corrected signal chain in the DS4.

Figure 6. The amplitude vs frequency response, measured along the axis of the tweeter (typical listening position) at a distance of 3 metres from the unit, shows that the –3 dB range extends from 30 Hz to 22 kHz. The residual ripple is within ±0.5 dB.

Figure 7. The impulse response curve, measured with an impulse width of 50 μs, is almost ideal, which points to an error-free frequency and phase response. Note the previously mentioned relatively large group delay of 110 ms, which, fortunately, in stereophonic music reproduction cannot be discerned.

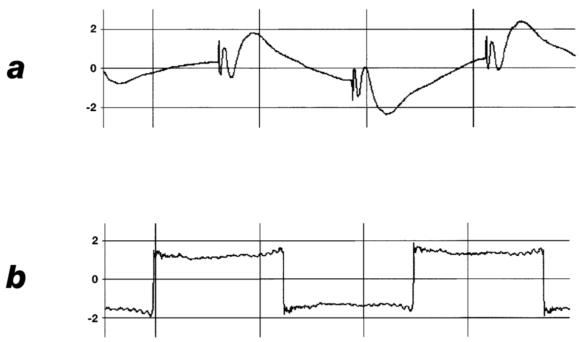
Figure 8. The correction in the transient response of the equalized DS4 system compared with that of an analogue system when a toneburst of 500 Hz is applied is clearly recognizable.

Figure 9. A loudspeaker can acoustically reproduce a square-wave signal only if the phase response and amplitude response are corrected simultaneously. The ideal way of doing so is by means of an FIR filter.

[980032]

Figure 9. Transfer characteristic of a 100 Hz square-wave signal in (a) an analogue system, and (b) the DS4 system.

9



* The name 'impulse' is used since the samples, that is, instantaneous values of the varying analogue signal, are regarded as impulses.

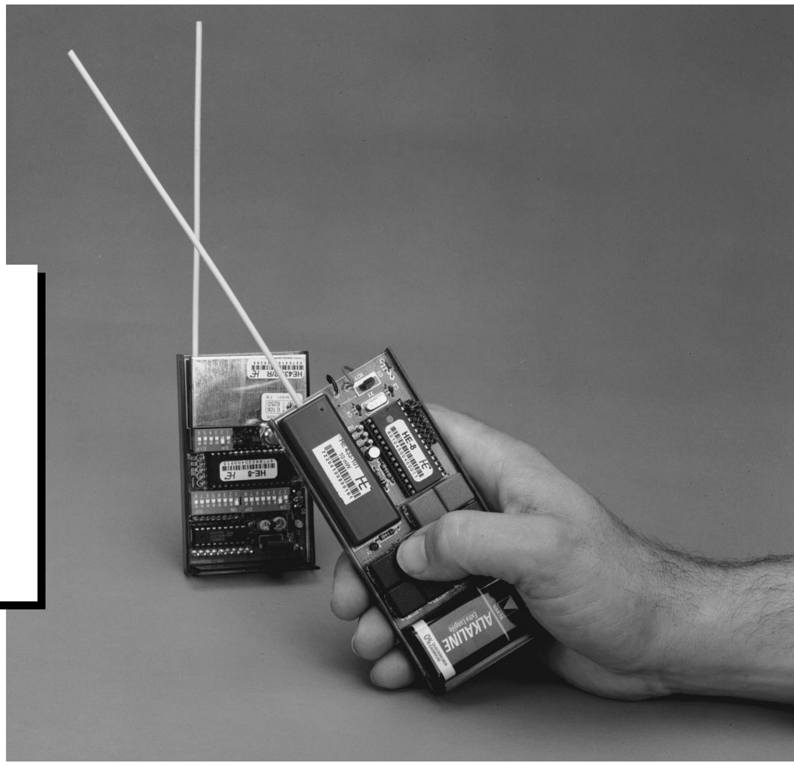
† Dither is low-level noise added to the signal input to randomize encoding errors at the level of the LSB. Dither effectively eliminates quantizing errors and acts to extend a system's dynamic range to well below its normal floor.

After this article had been prepared, it was learnt that the world's first digital loudspeaker has been developed by Cambridge-based research group 1…Limited. This consists of a flat panel matrix of small piezoelectric transducers, each of which is driven directly by digital signals. More details of the design will be published in a forthcoming issue of ***Elektor Electronics****.*
[Editor]

418/433 MHz control system

8 switching channels, 6 modes

Various electronics mail order outlets are currently advertising simple and relatively cheap wireless control system for use in and around the house. Although these systems are type-approved[1], that is no warrant whatsoever for sufficient range and reliability. The 433/418 MHz wireless control system discussed in this article does not aim to compete with these low-cost systems. Instead, it offers high-quality technology for a large number of applications, with special emphasis on reliability, security and connectivity.



Main Specifications

- *High-quality licence-exempt[1] transmitter and receiver modules*
- *Transmitter power 1 mW or 10 mW.*
- *8 universal control outputs with protection diodes.*
- *6 different receiver modes.*
- *Up to 256 transmitter idents.*
- *High transmission security*
- *Multiple transmitters with one receiver*
- *Low current consumption*

Based on a
Heiland Application Note

1. Readers should note that wireless signalling using short-range devices (SRDs) and certain allocated frequencies in the 70-cm band is subject to country-specific regulations. In the UK, Regulation no. MPT1340 applies, the full text of which is available from the DTI. MPT1340 specifies that the band section identified as '433 MHz' is for vehicle keys only. All other telecommand, telemetry and alarm systems should use a band section around 418 MHz.
This article is based on SRDs which are type-approved in Germany. Where '433 MHz' is mentioned in relation to remote control, UK readers should read '418 MHz ' (also for type numbers). When constructing the project described here, all readers should make sure the equipment complies with the SRD regulations that apply in their country.

Building your own transmitter for these frequencies is only possible (1) if you are a licensed radio amateur, and (2) you comply with radio amateur regulations specified for the 70-cm band (430-440 MHz). The alternative is to use a type-approved, licence-exempt SRD module as supplied by a number of manufacturers, including RadioTech and Germany-based Heiland Electronics. The article '418/433 MHz short-range communication' in *Elektor Electronics* May 1998 contains much useful information on 70-cm SRDs. These type-approved modules not only ensure that no undue interference is caused to other services sharing the 70-cm band, but also contribute considerably to the repeatability and reliability of a project for home construction.

TRANSMITTER

The circuit diagram of the handheld transmitter (**Figure 1**) remains quite simple thanks to the use of a ready-made module. The module type HE433-1/T (or optionally the HE433-10T) is a frequency-modulated transmitter operating on 433.92 MHz. An SAW (surface-acoustic wave) resonator is used to stabilize the transmitter frequency. Modulation with a 5-V digital signal causes a frequency deviation of ±20 kHz. The highest data rate is limited to 10 kbit/s to prevent an excessive output bandwidth.

The 'standard' module type HE433-1/T used here has an internal antenna in the form of a copper track on the PCB. Transmitter output power is rated at 1 mW. The alternative type HE433-10/T supplies 10 mW and has a quarter-wave (17 cm) wire antenna. The design technology of this module was discussed in some detail in the above-mentioned article.

The modulation input of the RF module is connected to the output of the digital receiver/transmitter chip type HE8 (IC2), which supplies the data to be transmitted. This chip is a custom-designed microcontroller that can be used as an encoder as well as a decoder for serial data transmission systems. At a clock rate of 8 MHz, produced by a quartz crystal, the HE8 supplies a data rate of 9600 bits/s. The eight address inputs, ADDR0-ADDR7 (pin 20-27) allow up to 256 addresses to be set up. Here, the address selection is realized by means of DIP switches or jumpers. Each of these pulls an input to ground. Normally, a single jumper is sufficient to select one of eight addresses. As a matter of course, the address set on the transmitter has to match that on the receiver. Push-button S11 (shift) is provided to enable you to switch from one receiver to another in a simple way. Because the push-button replaces the jumper in position S1-1, the latter may, of course,

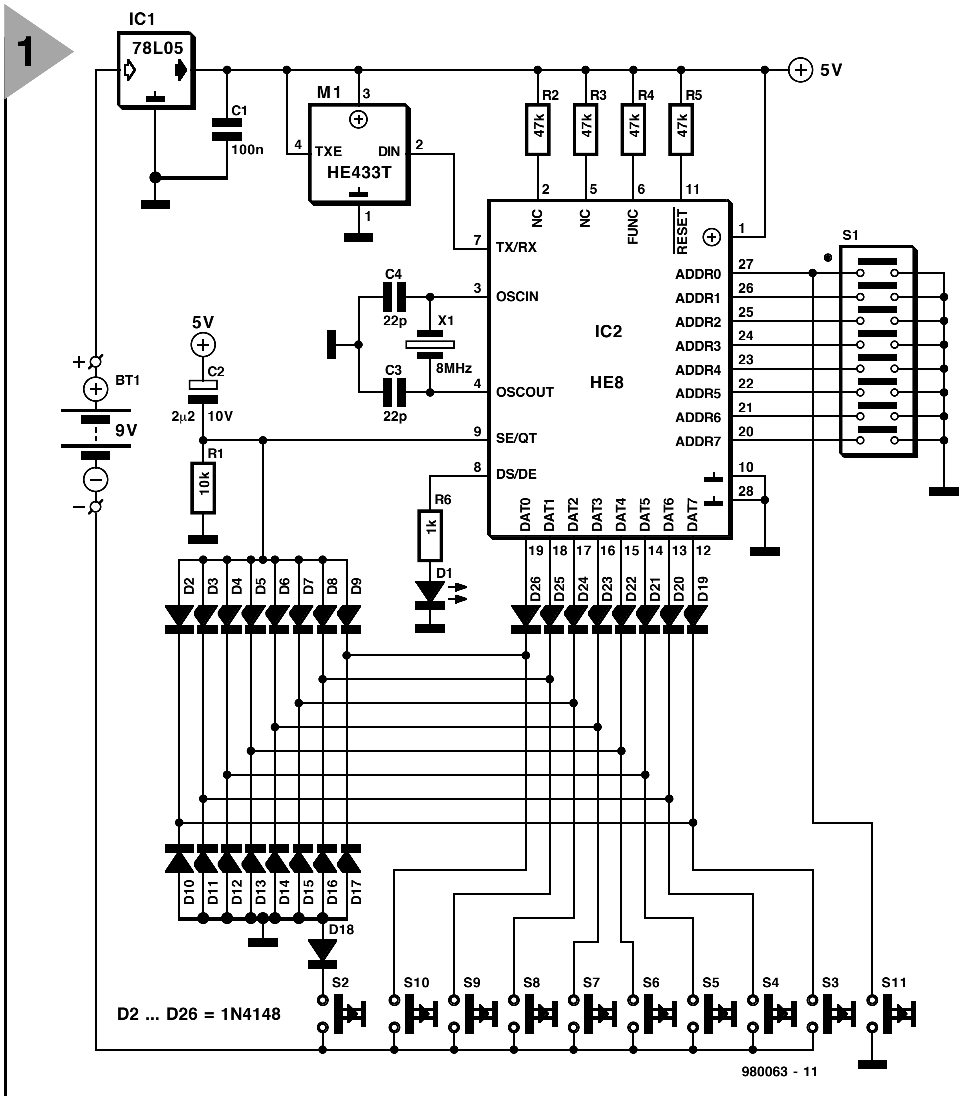


Figure 1. Circuit diagram of the transmitter, which consists basically of a 433-MHz SRD transmitter module and a special encoder IC.

not be installed.

Like the address bits, the data inputs DAT0-DAT7 (pins 12-19) are switched to ground to apply a databit.

While transmitting, the control input SE/QT (pin 9) allows one of two modes to be selected. When this input is tied to ground, the appearance of at least one databit at the input port (DA0-DAT7) triggers a transmission. Any transmission consists of at least five times the full data protocol packet, even when the databit is applied briefly. In all other cases, the transmission simply lasts as long as data are available.

In addition to this 'multiple send' feature, the security of the radio link is further guaranteed by parity checking and checksum appending.

The other transmission mode is selected when the SE/QT input is not at ground potential when the HE8 is switched on. In that case, databits applied to the input port are not copied and transmitted before the control input is pulled to ground. A fivefold transmission also takes place when a short 'low' pulse is applied. Else, the transmission simply takes as long as pin 9 is held 'low'.

The first mode is suitable for information 'bursts' as typically transmitted by hand-held transmitters (vehicle keys). By contrast, the second mode allows databytes to be sent, as for instance, in a system for wireless transmission of measurement data. For our hand-held transmitter, both modes are employed, as will be seen further on.

The DS/DE output (pin 8) remains logic high as long as data is being transmitted, and so allows a functional check on the IC to be implemented.

The circuit of the transmitter is designed such that the supply voltage is only applied when the 'transmit' button is pressed. This results in very short 'on' periods, so that the overall current consumption is modest in spite of the relatively high current demand while transmitting. When the 10-mW transmitter is used, the current consumption is 50 mA. The 1-mW module

2

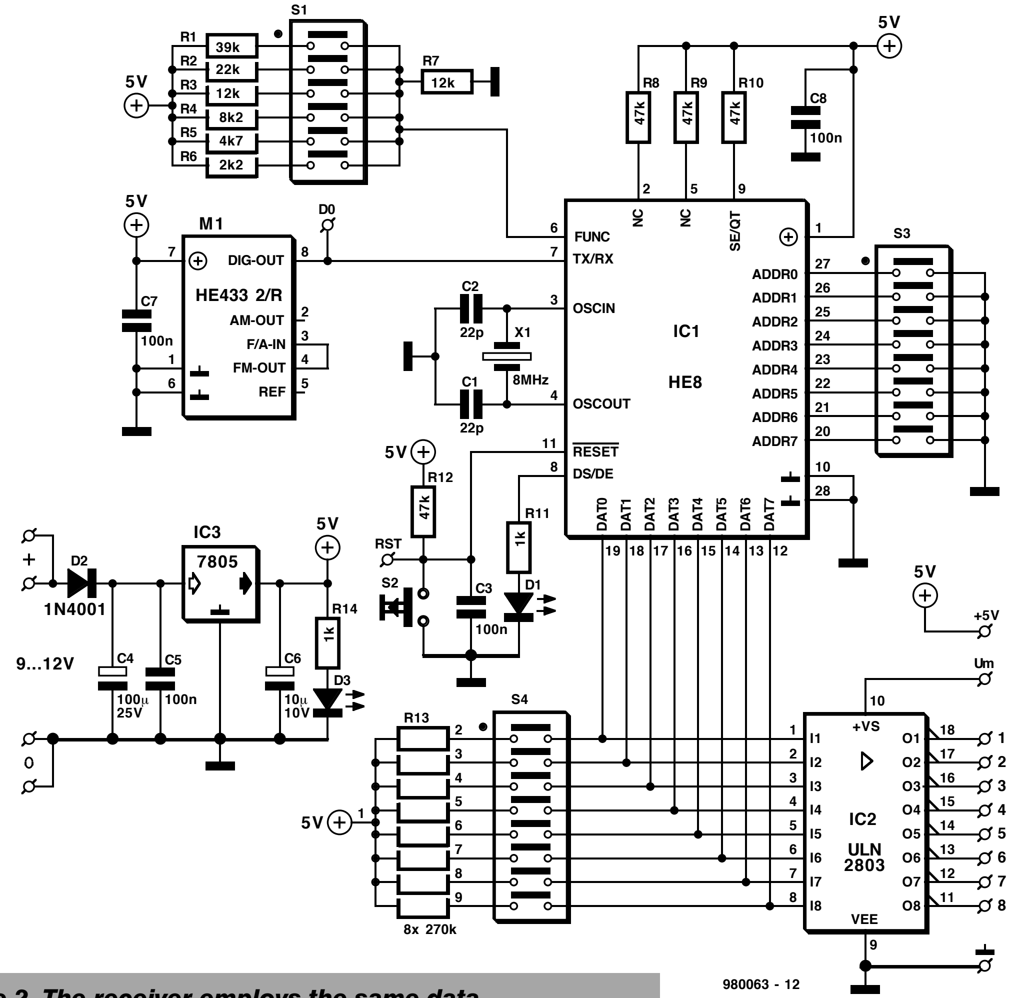


Figure 2. The receiver employs the same data encoder/decoder IC as the transmitter. The behaviour of the eight outputs is determined by six different modes selected by DIP switches in array S1.

is not much more economical at about 30 mA. LED D1 provides a useful 'transmitter on' indication because it lights whenever a button is pressed.

The positive battery terminal has a fixed connection to the input of the 5-volt regulator. The negative terminal, however, is taken to the transmitter push-buttons, so that the current flow is only established when one of the switches is pressed. The push-buttons are decoupled by diodes D10-D18 which ensure that any one of the actuated key can pull the supply voltage to ground, although only the one associated input of IC2 goes to ground, i.e., the input assigned to that particular switch.

An exception is formed by push-button S2, which can only be connected to ground via a diode, but is not connected to an IC input via a second diode. By contrast, all other switches have a third diode that connects them to the SE/QT input of the IC. The purpose of this arrangement is to enable S2 to act as the 'clear' push-button. The push-buttons connected to the encoder inputs are only capable of actuating one of the control channels when the contact pulls the relevant IC input to ground at the same time as the SE/QT input. That is achieved with the aid of diodes D2-D9, with a special function reserved for S2 because when pressed this switch connects the battery to ground via D19, causing the circuit to be switched on. Initially, however, pin 9 is not logic low, because C2 has to be charged first, just as with a power-up reset network for a microcontroller. The delay so obtained results in S2 being able to clear the switching functions stored in the receiver. Using S2, all actuated receiver outputs may be reset in one go provided the receiver is in the so-called 'overwrite' mode. Any one of modes the receiver is capable of working in may be selected by means of DIP switches.

Receiver

The receiver module used for this project (type HE433 2/R) contains a superheterodyne receiver with an intermediate frequency of 10.7 MHz. The local oscillator is frequency-stabilized by a SAW resonator. The datasheet states a bandwidth of 280 kHz for this module, and a sensitivity of 2.2 μV. The receiver is capable of demodulating AM as well as FM signals. To select FM demodulation, the FM/AM-IN input (pin 3) of the module is tied to the FM output (pin 4). This is also the case in the circuit diagram of the receiver shown in **Figure 2**. In case AM demodulation is required, the AM output (pin 2) is simply connected to pin 3. In FM mode, the AM output acts as a signal strength meter output supplying a direct voltage between 0 and 0.75 V which is logarithmically proportional to the RF input level.

FM-OUT and AM-OUT are analogue demodulator outputs. The FM output is internally connected to a comparator stage that converts received pulses into a TTL-compatible output signal available at the data output (DIG-OUT, pin 8). The comparator reference voltage is also available at the REF output (pin 2). It has a level of 2.4 V ±100 mV, and can be loaded with up to 1 mA.

In the circuit diagram of the receiver, the digital output, DIG-OUT, is directly connected to the TX/RX input of the decoder (IC1), which receives the data signal.

The configuration of the HE8 with its external quartz oscillator and DIP switch array is the same as in the transmitter. New, however, is the decoder mode selection by means of an analogue voltage at pin 6 (FUNC). This voltage is set up by a voltage divider whose configuration is determined by the switches in array S1. An overview of the individual modes that may be selected using the DIP switches may be found in the text inset. DIP switch S4 is only effective if mode 3 has been selected with S1-3. Mode 3 allows the behaviour (bistable or monostable) of the individual control outputs to be controlled. If, for example, contact S4-1 is closed (ON), then control output 1 is in bistable mode, while all others are in monostable mode (i.e., only logic as long as the push-button on the transmitter is held depressed).

LED D1 acts as a simple reception indicator. If flashes whenever a signal is received from a transmitter set to the same address as the receiver.

Changes made in the setting of the DIP switches are only effective after push-button S2 is pressed.

The eight switching channels of the receiver have relatively powerful outputs thanks to the use of an output buffer type ULN2803 (IC2). The ULN2803 is an inverting buffer/driver with open-collector outputs capable of driving relays or d.c. motors directly because the internal output transistors are protected by integrated surge suppression diodes, and they are capable of switching voltages up to 50 V to ground, at currents of up to 0.5 A per driver. The total driver output current supplied at one time may not exceed 1 A, however, so that a maximum load of 100 mA per output would appear to be a safe choice. The connection Um (max. voltage) is then connected to the positive supply rail (max. 50 V) used by the load (which is switched to ground).

When 5-V relays are used, they are connected to the 5-V line, together with the Um terminal.

If you do not want to the relays to load the voltage regulator, IC3, then the relay coils may be operated from an unregulated voltage which will be between 10 and 12 V.

CONSTRUCTION AND TEST

If the ready-made PCB is used, it has to be cut in two to separate the transmitter (**Figure 3**) and receiver sections (**Figure 4**). The compact size and high track density of these boards require care and precision when you fit and solder the components. In particular, be sure to fit all wire links and observe the polarity of the diodes and (mostly vertically mounted) electrolytic capacitors.

Very important: the transmitter only works properly when the push-buttons stated in the parts list are used, and they are fitted the right way around! This is because the PCB design is based on the fact that these keys have two pins that are always interconnected. If you want to use different push-buttons, you have to make sure the relevant connections

COMPONENTS LIST

Transmitter

Resistors:
R1 = 10kΩ
R2-R5 = 47kΩ
R6 = 1kΩ

Capacitors:
C1 = 100nF ceramic
C2 = 2µF2 10V radial
C3,C4 = 22pF ceramic

Semiconductors:
D1 = LED, red, high efficiency
D2-D6 = 1N4148
IC1 = 78L05
IC2 = HE8 (Heiland)

Miscellaneous:
BT1 = 9V battery with clip-on wires
X1 = 8MHz quartz crystal
S1 = 8-way jumper or 8-way DIP switch (narrow)
S2-S11 = push-button, PCB mount, type D6-R-RD with cap type D6Q-RD-CAP (ITT/Schadow)
M1 = HE433T-1/T or HE433-10/T (Heiland Electronics, see text)
Case: Heddic type 222 (Heiland Electronics)
PCB, order code 980063-1 (see Readers Services page)

3

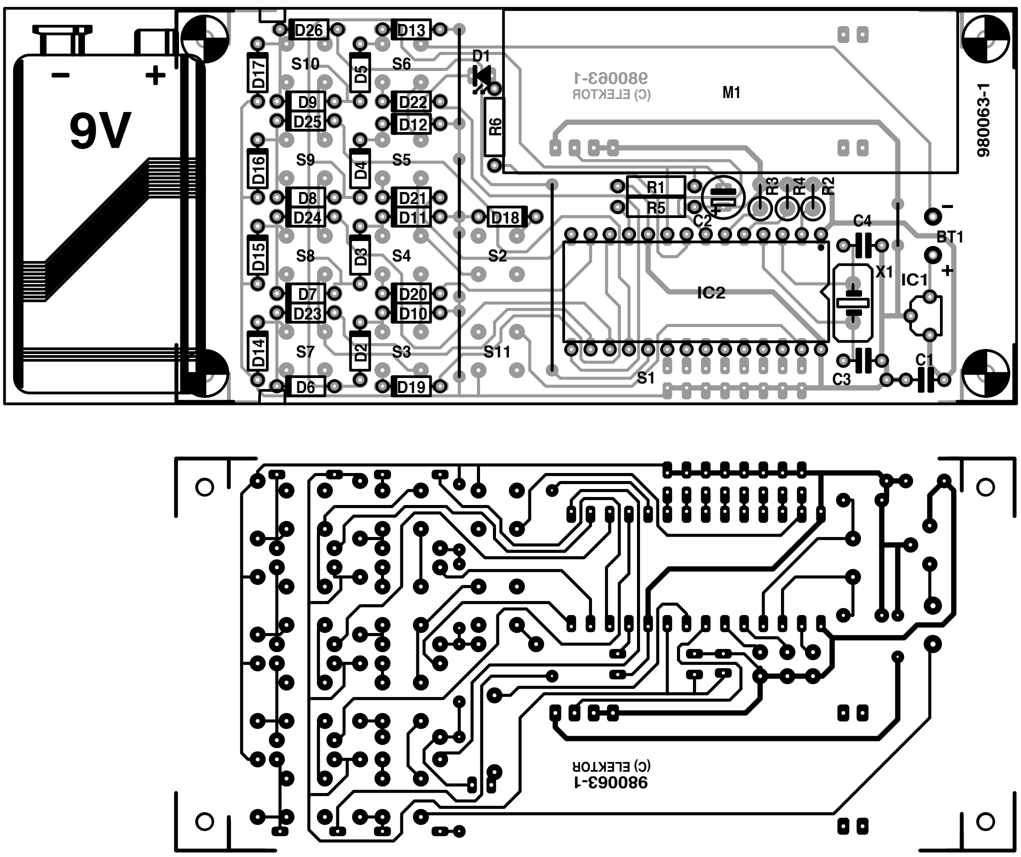


Figure 3. Copper track layout and component mounting plan of the transmitter section of the PCB.

4

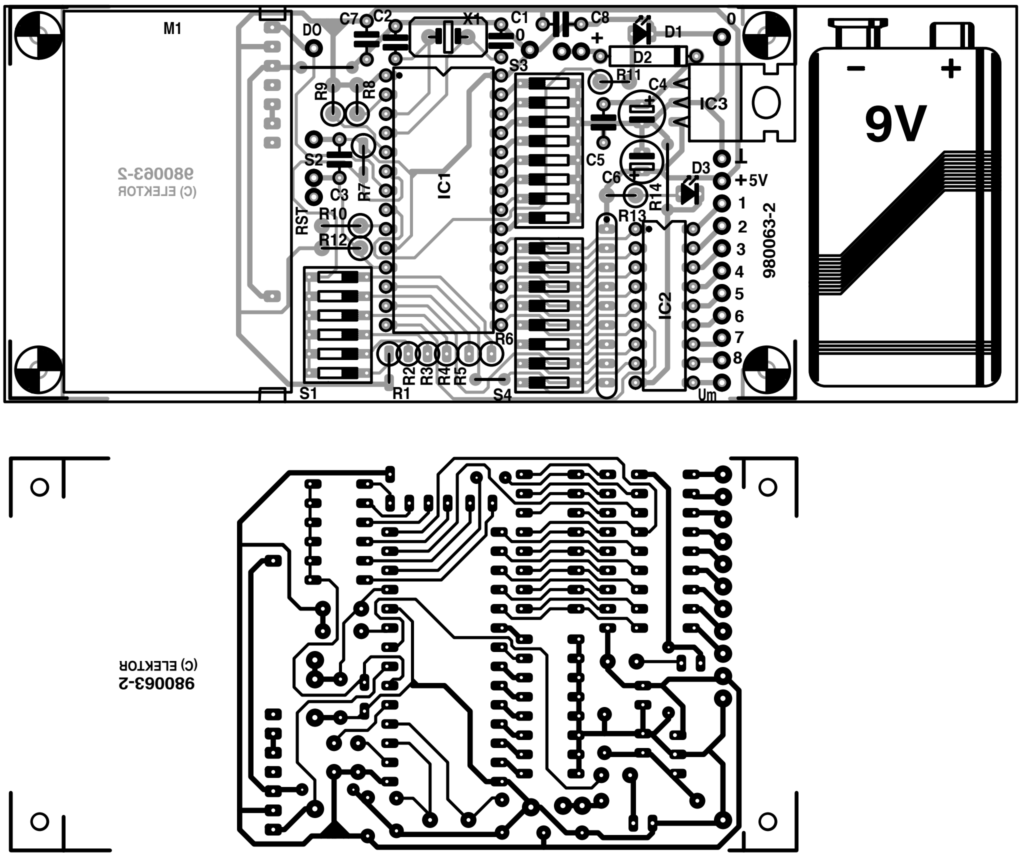


Figure 4. Receiver section of the PCB.

COMPONENTS LIST

Receiver

Resistors:
R1 = 39kΩ
R2 = 22kΩ
R3,R7 = 12kΩ
R4 = 8kΩ2
R5 = 4kΩ7
R6 = 2kΩ2
R8,R9,R10,R12 = 47kΩ
R11,R14 = 1kΩ
R13 = 8 x 270kΩ (SIL)

Capacitors:
C1,C2 = 22pF ceramic
C3 = 100nF MKT
C5,C7,C8 = 100nF ceramic
C4 = 100μF 25V radial
C6 = 10μF 10V radial

Semiconductors:
D1 = LED, green, high efficiency
D2 = 1N4001
D3 = LED, red, high efficiency
IC1 = HE8 (Heiland Electronics)
IC2 = ULN2803
IC3 = 7805

Miscellaneous:
M1 = HE433-2/R (Heiland Electronics), see text
X1 = 8MHz quartz crystal
S1 = 6-way DIP switch
S2 = push-button, 1 make contact
S3,S4 = 8-way DIP switch
PCB, order code 980063-2, see Readers Services page.
Case: Heddic type HE222 (Heiland Electronics)

are made using insulated wires. The indicated push-buttons consist of a square cap and the switch base (with connecting pins) which is marked by one bevelled corner. Because of lack of space, it was not possible to indicate this corner on the component overlay. To make sure the switch is fitted the right way around on the PCB, it has to be positioned such that the bevelled corner points to the long edge of the board (no matter which one), so, either in the direction of D26/D13 or D6/D19. Probably the simplest way of getting it all right is to decide on one particular mounting position and then make sure all push-buttons are mounted the same way around.

The diodes are soldered directly at the solder (copper) side of the PCB. The PCB will only fit in the case if the diodes are mounted flat against the PCB surface.

The connecting pads for the RF modules are designed to accept either one of the two alternative types stated in the parts list. Notes on the use of SRD modules from other

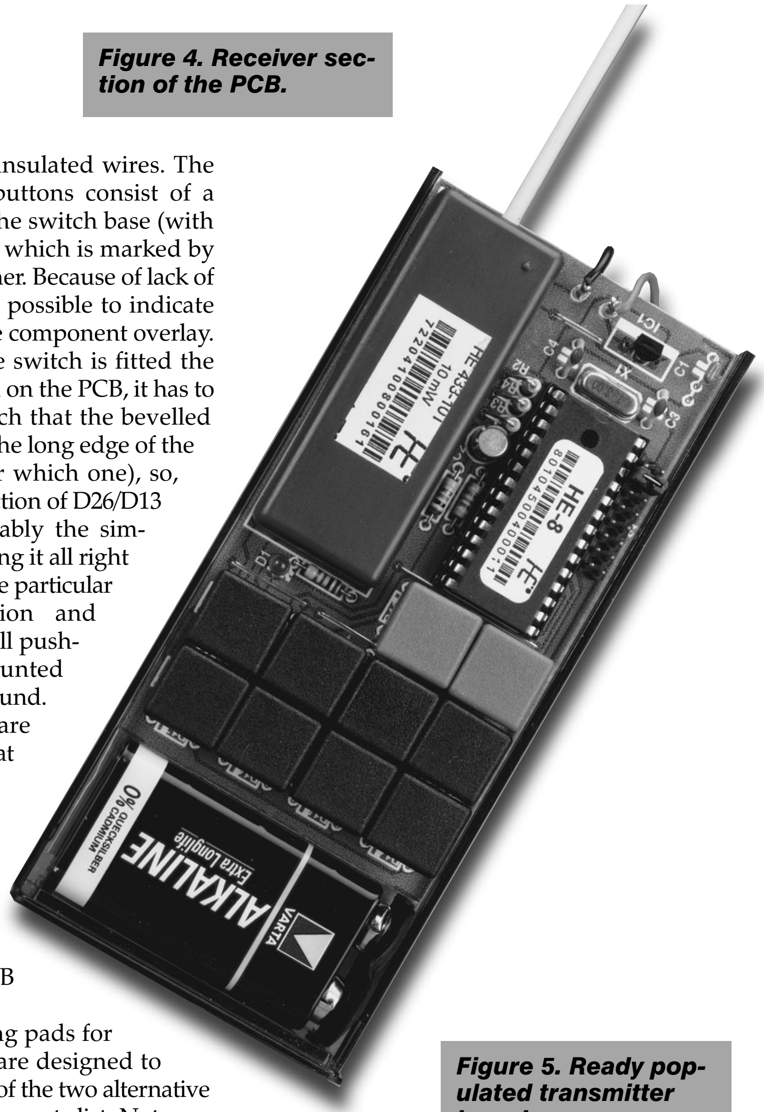


Figure 5. Ready populated transmitter board.

manufacturers may be found further on in this article under the heading *Alternative SRD modules*.

On the receiver board, resistors R1-R5 are fitted vertically. Their top terminals are 'commoned' and taken to R1 (see circuit diagram and photograph of the prototype board).

The large holes allow the boards to be secured in a suitable case. This is not necessary if the case stated in the parts list is used, and the relevant PCB pieces can be cut off.

Both the 10-mW transmitter and the receiver have a wire antenna made from flexible 'litz' (multi-strand) wire. Provided it is kept as short as possible, this wire may also be used to connect to the base of a telescopic antenna. The reason for keeping this connection as short as possible is that the length of the wire goes into the electrical length of the antenna, which has to be 17 cm.

To be able to use the transmitter you only need a 9-V battery. For the receiver, any common-or-garden mains adaptor will do if it supplies an unregulated direct voltage between 9 and 12 V. Current consumption of the receiver proper is modest at about 25 mA when the control outputs are not loaded. Of this current, only 8 mA goes on account of the HE433-2/R module.

For a quick first test, the control outputs are best connected to an array of LEDs. Each LED is then connected to the +5 V rail by way of a 330-Ω resistor. Do not forget to connect Um (at pin 10 of IC2) to +5 V as well!

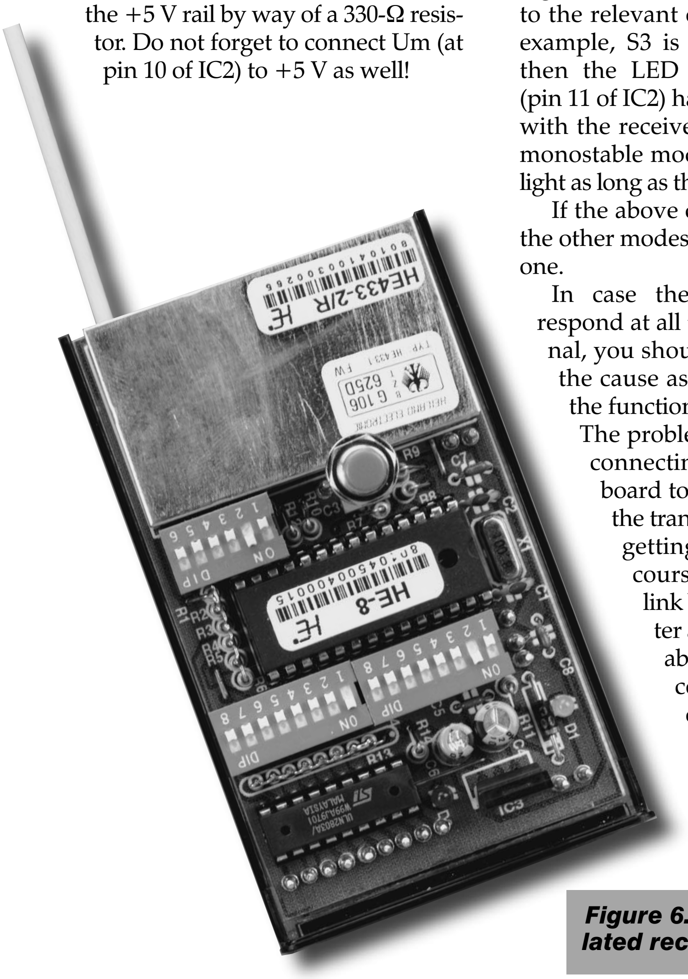


Figure 6. Ready populated receiver board.

As soon as one of the keys on the transmitter is pressed (that's any one except S11), LED D1 should light to indicate that IC2 is transmitting pulses. If it does not, first check the supply voltage. If the correct level of 5 V is measured at C2, IC2 (pin 1) and the RF module (pin 3), then the whole board should be given a thorough inspection — you may have missed something! If the 5 V is missing, the fault may be in the battery circuit, the voltage regulator, or the 5-V rail is short-circuited to ground somewhere.

On the receiver, D3 should light immediately after the supply voltage is applied. Use a multimeter to check that the supply voltage is actually 5 V.

Before checking the system functions by using the transmitter and the receiver in a 'real' wireless link, DIP switch S1-6 in array S1 has to be closed (ON) — all other DIP switches remain OFF (monostable output mode). It is best to switch all contacts of S4 to OFF. At this point, it is important for S3 to be set to the same address (switch configuration) as the transmitter board. Next, you press the 'clear/rest' key, S2, to enable IC1 to copy the address set on the switch array.

Try a couple of the channel control switches (S3-S10) on the transmitter. If the system works, not only D1 on the transmitter lights up, but also D1 on the receiver (reception indicator, flashing), and, of course, the LED connected to the relevant control output. If, for example, S3 is pressed (channel 8), then the LED at control output 8 (pin 11 of IC2) has to light. Remember, with the receiver data outputs set to monostable mode, the LED will only light as long as the transmitter is keyed.

If the above checks are successful, the other modes may be tested one by one.

In case the receiver does not respond at all to the transmitter signal, you should be able to identify the cause as either the RF link or the function of one of the boards. The problem is easily solved by connecting D0 on the receiver board to IC2 pin 7 (TX/RX) on the transmitter board, not forgetting the ground wire, of course. This creates a wire link between the transmitter and the receiver. If the above tests are then successful, the problem can be isolated down to one of the the RF modules.

Finally, an important note on **safety**. In case the receiver is used to control mains-operated loads, you should observe the electrical safety precautions which are regularly printed in this magazine, particularly in respect of insulation and minimum insulation distances for any connection at mains potential. Another important point to observe is the contact rating of the relays used, both in respect of the permissible contact current and contact voltage.

Range

The range of the wireless control system depends not only on the RF power supplied by the transmitter module, but also on the surroundings and interference levels within the range of the receiver. The frequency used here, 433.92 MHz, is by no means exclusive, in fact it has the same status as any other channel in the licence-exempt section of the 70-cm band: *users must accept mutual interference*. In many European countries where only the 433-MHz section is allocated for licence-exempt SRDs, the band is quite crowded in urban areas, so that interference from other users can not be excluded. Fortunately, the typical SRD vehicle key is marked by short transmission bursts, increasing the chance of finding a free 'slot' to reach the receiver. In the UK, there is a clear and fortunate distinction between the 418 MHz and 433 MHz bands as far as their usage is concerned, vehicle keys being allowed to work on 433 MHz only.

Without the deteriorating effects of interfering signals, the range of a system like the one described here will typically depend on the path loss which exists between the transmitter and the receiver. Inside buildings, this path loss will be much higher than for a (quasi) line-of-sight link in open terrain. Under these (optimum) circumstances, ranges of 1 to 3 km may be expected (the latter only when the 10-mW transmitter is used). In built-up areas, this is reduced to a couple of hundred metres, while inside concrete buildings it may not even be possible to reach the next floor. When mounting the receiver, make sure the antenna is as far removed as possible from steel cabinets, steel beams or other support structures and similar RF obstacles. In certain situations, it may be useful to measure the strength of the received signal using a meter connected to the AM output (pin 2) of the receiver. This can be relied on to supply a fairly accurate (though relative) field strength indication, allowing the best possible location for the receiver to be found. During the measurement, you have to key the transmitter, of course.

MULTIPLE TRANSMITTERS

'Multi-transmitter' operation as indicated under the available modes will require some clarification. First, however, we should note that even without this special mode it is also possible to use more than one transmitter for one receiver, the single condition being that the address set on each transmitter matches that of the receiver. In this way, several transmitters may be used in different locations in and around your home, and one will always be at hand.

A special feature of the 'multiple transmitter' mode (mode 2) is that the receiver will only process the last four address bits. Consequently, only the DIP switches on lines ADDR4 through ADDR7 of the HE8 chips on the receiver and the transmitter have to be set to give an identical address. The other four bits are then not relevant, although they may be used to convey identification data from each individual transmitter to the receiver. These lower four bits, ADDR0 through ADDR3, are copied to the pins with the same names on the receiver chip, allowing each individual transmitter to be identified when the multi-transmitter mode is being used. The first four bits then represent the 'transmitter ID' and the last four bits, the 'message'.

MULTIPLE RECEIVERS

Push-button S11 on the transmitter enables ready switching between two addresses and, consequently, between two receivers. If the full address range is exploited, a single transmitter is capable of selectively addressing up to 256 different receivers. If the receivers are in one and the same location, they can even share one 433-MHz receiver module. On the board you will see a connection D0 that allows a data signal from a single receiver module to be fed to several receiver boards. Similar 'distribution' points are available for the 5-V supply and the reset key. If you use this option, then push-button S2, as well as components D2, C4, C5 and IC3 have to be fitted on one receiver board only. The relays are then powered separately to prevent overloading of the on-board voltage regulator.

ALTERNATIVE RF MODULES

The printed circuit boards are specifically designed to accept the RF modules from Heiland Electronics. However, that should not be taken to mean that only these modules can be used. In principle, the system should function with any pair of SRD modules that guarantees secure data transmission. Even AM modules may be employed, although these will provide shorter ranges and inferior signal quality as compared with SRD modules designed for FM.

In case you already have SRD modules, these may be used provided they comply with the following points:

- 5 V supply voltage (or modify to 5 V);
- Transmitter input accepts 5 V (TTL level) swing;
- Receiver output supplies 5-V (TTL level) swing
- Module can be connected properly by wires to PCB.

For the circuits of the transmitter and the receiver it is, in principle, immaterial how the data signal travels from TX/RX pin of the encoder chip to that of the decoder chip, provided it arrives in good shape, that is, with 'clean' 5-V pulses. So, it is even possible to use the receiver and transmitter boards without recourse to any kind of RF modules whatsoever. An infrared link, fibre-optics and even the simplest connection by way of two wires, are just a few alternatives.

(980063-1)

Source:
The basic application circuits and technical data for the 433-MHz modules were obtained from product datasheets supplied by
Heiland Electronic,
D-48351 Everswinkel, Germany.
Tel. (+49) 2582-7550,
fax (+49) 2582-7887.

Receiver Modes

DIP switch S1 allows the user to select one of six different modes for the receiver. To select a particular mode, close only the indicated switch, and leave all others 'open'. Changes in the configuration are not effective until the circuit is reset.

Mode 1: Overwrite (S1-1)
Any selected channel remains active until the 'clear' button is pressed on the transmitter, or the reset button on the receiver.

Mode 2: Multi-transmitter (S1-2)
In this mode the address is only 4 bits wide, using S3-4 through S3-8. In this mode, outputs may also be programmed as in Mode 3.

Mode 3: Programmable (S1-3)
The DIP switches in array S4 enable each individual output to be programmed as bistable (as in Mode 5) or monostable (as in Mode 6). A closed switch selects bistable operation of the relevant output.

Mode 4: Latching (S1-4)
Actuated outputs remain on until the reset key on the receiver is pressed.

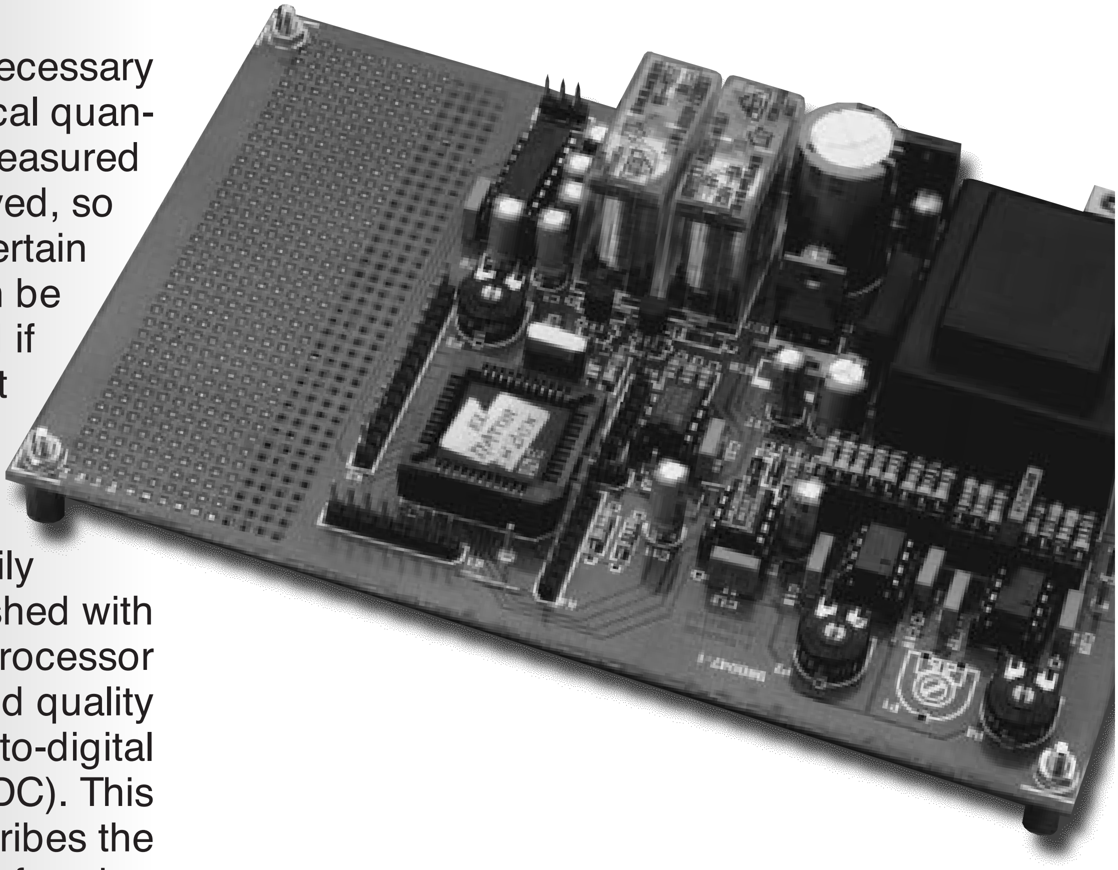
Mode 5: Bistable (S1-5)
When the transmitter is keyed, the relevant channel is switched on. The next key action de-actuates the relevant channel.

Mode 6: Monostable (S1-6)
Selected channel output only remains active as long as the transmitter key is held depressed.

multiple test card

for microcontrollers

It is often necessary for an electrical quantity to be measured and displayed, so that a certain action can be instigated if and when it has reached a limiting value. Today, this is readily accomplished with the aid of a processor and a good quality analogue-to-digital converter (ADC). This article describes the design of such a setup, complete with power supply and a number of input and output facilities.



Features

- *12-bit converter operating at up 70,000 samples/sec*
- *general-purpose preamplifier*
- *on-board power supply*
- *printed-circuit board allows experimental layouts*
- *CPU options:* *Matchbox for simple programming*
  AT89S8252 for fast programming via a PC and adaptor
  87C51 for economy
- *may be used as general-purpose card for an 8051 controller*
- *Interfaces:* *12-bit analogue input*
  RS232
  LCD (parallel or I^2C)
  two relays
  ports for I/O
  SPI with AT89S8252 CPU
  I^2C with Matchbox CPU

Design by M. Ohsmann

1

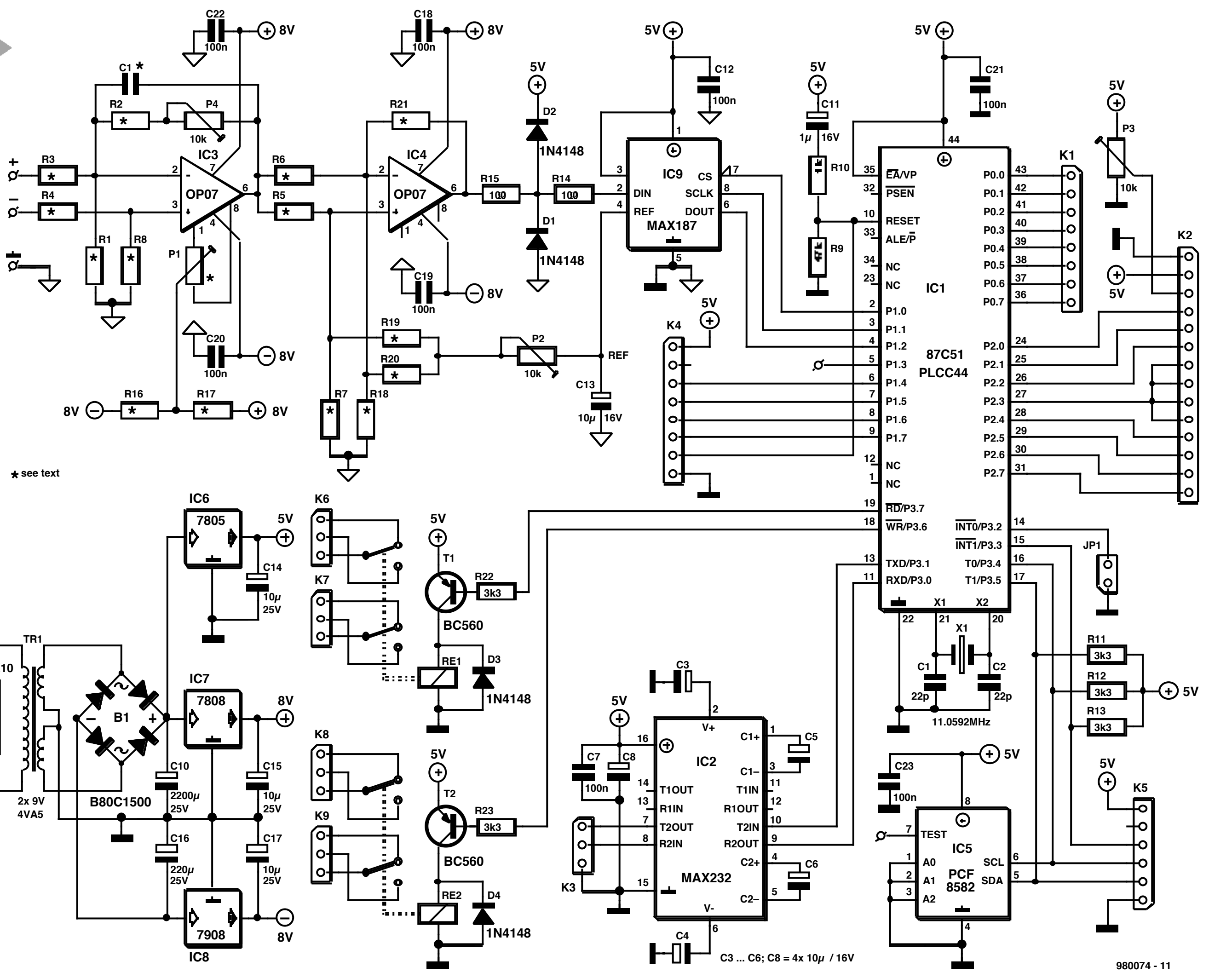


Figure 1. Circuit diagram of the test card.

The test card consists of a 12-bit analogue-to-digital converter (ADC) that can operate at up to 70,000 samples/sec, a preamplifier that enables the ADC to work with a number of inputs, and a controller that drives the ADC and processes the quantized samples.

The controller may, for instance, be a Matchbox single-board computer (SBC), programmed in BASIC, which also provides a liquid crystal display (LCD) and an I^2C bus.

Another possibility is the use of an AT98S8252, which can be programmed readily by a PC via a suitable adaptor. This controller is specially intended for real-time applications that use the maximum processor power.

A similarly programmed Type 87C51 controller may also be used. The data may then be applied to the PC via an RS232 interface, or displayed on the LCD, or used to drive computer ports or relays.

Several interesting applications are possible as shown in **the features list**. The controller ports must, of course, not be used for other than light loads. If, for instance, it is desired to drive a relay, a buffer stage or stages such as those at ports P3.7 (RD) and P3.6 (WR) should be used.

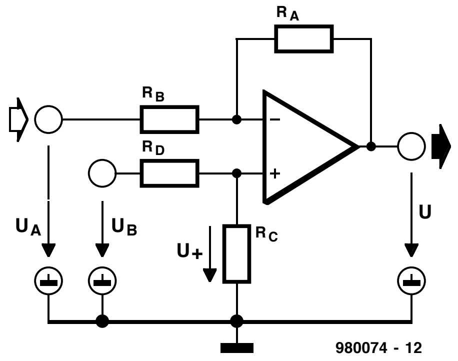
The printed-circuit board for the test card (**Figure 8**) contains a number of terminal strips to which a sprinkling of small extensions may be connected.

ANALOGUE SECTION

The analogue section of the circuit in **Figure 1** consists of a two-stage preamplifier that enables various inputs to be linked to analogue-to-digital converter IC_9. Although this part of the circuit looks rather complex, bear in mind that not all components are used for all possible applications. The relevant components (marked with an * in Figure 1) are not soldered on to the PCB, but are inserted into two 16-way direct-in-line (DIL) sockets. This makes their omission or exchange for various applications straightforward. The arrangement makes it possible for the relevant components for a certain application to be soldered on to a suitable plug which can then be inserted into the DIL socket as a small unit.

Operational amplifier IC_3 is config-

2



$$U = -\frac{R_A}{R_B}\cdot U_A + \left(1+\frac{R_A}{R_B}\right)\cdot\left(\frac{R_C}{R_C+R_B}\right)\cdot U_B$$

Figure 2. Basic configuration of an inverting amplifier.

Figure 3. Input amplifier for operation with 0–1 V inputs.

3

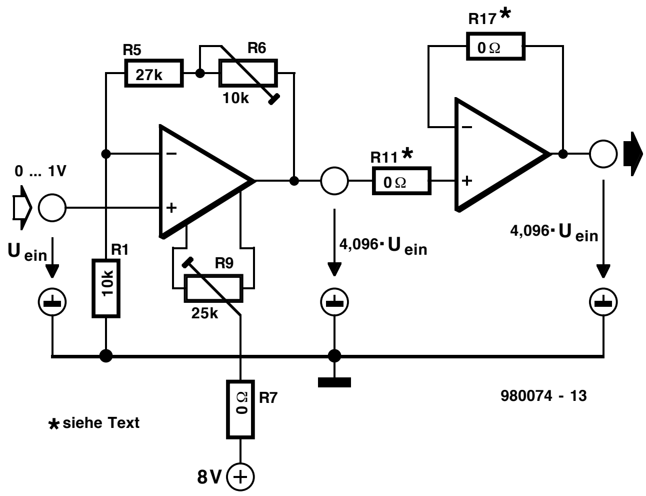


Figure 4. Matchbox program for voltage adaptation.

ures as an invertor, whose basic circuit is shown in **Figure 2**. This basic circuit enables the requisite values of certain components to be calculated.

Reverting to Figure 1, if needed for an application, C_1 may be added to form a low-pass filter at the input. The amplification of IC_3 is set with P_4, while its off-set compensation is set with P_1. Depending on the type of op amp used, the wiper of P_1 may be linked to the postive or the negative supply line.

The output of IC_3 is applied to a second op amp, IC_4, via R_5 or R_6. This makes it possible for IC_4 to be used as an inverting or a non-inverting amplifier. The exact reference from the ADC can be added as an offset, whose level is set with P_2, to the positive-input signal via R_{19} or to the negative-input signal via R_{20}.

The amplification of IC_4 is determined either by R_{21} in conjunction with R_{18} or by R_7. The output of this op amp is applied to analogue-to-digital converter (ADC) IC_9 via R_{15} and R_{14}.

AMPLIFIER OPTIONS

To clarify some of the many possibilities available, here are some examples.

Input 0–1 V

If the input voltage is 0–1 V, the signal must be amplified by 4.096 to enable the ADC to quantize it over the range 0–4.096 V. It is, of course, preferable for the ADC to be driven over the full range. In this application, the circuit of which is shown in **Figure 3**, the input impedance should be high, if at all possible. In Figure 2, R_A= 30.096 kΩ, R_B= 10 kΩ, R_C= 0, U_A= 0, U_B= U_m, where U_m is the measured voltage.

4

```
; XMESS1.MBL                                        : Voltmeter : Range 0 ... 1.00 Volt

RESOURCE 8051-IRAM  10H BYTES @070H
RESOURCE IIC-EEPROM 0200H  BYTES @05000H            ; ST24C04

INTEGER K, ADvalue

START:
P1.0:=1                                             ; CS inactive
P1.1:=0                                             ; set clock line LOW
P1.0:=0                                             ; CS active
P1.1:=1                                             ; clock high
ADvalue:=0                                          ; get AD result there
K:=11; MAX 187 is ready here
WHILE K>=0 DO
        P1.1:=0                                     ; clock goes low
        ADvalue:=(ADvalue SHL 1)+P1.2               ; shift in the bit
        P1.1:=1                                     ; clock high again
        K:=K-1                                      ; do 12 bits
WHEND
FORMAT(RS232 D DP=3 DPSHOW=3 I  N LENGTH=6 )        ; RS232 decimal output
PRINT( SCALE(ADvalue,1000,4096),' Volt  "0D"0A')    ; display AD*1000/4096
GOTO START                                          ; restart again

END
```

Reverting to Figure 1, the exact amplification is set with P_4 and the offset compensation with P_1. In this examples, Type LF356 op amps are used, which means that the compensation voltage is derived from the positive supply line via R_{17} and P_1.

The Matchbox must, of course, be programmed as appropriate to display the input signal level. This is accomplished by driving the ADC, whereupon the result of the conversion is weighted (with the correction of the amplification factor) and read in 12-bit form. The complete program is shown in **Figure 4**.

Input 0–100 V

If the input voltage is in the range 0–100 V, the input terminal may be preceded by a 100:1 potential divider. Its tolerance can be nullified with P_4. Then, the signal must be amplified ×4.096. In view of the noise and offset voltages, this is not a good solution. A better alternative is shown in **Figure 5**. Here, the potential divider formed by R_5 and R_8 provides a signal at the non-inverting input of IC_3 of 3.754 V (which is close to the wanted level of 4.096 V) when the input is 100 V. The correct amplification is obtained by giving suitable values to R_1 and R_2, and setting P_4 as appropriate.

Current –1 A to + 1 A

Currents between –1 A and + 1 A are measured with the circuit configured as in **Figure 6**. Since this current range is symmetrical around 0 A, the input to the ADC when the current is zero must be 4.096/2= 2.048 V. This is accomplished by using IC_3 as a current-to-voltage converter and R_8 as the current sensor.

When the current is + 1 A, the voltage drop actross R_8 is 0.1 V. This level must be amplified by 20.48 to obtain the correct input level to the ADC. The values of the various components, assuming that R_1 is 2.2 kΩ, are determined from

$$1+ (R_2+ P_4)/R_1= 20.48$$

$$\therefore\ R_2+ P_4= 19.48R_1= 42.856\ k\Omega.$$

These values ensure that the output voltage of the op amp has a range of –2.048 V to + 2.048 V.

Operational amplifier IC_4 is arranged as an inverting amplifier whose output voltage is

$$U_{out}= U_{in}+ U_{ref}/2.$$

This is accomplished by giving the components in Figure 2 these values: $R_A= R_B= R_C =$ 10 kΩ; R_D= 30.95 kΩ and $U_B= U_{ref}=$ 4.096 V.

The offset voltage is needed to shift

5

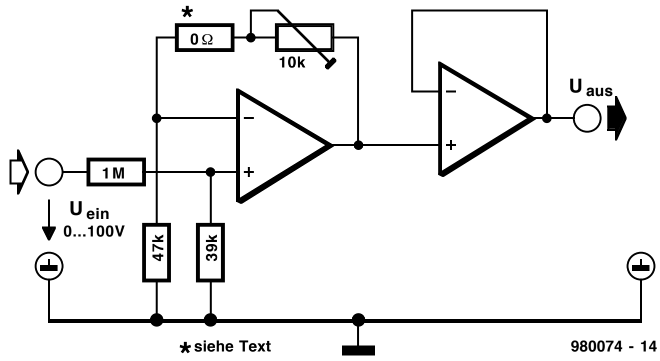


Figure 5. Input amplifier for operation with 0–100 V inputs.

Figure 6. Input amplifier for operation with –1 A to + 1 A input currents.

6

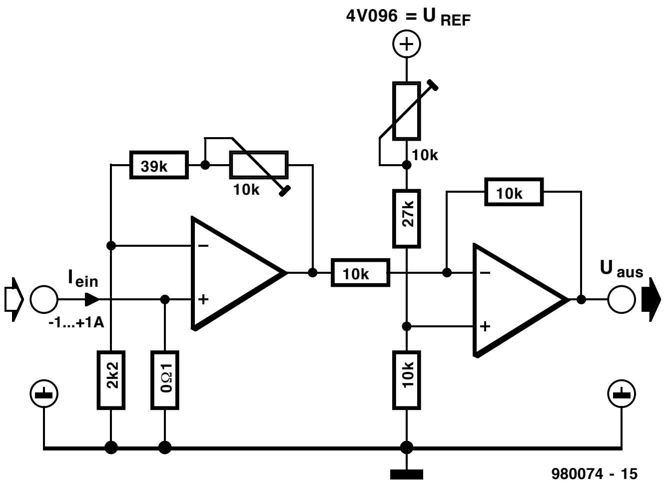
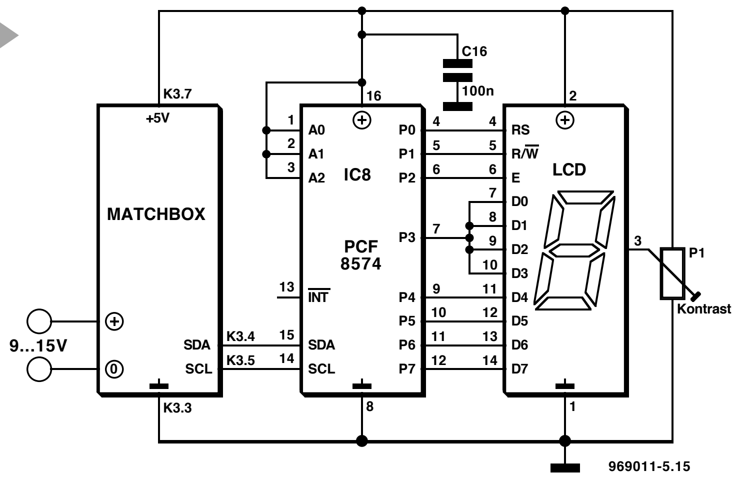


Figure 7. How to connect a liquid-crystal display to the Matchbox interface.

7



8

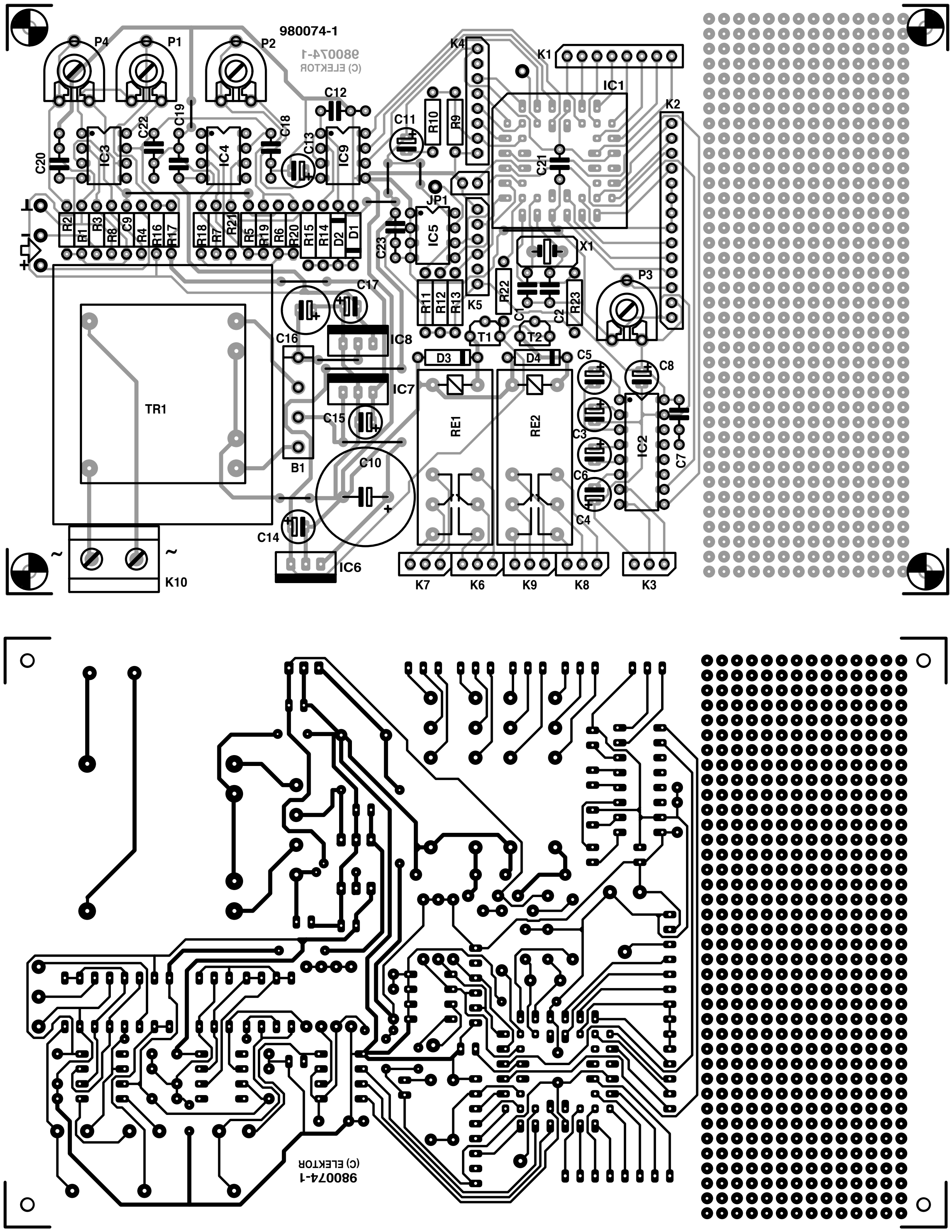


Figure 8. The single-sided printed-circuit board for the test card.

the output of IC_4 into the positive range, which is imperative for correct operation of the ADC.

When the output data of the ADC are being evaluated, the offset and inversion must be taken into account by IC_2 so that the relevant line in the program is changed to

```
PRINT( SCALE(2048-ADvalue,1000,2048),' Amp "0D"0A'); display AD*1000/4096
```

The displayed value of (2048-AD)× 1000/2048 accords exactly with the current in amperes. The factor 1000 is corrected by the decimal point.

When a rectifier or true-rms converter is connected at the input, alternating voltages may also be measured. Other test adapters, such as a negative-temperature-coefficient (NTC) or positive-temperature-coefficient (PTC) resistors, or magnetic-field

Parts list

Resistors:
R_1–R_8; R_{16}–R_{21} = see text
R_9 = 47 kΩ
R_{10} = 1 kΩ
R_{11}–R_{13}, R_{23} = 3.3 kΩ
R_{14}, R_{15} = 100 Ω
P_1 = see text
P_2–P_4 = preset, 10 kΩ

Capacitors:
C_1, C_2 = 22 pF
C_3–C_6, C_8, C_{13} = 10 μF, 16 V, radial
C_7, C_{12}, C_{18}–C_{23} = 0.1 μF
C_9 = not used
C_{10} = 2200 μF, 25 V, radial
C_{11} = 1 μF, 16 V, radial
C_{14}, C_{15}, C_{17} = 10 μF, 25 V, radial
C_{16} = 220 μF, 25 V, radial

Semiconductors:
B_1 = rectifier bridge B80C1500
D_1–D_4 = 1N4148
T_1, T_2 = BC560

Integrated circuits:
IC_1 = 87C51PLC44
IC_2 = MAX232
IC_3, IC_4 = TL071
IC_5 = PCF8582 or ST24C02
IC_6 = 7805
IC_7 = 7808
IC_8 = 7908
IC_9 = MAX187

Miscellaneous:
X_1 = crystal 11.0592 MHz
PC_1–PC_5 = PCB pin
JP_1 = 2.54 mm pin strip and pin jumper
Re_1, Re_2 = 6 V relay with 2 change-over contacts for board mounting
Tr_1 = mains transformer with 2×9 V secondary, 4.5 VA
K_1, K_4 = 8-way terminal strip
K_2 = 14-way terminal strip
K_3, K_6–K_9 = 3-way terminal strip
K_5 = 6-way terminal strip
K_{10} = 2-way mains terminal board (insulated)

sensors, may also be used. The controller does not only compute the test results, but also carries out any requisite linearization.

CPU OPTIONS

The digital section of the circuit in Figure 4 is a straightforward design. The central processing unit (CPU) is linked to the outside world via an RS232 interface. Circuit IC_2 converts the single 5 V supply into ± 12 to ± 15 V as required in RS232 communications.

The ports of the CPU are used for the various inputs and outputs. Depending on the CPU used, a variety of facilities are possible.

There is also an I²C EEPROM available, not only for compatibility with the Matchbox, but also for use with a number of other applications, for instance, the storing of measurement data.

Matchbox

The printed-circuit board is designed to cater for a number of different CPUs. The best of these for less experienced readers is the Matchbox. This controller enables an application to be programmed in BASIC, whereupon all the input and output facilities as well as the various interfaces are operated via the controller.

AT89S8252

If use of the full speed of an 8051 controller is desired, that is, by programming in the assembler, the AT89S8252 is recommended. The program generated in the PC is then stored in an internal EEPROM via a simple interface. A special programming unit is not needed.

87C51

Neither the AT89S8252 nor the Matchbox is cheap. If there is no objection to the use of a number of test cards with fixed programs, the well-known 87C51, AT89C51 or AT89C52 may be used. These are the most economical controllers available, but they need a special programming unit, which is probably available to many readers.

FINALLY ...

The test card permits the parallel connection of a liquid-crystal display (LCD) to port P2 (4-bit mode). If, however, the Matchbox is used, its excellent LCD output capabilities should not be ignored, but made full use of via the I²C bus—see **Figure 7**.

The power supply of the test card provides a regulated + 5 V line for the digital section and a regulated ± 8 V line for the analogue section of the circuit. The regulator for the + 5 V line, IC_6, is connected to a fairly high input voltage and dissipates about 2 W when the relays are energized. It must, therefore, be fitted on a suitable heat sink.

The relatively high supply voltage for the analogue section obviates the need for rail-to-rail op amps in the IC_3 and IC_4 positions to drive the converter over its full range. If, apart from the two op amps, no other loads are connected to the ± 8 v line, regulators IC_7 and IC_8 do not need heat sinks.

There is not much that need to be said about the construction and use of the test card other than has already been mentioned. One important point is that all ICs should be seated in an appropriate socket.

Before the card is taken into use, the supply lines should be checked carefully before the ICs are inserted into their sockets.

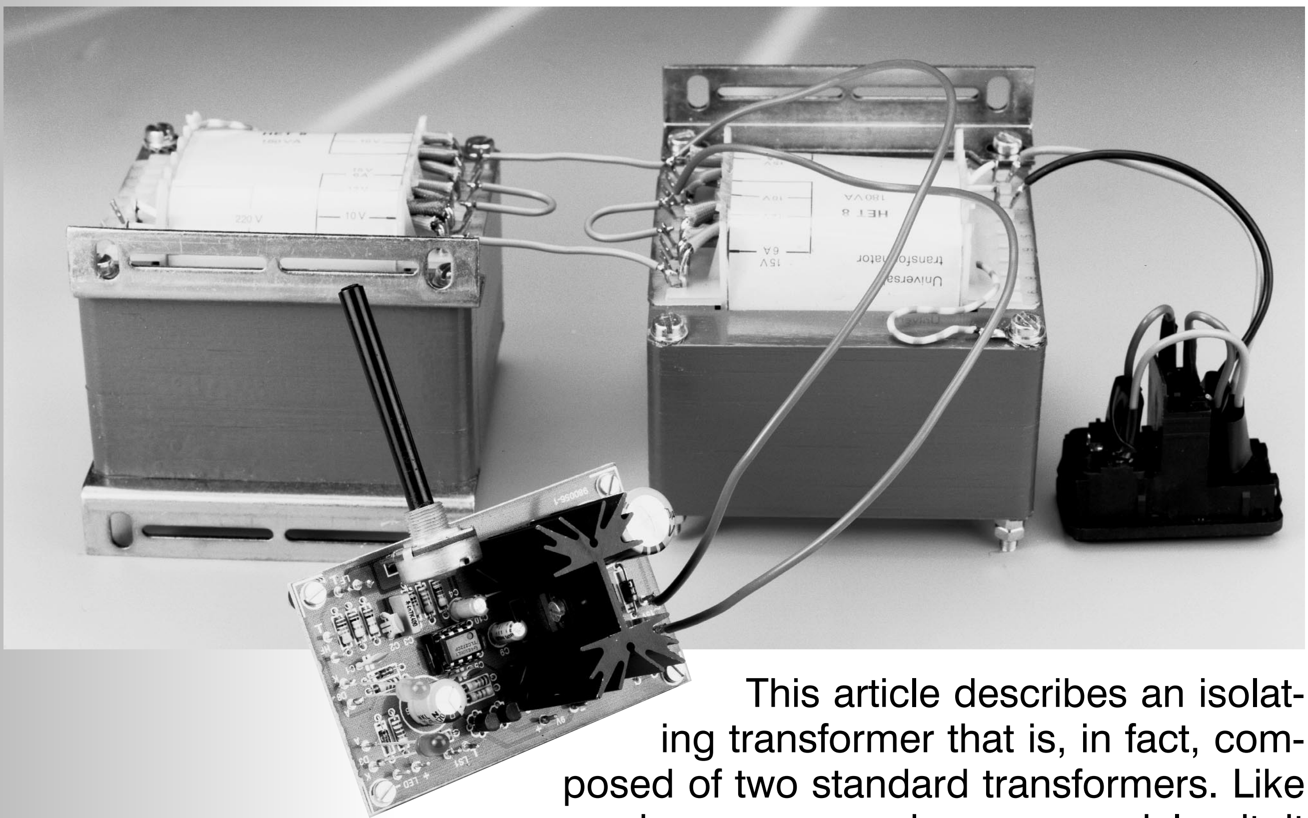
[980074]

Applications:

- *multimeter with serial output*
- *heating controller*
- *serial test network*
- *data processor monitor*
- *processing controller*
- *linearized thermometer*
- *a.c. measurement with dB display*
- *data logger*

versatile aid for experimenters

with signal tracer & continuity tester



This article describes an isolating transformer that is, in fact, composed of two standard transformers. Like a much more expensive commercial unit, it isolates any equipment on test or being repaired from the mains supply. During the design, it proved convenient to add a signal tracer, a regulated 9 V power supply and a continuity tester.

It should be noted, however, that a Class 2 (double-insulated) isolating transformer to BS3535 has no earth connection on the secondary side. In the event of a circuit supplied from such a transformer developing a live fault to an exposed conductive part, there would be no path for a shock current to flow. An inadvertent connection to earth, or interconnection with other circuits, would render the protection useless. [IEE Wiring Regulations]

Design by P. Lay

SAFETY

It cannot be stressed too much that in the construction, testing, repair and maintenance of electronic equipment operated from the mains power supply the greatest care must be taken. It is easy to become nonchalant in our home workshop, but remember that every year hundreds of people die – most at home – owing to electric shock. In fact, in a public place, such as a school or college, or a home workshop open to outsiders, there is a statutory duty on ensuring safety from electric shock. In the United Kingdom, the Health and Safety Executive produces guidance notes for such public places.

One common and advisable means of ensuring safety when work is carried out on a mains-operated equipment is the use of an isolating transformer to BS3535. Such a device ensures that (a) the equipment on test is electrically isolated from the mains supply, and (b) the current through the equipment on test is limited by the transformer rating (and relevant fuse). Mind any inadvertent earth connection, however, as pointed out in the note in the introduction to this article.

COMPOSITE TRANSFORMER

An isolating transformer is fairly expensive, which is probably the reason that it is not found in most small workshops (but how much is your life worth to you?). A less expensive one may be made from two identical mains transformers as shown in in the wiring diagram in **Figure 1**.

The 2 × 15 V secondary windings of each of the two transformers are connected in series and then interconnected as shown. So, looked at from the mains entry, transformer Tr_2 converts the 240 V mains voltage to 30 V, after which Tr_1 converts the 30 V back to 240 V.

The L(ive) mains line is connected to the relevant input terminal of Tr_2 via fuse F_1 and on/off switch S_1. [*Two comments here: (1) it is advisable to use a double-pole switch and, in line with common practice, also switch the N(eutral) mains line, and (2) although the letter L is used for the live mains line, the letter P for phase is commonly used in many publications. The letter L is preferred here since it coincides with the designation of the live mains line in most domestic installations and appliances*. Editor].

TRACER & TESTER

Since the composite transformer makes a low voltage available, the designer felt that some additional components, which cost relatively little, would make the circuit even more useful in the small or home workshop. The additions are a signal tracer for high-frequency (100 kHz – 10 MHz) and low-frequency (50 Hz – 20 kHz) signals with variable sensitivity, a simple continuity tester, and a regulated 9 V power supply.

The signal tracer is very handy, in

1

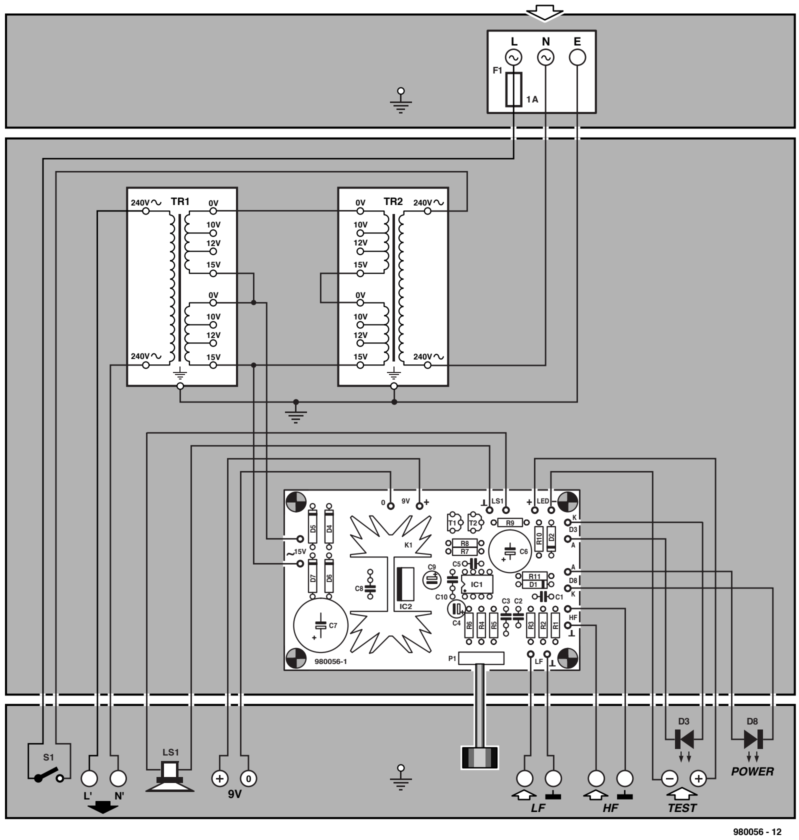
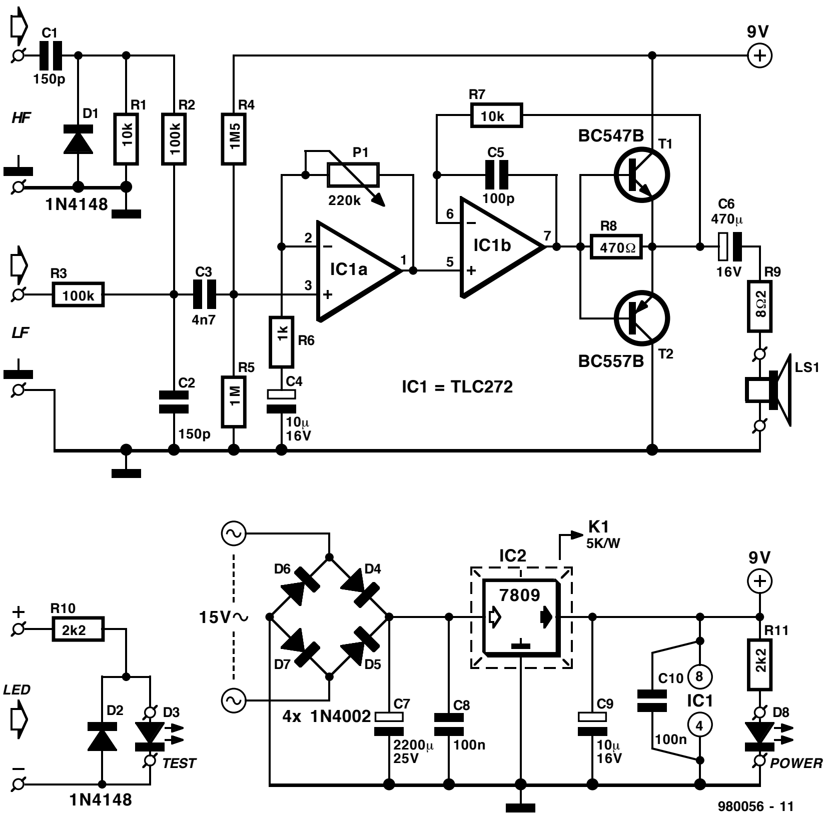


Figure 1. The wiring diagram and layout diagram of the composite transformer and ancillary circuits.

Figure 2. There are three ancillary circuits: the signal tracer, the continuity tester, and the regulated 9 V power supply.

2



3

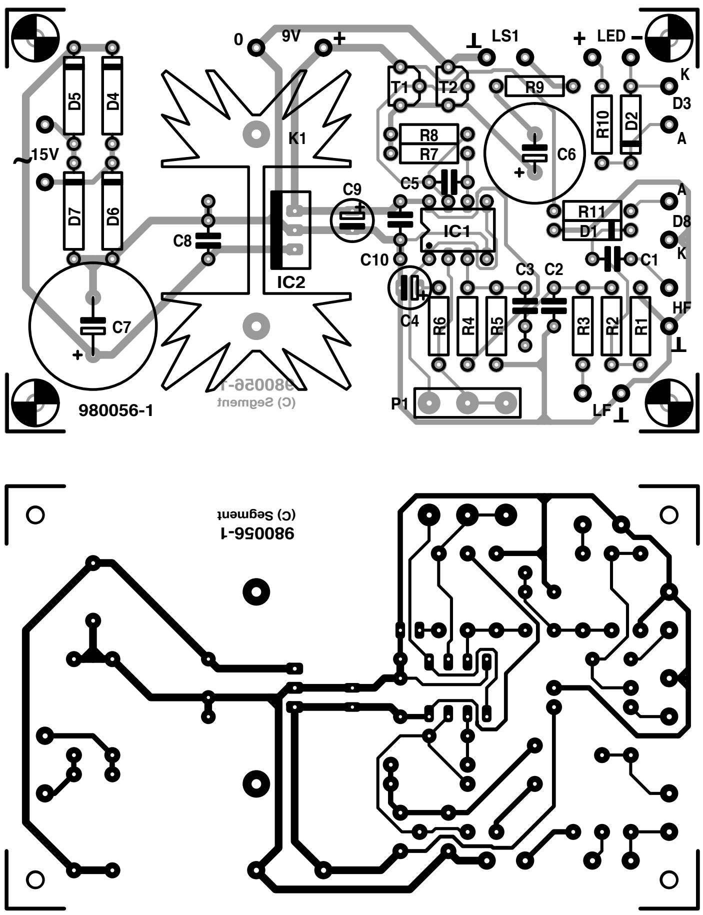
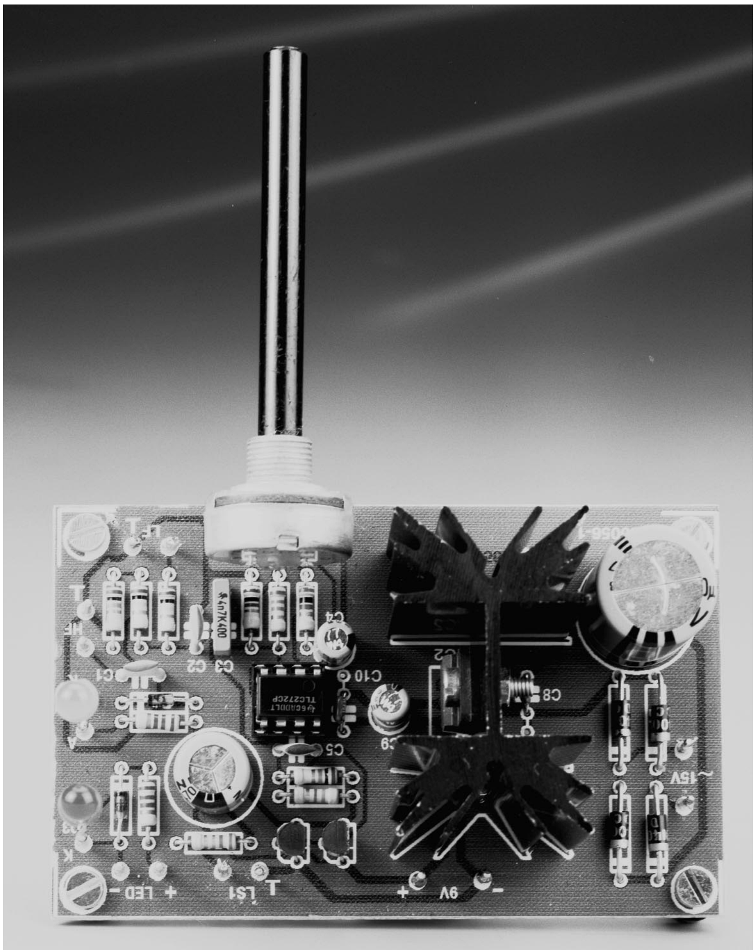


Figure 3. The printed-circuit board for the ancillary circuits .

4



Parts list

Resistors:
R_1, R_7 = 10 kΩ
R_2, R_3 = 100 kΩ
R_4 = 1.5 MΩ
R_6 = 1 kΩ
R_8 = 470 Ω
R_9 = 8.2 Ω
R_{10}, R_{11} = 2.2 kΩ
P_1 = 220 kΩ, linear

Capacitors:
C_1, C_2 = 150 pF, ceramic
C_3 = 0.0047 μF, metallized polyester
C_4, C_9 = 10 μF, 16 V, radial
C_5 = 100 pF, ceramic
C_6 = 470 μF, 16 V, radial
C_7 = 2200 μF, 25 V, radial
C_8, C_{10} = 0.1 μF, ceramic

Semiconductors:
D_1, D_2 = 1N4148
D_3, D_8 = LED, low current
D_4–D_7 = 1N4002
T_1 = BC547B
T_2 = BC557B

Integrated circuits:
IC_1 = TLC272CP
IC_2 = 7809

Miscellaneous:
F_1 = fuse holder and fuse, 1 A, slow
LS_1 = miniature loudspeaker, 8 Ω, 500 mW
Tr_1, Tr_2 = 180 VA mains transformer with 2 × 15 V secondary
S_1 = mains on/off switch, double pole preferred, see text
K_1 = heat sink for IC_2, 5 K W^{-1}
8 off banana socket
1 off mains entry
1 off mains output socket (panel mounting)

conjunction with a suitable signal source, to test signal paths. It may seem odd, but it appears that many small or home workshops have a function generator available, but not a signal tracer.

The continuity tester (test LED) is a bit of a gismo, while the 9 V power supply is intended primarily to power the signal tracer circuitry, but may be used for experimental purposes.

CIRCUIT DESCRIPTION

The circuit diagram of the composite isolating transformer is shown in **Figure 2**.

The input for the 9 V regulated power supply is taken from the 15 V secondary of Tr_1. This voltage is rectified by bridge D_4–D_7, smoothed by capacitor C_7, and stabilized by regula-

Figure 4. Photograph of the completed printed-circuit board.

tor IC_2 at 9 V. If IC_2 is mounted on a suitable heat sink, it can handle currents up to 1 A. Since the signal tracer draws a current of only 50 mA, there is ample reserve for experimental purposes.

The continuity tester circuit consists merely of light-emitting diode D_3, protection diode D_2, and bias resistor R_{10}. The positive and negative input of the circuit may be used as low-voltage tester. When the positive terminal is linked to the positive terminal of the 9 V power supply, the circuit may be used as continuity tester.

The signal tracer section is basically a small, sensitive amplifier, consisting of two op amps and two transistors, which makes the detected test tones audible via a small loudspeaker. There are separate inputs for low-frequency (LF) and high-frequency (HF) signals.

Signals applied to the LF input are fed via low-pass filter R_1-R_2-R_3-C_2 to the non-inverting input of op amp IC_{1a}. The filter has a cut-off frequency of 20 kHz.

Signals applied to the HF input are fed to the non-inverting input of op amp IC_{1a} via AM detector R_1C_1-D_1 and filter R_2-C_2.

The d.c. operating point of IC_{1a} is arranged by R_4 and R_5 to ensure maximum drive to the op amp. Any residual direct voltage is blocked by capacitor C_3.

Since the feedback is variable, the amplification of IC_{1a} can be varied continuously between unity and × 221. To avoid overdriving the stage, it is advisable to start any signal tracing with P_1 set to minimum or nearly so.

The output of IC_{1a} is fed to driver IC_{1b} and output amplifier T_1-T_2, which drives loudspeaker LS_1. Resistor R_7 and capacitor C_5 ensure adequate stability of the amplifier. Capacitor C_6 prevents any residual direct voltage from reaching the loudspeaker. Resistor R_6 makes the output short-circuit-proof. The peak power output is 100 mW.

CONSTRUCTION

Apart from the two transformers, on/off switch, fuse and LEDs, all components are conveniently housed on the printed-circuit board shown in **Figure 3**. This board is, however, not available ready made.

Voltage regulator IC_2 is near the centre of the board and should be mounted on a heat sink.

Capacitor C_8 is located as close as feasible to IC_2 so as to suppress any interference pulses as effectively as possible.

The completed prototype board is shown in the photograph in **Figure 4**.

The transformers and board should be housed in a suitable enclosure. The mains entry and fuse should be fitted at the rear, and the input and output terminals, the LEDs, and the on/off switch, at the front of the enclosure. The input and output terminals may be banana sockets, but the LF and HF inputs should be audio or BNC type sockets.

The outputs of the isolating transformer, that is, L′ and N′, should be accessible via a mains output socket at the front panel.

The wiring up is shown in Figure 1. Comparing this with Figure 3 shows that the terminals on the PCB are actually where they are shown.

Finally, make sure that the wiring of the mains leads is sound: well insulated cable and the use of strain relief bushes is sound practice!

[980056]

ELEKTOR		☐
240V~	50Hz	
No. 980056		
F = 1A		

Command Codes for Specific System Addresses

Command Address	Command Code						Symbol (IEC417)	Command Allocation
	C5	C4	C3	C2	C1	C0		
Command Codes for Specific System Addresses								
Video Recorders (system address = 5)								
30	**0**	**1**	**1**	**1**	1	0	- - -	search forward to next marker
31	0	1	1	1	1	1	- - -	search reverse to next marker
34	1	0	0	0	1	0		picture slow run reverse
37	1	0	0	1	0	1		picture frame by frame reverse
38	1	0	0	1	1	0		slow run forward
39	1	0	0	1	1	1		slow run reverse
40	1	0	1	0	0	0		picture slow run forward
41	1	0	1	0	0	0		picture frame by frame forward
42	1	0	1	0	1	0		picture fast run forward
44	1	0	1	1	0	0		picture moderate run reverse
45	1	0	1	1	0	1		eject
46	1	0	1	1	1	0		picture moderate run forward
47	1	0	1	1	1	1		picture normal run reverse
48	1	1	0	0	0	0		pause
50	1	1	0	0	1	0		fast run reverse

Command Address	Command Code						Symbol (IEC417)	Command Allocation
	C5	C4	C3	C2	C1	C0		
Command Codes for Specific System Addresses								
Audio Recorders (system address = 18)								
30	0	1	1	1	1	0	- - -	search forward to next marker
31	0	1	1	1	1	1	- - -	search reverse to next marker
45	1	0	1	1	0	1		eject
48	1	1	0	0	0	0		pause
50	1	1	0	0	1	0		fast run reverse
52	1	1	0	1	0	0		fast run forward

RC-5 System Addresses

System Address	System Code					Symbol (IEC417)	Equipment Type Allocation
	S4	S3	S2	S1	S0		
0	0	0	0	0	0		television receiver
1	0	0	0	0	1		reserved for future standardisation
2	0	0	0	1	0		Teletext mode
3	0	0	0	1	1		viewdata mode
4	0	0	1	0	0		pick up/VLP mode
5	0	0	1	0	1		video tape recorder
6	0	0	1	1	0	—	reserved for future standardisation
7	0	0	1	1	1	—	free for experimental use
8	0	1	0	0	0	- - - -	video tuner
9	0	1	0	0	1		video camera
10	0	1	0	1	0	—	reserved for future standardisation
11	0	1	0	1	1	—	reserved for future standardisation
12	0	1	1	0	0	—	reserved for future standardisation
13	0	1	1	0	1	—	reserved for future standardisation
14	0	1	1	1	0	—	reserved for future standardisation
15	0	1	1	1	1	—	reserved for future standardisation
16	1	0	0	0	0	- - - - -	audio preamp
17	1	0	0	0	1		radio receiver
18	1	0	0	1	0		tape recorder
19	1	0	0	1	1	—	free for experimental use
20	1	0	1	0	0	- - -	compact disc
21	1	0	1	0	1		pick up for disc recorder
22	1	0	1	1	0	—	reserved for future standardisation
28	1	1	1	0	0	—	reserved for future standardisation
29	1	1	1	0	1		lighting applications
30	1	1	1	1	0	—	reserved for future standardisation
31	1	1	1	1	1	—	reserved for future standardisation

ELEKTOR ELECTRONICS

RC-5 Command Allocations

DATASHEET 09/98

RC-5 Command Allocations

Command Address	C5	C4	C3	C2	C1	C0	Symbol (IEC417)	Commands Allocated: General	Commands Allocated: Audio	Commands Allocated: Video
0-9								numerical values 0-9		
12	0	0	1	1	0	0		standby		
13	0	0	1	1	0	1			mute	
14	0	0	1	1	1	0			personal preference	
15	0	0	1	1	1	1		display		
16	0	1	0	0	0	0	+		volume +	
17	0	1	0	0	0	1	–		volume –	
18	0	1	0	0	1	0	+			brightness +
19	0	1	0	0	1	1	–			brightness –
20	0	1	0	1	0	0	+			colour saturation +
21	0	1	0	1	0	1	–			colour saturation –
22	0	1	0	1	1	0	+		bass +	
23	0	1	0	1	1	1	–		bass –	
24	0	1	1	0	0	0	+		treble +	
25	0	1	1	0	0	1	–		treble –	
26	0	1	1	0	1	0			balance right +	
27	0	1	1	0	1	0			balance left +	
49	1	1	0	0	0	1		erase		
53	1	1	0	1	0	1		play		
54	1	1	0	1	1	0		stop		
55	1	1	0	1	1	1		recording		
56	1	1	1	0	0	0	- - -	connect		
57	1	1	1	0	0	1	—	reserved for future use		
61	1	1	1	1	0	1		system standby		
63	1	1	1	1	1	1	- - -	system select		

ELEKTOR ELECTRONICS

Command Codes for Specific System Addresses

DATASHEET 09/98

Command Codes for Specific System Addresses

Video Players (system address = 4)

Command Address	C5	C4	C3	C2	C1	C0	Symbol (IEC417)	Command Allocation
34	1	0	0	0	1	0		picture slow run reverse
37	1	0	0	1	0	1		picture frame by frame reverse
38	1	0	0	1	1	0		slow run forward
39	1	0	0	1	1	1		slow run reverse
40	1	0	1	0	0	0		picture slow run forward
41	1	0	1	0	0	0		picture frame by frame forward
42	1	0	1	0	1	0		picture fast run forward
44	1	0	1	1	0	0		picture moderate run reverse
45	1	0	1	1	0	1		eject
46	1	0	1	1	1	0		picture moderate run forward
47	1	0	1	1	1	1		picture normal run reverse
48	1	1	0	0	0	0		pause

Command Codes for Specific System Addresses

Tuners (all) (system address = 8 and 17)

Command Address	C5	C4	C3	C2	C1	C0	Symbol (IEC417)	Command Allocation
30	0	1	1	1	1	0	+	automatic search +
31	0	1	1	1	1	1	–	automatic search –

Command Codes for Specific System Addresses

Phono (system address = 21)

Command Address	C5	C4	C3	C2	C1	C0	Symbol (IEC417)	Command Allocation
59	1	1	1	0	1	1	- - -	arm-up
60	1	1	1	1	0	0	- - -	arm-down