Camera On Model Train

Get the right perspective!

PAL TV Pattern Generator

E-Key Secure Access System

Electronic Bell for Christmas

Mini Audio Amp for PCs

Regenerative Receiver

LCD Driver for BASIC Stamp II

GBDSO Part 2

9 770268 451081

GBDSO

Gameboy Digital Sampling Oscilloscope (2)

Part 2: PC link, DSOGrab, construction and testing

Design by Steve Willis

PC reads an initiation byte from the serial port via pin 10. The PC will then write back to the GB via pin 2 and serial transfer commences. Two modes of transfer are possible:

Screen transfer where the entire screen is sent to the PC and saved in a .BMP format.

Data transfer where the actual data values of CHA/B are sent to the PC.

The raw data format is as follows:

600 bytes of CHA data, 600 bytes of CHB data.
CHA position, CHB position, CHA gain, CHB gain, TIMEBASE setting (1 byte each).

The CHA/B data values are the actual screen points and have a range between 7 and 127. The CHA/B position bytes are where the trace zero reference markers are on the screen, again between 7 and 127. The CHA/B gain values are between 0 and 9, with 0=OFF and 9=10V (see 'Standard Menus'). In FFT mode 0=OFF and 9=35dB (see 'Getting the most out of the FFT'). The TIMEBASE setting is between 2 and 26, with 2=5uS and 26=500S (see 'Standard Menus'). In FFT mode 2=100KHz and 12(max)=10Hz (see 'Getting the most out of the FFT').

When data is saved as MathCad 6.0 format, data and position values range between 0 and 127. The GAIN

The PC Link Interface

Data may be transferred from the GB to a standard PC computer via a link lead, which connects the GB link port to the PC printer port. The associated software utility to run on the PC is called 'DSOGrab' and may be obtained on floppy disk (see Software Items inset). The GB link port is in fact a serial data port but unfortunately the data format is non-standard and therefore has to be read as a data stream by the PC and converted back into byte format. The connections of the GB link port are shown in **Figure 7**.

All outputs and inputs to the GB link port are TTL compatible and can be connected directly to the PC printer port. Extra care

must be taken when wiring the link lead to make sure all the connections are correct as errors could cause permanent damage to the GB or PC ports. The loop-back connection between pins 4 and 11 is used to test if the software can see the connector and is used for fault diagnoses.

The GB link port contains an 8-bit shift register, which contains the current data byte to be sent or read. Clocking of this register can be done externally by pin 3 of the printer port. Initial synchronisation between the GB and PC is achieved when the
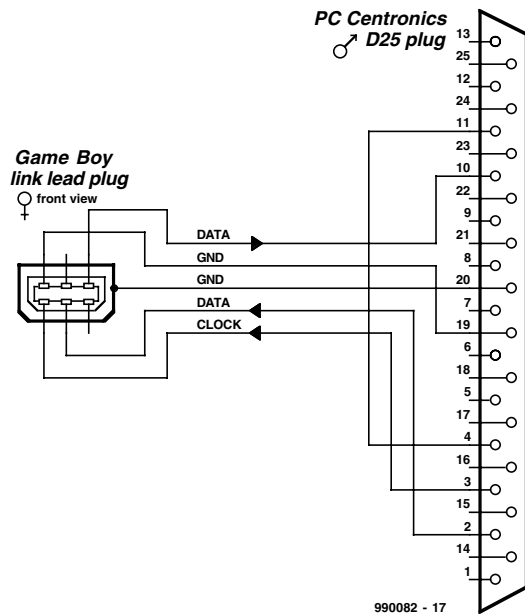
Figure 7. GB to PC link lead (view shows front of plugs).

and TIMEBASE values are converted to floating point values representing the actual scale settings. A MathCad demonstration file is included in the Windows 95/98 link software disk supplied for this project.

Assembly

Assembly will require a very steady hand and some practice if you have never soldered surface mount assembly (SMA) components before. Soldering will require a fine tip iron with a 1-mm tip, 26-gauge low melting point solder or solder paste and pair of fine tweezers. A solder wick is useful for removing excess solder, but do not use a solder sucker as this will probably break the PCB tracks. There are two methods of building the circuit, if you are competent at SMA handling then you skip the step by step approach below.

The following steps allow each semiconductor to be soldered and tested in turn to check for

COMPONENTS LIST

All components SMA (surface mount assembly)

Resistors:
SMD case 0805, 0.1 watt
R1,R2,R4,R8,R9,R11 = 1MΩ 1%
R15 = 15kΩ
R5,R12 = 470kΩ 1%
R3,R6,R7,R10,R13,R14 = 4kΩ7 1%
R16,R17 = 100kΩ 1%
P1,P2 = 100kΩ preset

Capacitors:
SMD case 0805
C1,C10 = 18pF NP0

C2,C4,C5,C8,C9,C11,C12,C14,C17-
C21,C23,C27,C29,C30 = 100nF
C3,C13 = 1pF8 NP0
C6,C15 = 15pF NP0
C7,C16 = 220pF NP0

Electrolytic capacitors
SMD Case A
C22,C24,C25,C26,C28,C31,C33 = 10µF 16V

Inductors:
L1,L2,L3 = 100µH

Semiconductors:
D1,D2 = BAV199 (print on case: JY)
D3 = ZR25D01 (print on case: 25R)
IC1,IC3 = MC33182D (Motorola)

IC2 = DS1267S100 (Dallas Semiconductor)
IC4 = MAX114CAG (Maxim)
IC5 = 74HC175D
IC6 = 74HC138D
IC7 = AT27C256R-12JC in PLCC44 case (programmed, Publishers' order code **996528-1**) (Atmel)
IC8 = TLC27L2CD
IC9 = MAX828EUK (print on case: AABI) (Maxim)

Miscellaneous:
S1,S2 = "Secme' slide switch, 1 changeover contact, PCB mount
K1,K2 = 3.5mm PCB mount stereo socket (make sure it fits the board)
PCB, Publishers' order code **990082-1**
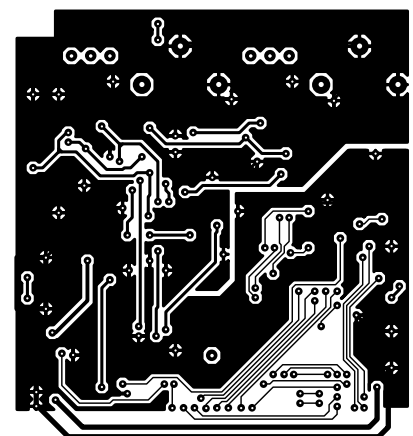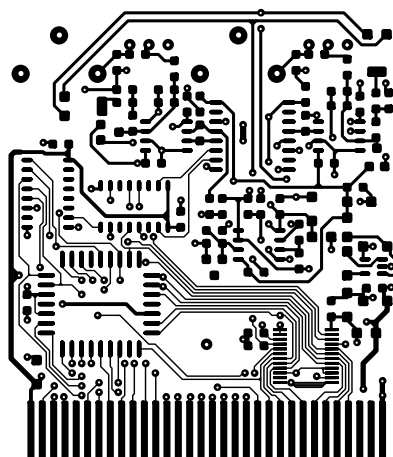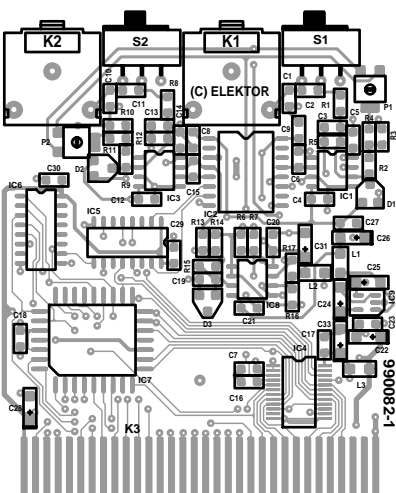Disk, Publishers' order code **996035-1**

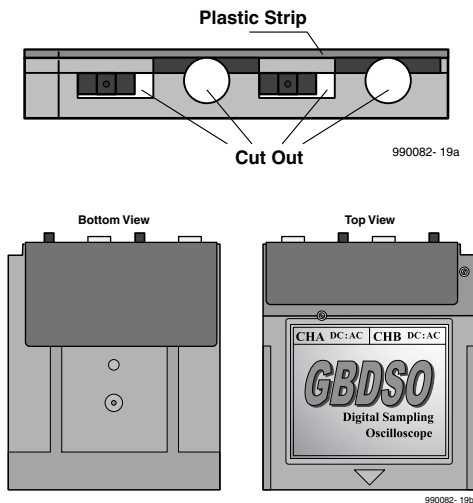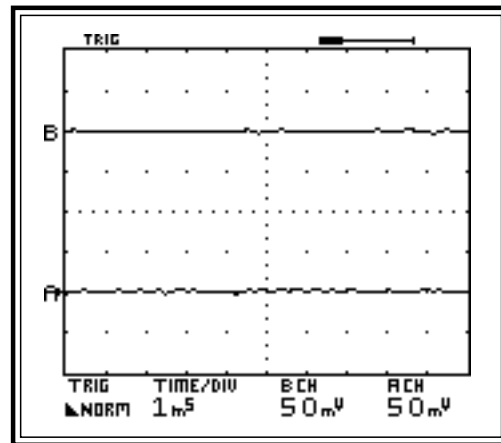Figure 8. PCB design for the double-sided through-plated cartridge board.

Figure 9. ROM case cut outs, and home made metal film.

Figure 10. Calibrating the 50 mV/DIV range on CHA and CHB

Did you know

that all hyperlinks printed in this magazine are directly accessible through the Hyperlinks page of our website at http://www.elektor-electronics.co.uk ? No need to type urls anymore, plus we'll do our best to keep track of websites moved since publishing the magazine.

short circuits during assembly.

1. Disassemble the plastic ROM case (see below) and place the PCB in the bottom. Carefully plug it into the GB. Switch on and check the black scrolling start screen appears. If not, there is a short on one of the GB interface tracks.
2. Solder the EPROM onto the PCB taking the usual static precautions. A good tip is to solder just two corner pins first and get the device aligned before soldering the rest of the pins. Place the PCB back into the case and switch on. The GBDSO intro screen should now appear and all the scope menus should work. If not, check for shorts.
3. Now solder the MAX114 ADC and 74HC138 and check that the unit still starts.
4. Finally solder the 74HC175 and DS1267 EPOT devices and capacitors C17, C30. Check the unit still starts. If not, check for shorts.

Start with the resistors and small capacitors, taking care not to short any tracks or touch the edge connector with solder. Some tracks run under components, and care should be taken not to short out these tracks. The

inductors and tantalum capacitors are next, followed by the semiconductors. Note that the tantalum capacitors and semiconductors must be soldered the correct way around. Static precautions **must** be taken when soldering the sensitive input amplifiers IC1 and IC3. Finally, solder the jack sockets and AC/DC switches. It is advisable to cut the socket leads flush to the board before soldering and then gently file/sand the joints to be flat to the PCB.

The ROM cartridge is a standard case, which can be obtained from an old game. It is held together with one tamperproof screw that can be undone with a pair of fine nose pliers or cutters if the correct tool is not available. It is necessary to cut and file out the back of the bottom plastic case to accommodate the jack and AC/DC switches at the rear of the ROM cartridge — see Figure 9 and the photographs. The PCB should now fit snugly into the bottom of the case. Finally, the top case section must be cut to give enough clearance for the jack sockets. It is
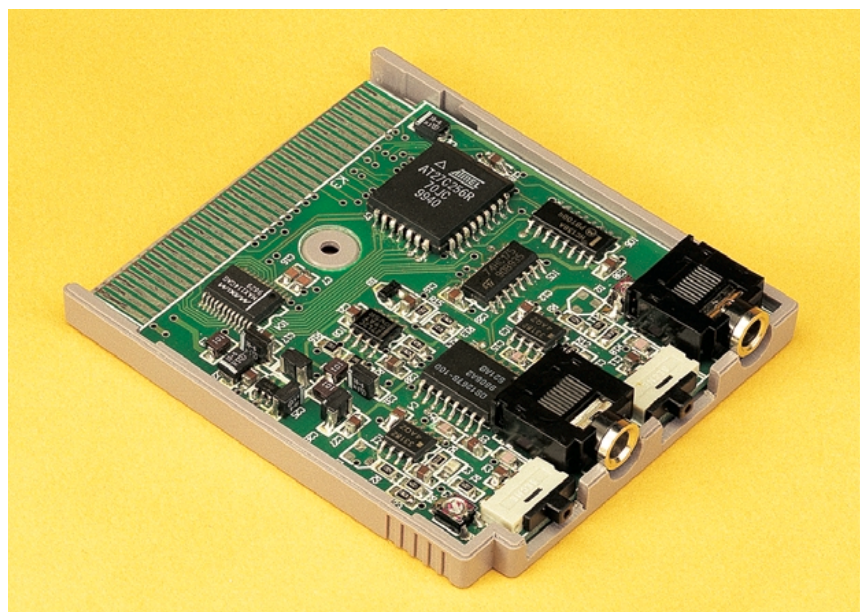

Figure 11. Completed cartridge board, ready for inserting into the Gameboy console.
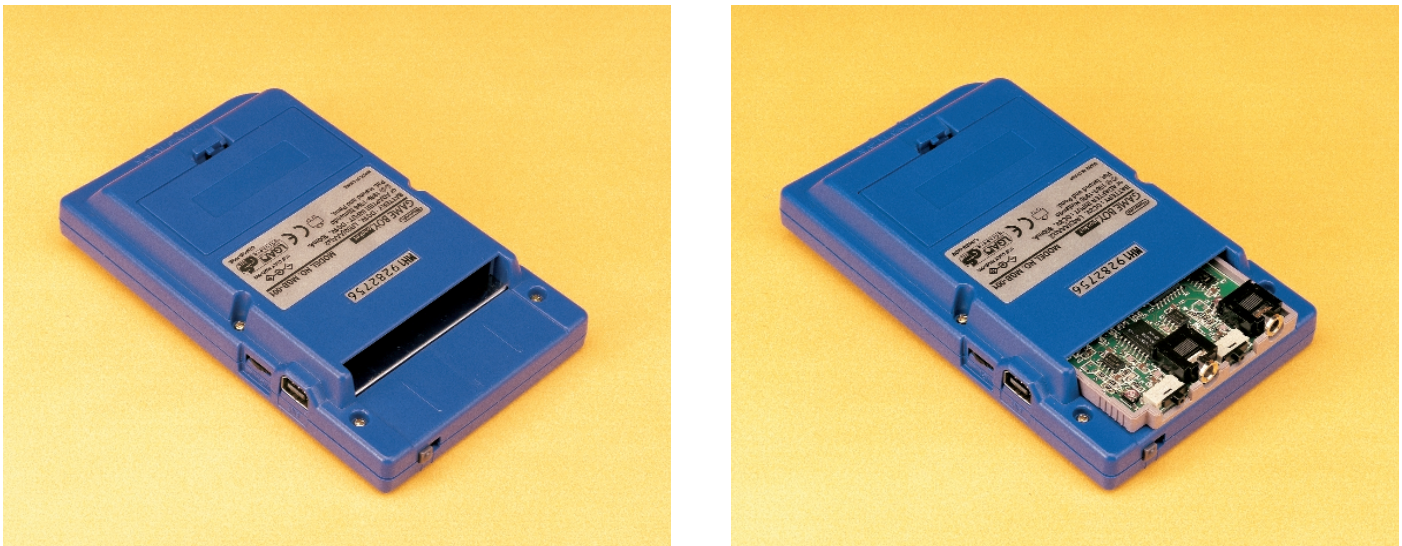
Figure 12. Rear view of Gameboy console with GBDSO cartridge removed (left) and installed (right).

advisable to stick a thin sheet of plastic (1×17×55mm) along the top of the cartridge for strengthening. To improve the GBDSO performance when measuring small signals, a thin sheet of metal (copper or aluminium) is bent around the case and stuck with double-sided tape. This is grounded by the jack plug nuts. This reduces interference caused by the LCD controller that can be picked up by the high impedance input amplifiers.

Test and calibration

To test the scope, switch on with no inputs applied and select dual-channel AC from the start screen. Set the AC/DC switches to DC (right), and both traces should appear in line with their respective A/B marker on the left-hand side. If not, adjust the DC zero level of the input amplifiers with the presets P1/2 so the traces are correctly aligned. If the traces are still not visible, check the DC voltages around the input amplifiers and ADC and compare these with the circuit diagram. Next increase the input sensitivity to 50 mV/DIV and adjust the presets again to finely calibrate the DC levels as shown in **Figure 10**. Set the sensitivity back to 1 V/DIV and apply a 1 kHz 1 V_{pk} sine wave to the either input channel and check that each trace responds to the signal. Next, apply a DC voltage to the inputs (e.g., 5 V regulator) and check the Y scale calibration. If you switch

the inputs to AC then the traces should return to their zero position.

Scope probes

For normal operation, conventional scope probes with a 1:1 or 10:1 switch give ideal performance and extend the input voltage range by a factor of ten. The screen scale is calibrated for 10:1 probes (9 MΩ resistance) and one should remember to multiply the scale by a factor of ten when using 1:1 probes (0 MΩ resistance). Most commercial probes come with a BNC plug attached, which should be replaced with a mono 3.5-mm jack plug to connect to GBDSO. Care must be taken when selecting the probe to ensure that the compensation network is in the probe end and not the BNC connector. Often, soldering the inner wire is difficult and plated wire should be cleaned first.

(990082-1)

References:
1. Digital signal Processing – Ifeachor Jervis, ISBN 0-201-54413-X
2. Z80 Assembly Language Programming – L.A. Leventhal, ISBN 0-931988-21-7
3. Author's Gameboy web page: www-ev.phy.cam.ac.uk
4. Jeff Frohwein's Technical Page: www.devrs.com/gb/
5. Pascal Felber and Michael Hope's GBDK: http://gbdk.sourceforge.net/
6. Ian James GBDS: www.geocities.com/Eureka/9827/

Ready-Built GBDSO Cartridge Boards

Please check our website http://www.elektor-electronics.co.uk for a readership poll and other information on ready-made GBDSO cartridge boards with all SMA parts soldered in place.

7. Dr Pan's Gameboy technical documentation: www.gbdev.org/news/dl.html
8. Paul Robson's GB97 emulator: http://users.aol.com/autismuk/gameboy.htm

urls available as hyperlinks on the Hyperlinks page of the Elektor Electronics website.

Project Software

The following software items may be obtained through the Elektor Electronics Readers Services:

EPROM AT27C256, ready-programmed, order code **996528-1**.
**Disk**, contains DSOGrab utility and MathCad demonstration file, order code **996035-1**.

Please note:
these software items are not available as free downloads from our website because the author retains the copyrights. Also, by contract he receives royalty payments for every copy sold of the project EPROM (996528-1) and disk (996035-1).

An Electronic Bell

a novel decoration not just for Christmas time

Design by D. Petig

With Christmas not far away this project is guaranteed to add a sparkle to the festivities.
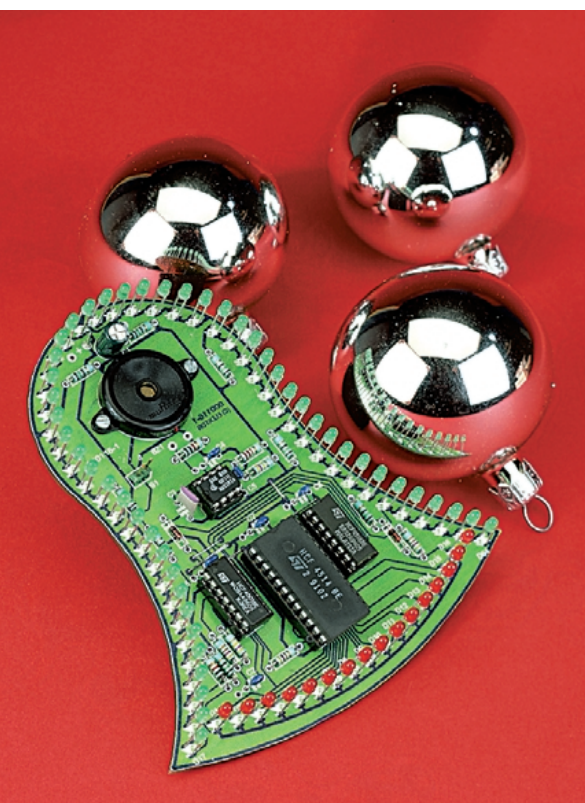
This novel design is of an electronic bell. The shape of the bell is outlined by a series of green LEDs while a moving light point on an arc of red LEDs represents the clapper. Each time the clapper hits the bell a delicate chime is generated.

Circuit description

The circuit diagram shown in **Figure 1** can be divided into two parts. The simplest part consists of 48 green LEDs forming the outline of the bell. The 150 Ω series resistors have been calculated assuming a forward conduction voltage drop of about 1.9 V for each LED so it is important here not to use high efficiency types.

The rest of the circuit is used to control the clapper display and chime generator. 16 red LEDs are used to simulate the bell clapper by a moving light point (again high efficiency types are unsuitable here). IC3a/b together with R1 and timing components R2 and C2 form an oscillator that controls the speed of the clapper. The output of this oscillator is used to clock a binary up/down counter IC4. This counter has four outputs and therefore counts up from 0 - 15 or down from 15 - 0 depending on the logic state of its up/down input. The outputs of this counter are connected to the inputs of the decoder IC2. This chip will set high only one of its 16 outputs corresponding to the binary code at its four inputs. Each of these 16 outputs is connected to an LED. The outputs representing each end of the binary count (pin 11 and pin 15 of IC2) are also used to toggle a flip-flop formed from IC3c/d. This has the effect of switching the counter to count down when it reaches its maximum count and to count up when it reaches its minimum count.

The overall effect is that the red light point swings continually backwards and forwards between D1 and D16.

The gong with eight legs

The two trigger signals from IC2 are also connected to an OR gate formed by diodes D65 and D66. The output of the OR gate is connected to the trigger input of IC1. This component is the SAE800 gong IC manufactured by Infineon. (**Figure 2**). This IC produces a single, dual or triple tone sound envelope from a single trigger signal and can directly drive a small loudspeaker or piezo sounder. The frequency of the tone is set by the values of C3 and R6 and the output volume by R7. The internal logic not only controls sequencing of the tones in the sound envelope but also the volume of each tone and its sustain time. Altogether each gong sound lasts for approximately 7 s. This chip has many interesting features and a copy of the datasheet is available for download from the Infineon website at: http://www.infineon.com.

In our application the IC is operated in its single tone mode, the intention here is to imitate the delicate chime of a glass hand bell and not the deep sonorous clang of Big Ben. The operating frequency is given as $f_0 = 0.03125/(R6/C3) = 4300$ Hz. This is relatively high and a piezo sounder is well suited to reproducing this frequency.

Circuit tuning

This circuit lends itself well to a bit of experimentation. The pitch and sustain of the bell ring can be adjusted by altering the value of capacitor C3. Increasing the capacitance will produce a lower note with a longer sustain.

Figure 1. The electronic bell circuit.

The values of R2/C2 govern the speed of the clapper. Using a smaller value of capacitor C2 or reducing the resistance of R2 will speed up the oscillator and make the light point move faster. If you want the speed to be adjustable, R2 could be replaced by a fixed resistor of 47 kΩ in series with a 1 MΩ preset potentiometer. Increasing the speed too much however, will cause the sound of the chime to go out of step with the displayed clapper. In this case the gong IC will be receiving new trigger impulses before it has finished with the previous chime.

A stabilised 12 V mains unit can be used to power the circuit. Current consumption is in the order of 50 – 55 mA.

Figure 2. Block diagram of the SAE800 Gong IC.

PARTS LIST

Resistors:
R1,R3,R4 = 47kΩ
R2,R7 = 470kΩ
R5,R8 = 1kΩ
R6 = 22kΩ
R9-R16 = 150Ω

Capacitors:
C1 = 100µF 25V radial
C2,C4-C8 = 100nF
C3 = 330pF

Semiconductors:
D1-D16 = red LED (no high-efficiency)
D17-D64 = green LED (no high-efficiency)
D65,D66 = 1N4148
IC1 = SAE800 Siemens/Infineon (Eurodis)
IC2 = 4514
IC3 = 4001
IC4 = 4516

Miscellaneous:
S1 = 2-pin header with jumper or switch
BZ1 = AC (Piezo) buzzer with connecting
   wires (dia. 24 mm).
PCB, order code 000116-1 (see Readers
   services page)
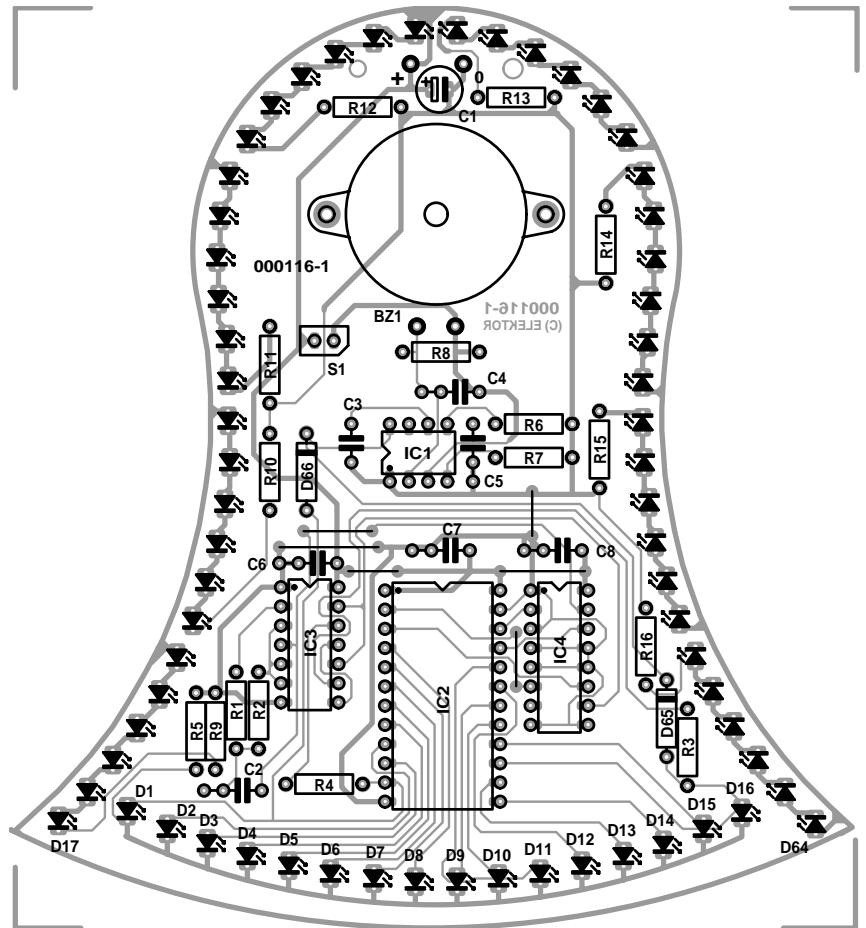
PCB assembly

Shown in **Figure 3** is the assembled PCB. Fitting the components should be quite straightforward and investing a little time and patience here will be well repaid in the finished product. All components with axial leads should be carefully bent to fit the position on the PCB (not forgetting the four wire jumpers) and then soldered into place. The best method of mounting the LEDs is to fit them into their positions on the PCB, flip the board so that it is track side up and on an even surface, then carefully solder only one lead of each LED. Now check that you really did mount them all the right way round! Also now you have the chance to slightly re-position them, if necessary, to ensure they are exactly in line with the outlines. Next solder the second leg of each of the LEDs and fit the remaining components onto the PCB. The board should be given a final inspection before power is applied and the jumper across S1 is inserted to enable the Gong IC.
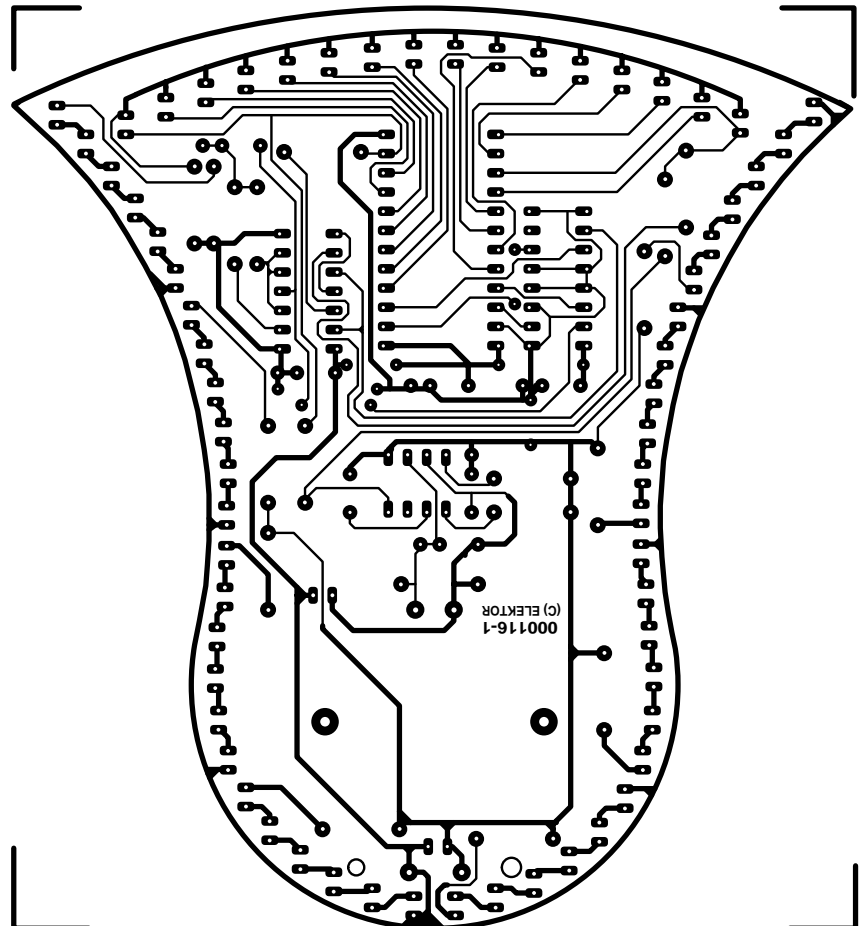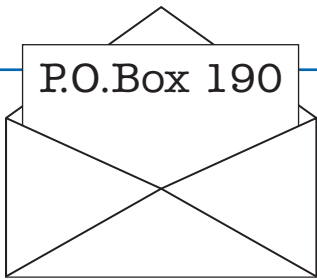
(000116-1)

Figure 3. The electronic bell PCB is available ready-made through our Readers Services.

P.O.Box 190

Oscar MP3 Player

Dear Editor, correct me if I'm wrong, but is the data given in Table 2 (IDE Register Set) not incorrect in that /CS1FX and /CS3FX are transposed. All of the research that I have conducted into this area I'm also developing a MP-3 Player) suggest that the data is transferred to and from the dive when /CS1FX is active. Data is transferred to and from the dive when /CS1FX is active. See http://minyos.its.rmit.edu.au/~s990678/pic/IDE_to_8255.html or http://www.prjc.com.

**Richard Broughton,
by email**

The OSCAR design team replies:

The signals /CS1FX and /CS3FX are " active low " which means that if they are active the actual voltage level on the line is low. So, in the table, the DATA register is listed with /CS1FX = '1' which means that as it is active-low the level on the line would be low.

**Vladimir Pantelic,
by email**

Delphi programming, please

Dear Editor, I have been reading Elektor for the last 10 years and the articles and projects are great. I was pleased to see the PC Peripheral Design and the USB projects. However, I think (and hope) that the Delphi programming language would be a better choice for interfacing and accessing the PC ports and others. Delphi is easier than VB, can access the ports easy through simple and short in line assembler routines, is fast and does not need any runtime or other .dll files. At this time Delphi is inexpensive to get, and I'm sure that most of your readers should have it along VB and others. Actually, computer magazines like PC Plus supplied Delphi 1, 2 and 3 on their covers in the last year or so. Anyway, it's always good to be wishing, but you never know... Keep up the good work.
Alexandre Cazin, by email

Thank you for your suggestion, it has been copied to our design staff.

Size, does it matter?

Dear Editor, I have just had a quick look around your website, and decided to download a file — the one I downloaded was 000122-11.exe, a self extracting zip file (size about 47K). When I ran this I got the PDF file — size 23K! Why do you convert a file to be a self-extracting zip, if the resulting file is bigger than the original?
**Mark Fiddament,
by email.**

In the past we've had serious problems with pdf documents opening automatically and inadvertently in browsers like IE5.0, and readers being unable to save the file from there. We gave out instructions to readers to right-click on the download button, change browser settings etc, but to no avail, we still got hundreds of questions about this every week. You have to realise that our downloads go by the thousands every day and not everyone is experienced enough to solve such a problem, while we do not have the time to deal with individual enquiries. So for that reason we decided to change to .exe files only. Also, we can not assume just like that that everyone has Winzip.

Moving urls...

Dear Editor, I was unable to find the Visual BASIC webpage you mentioned in your otherwise excellent article "USB Interface".
Grace McLeigh.

Apparently Microsoft moved the information to http://msdn.microsoft.com/downloads/default.asp?url=/code/sample.asp?url=/msdn-files/027/000/133/msdncompositedoc.xml
All readers should note that urls printed in the magazine are subject to moving by their originators. Using the Hyperlinks page on our website at http://www.elektor-electronics.co.uk we will do our utmost to keep track of moved urls, and publish an alternative or corrected url whenever possible. In this case, the corrected url is available as hyperlink from our website, so you need not even type into your browser.

Twinkling GSM antennas

Dear Editor, regarding the 'Twinkling' antenna type of call indicator mentioned in the 'GSM Call Indicators' instalment of your series E-Insider, you may wish to look at the following references and attachments and maybe publish a warning about their effects in a future edition. This information is being posted purely in a personal capacity as a subscriber and reader of Elektor and not in any official capacity. The information attached is publicly available from the Radio Agency's (RA) website. http://www.radio.gov.uk/busunit/ptnu/cellular/index.htm http://www.radio.gov.uk/busunit/research/rtcg_564/proj564.htm
Martin King, by email

Thank you for warning note, the technical report you attached with your email, and the hyperlinks to further information on the subject. Readers should note that our description of the 'twinkling' GSM antenna variety does not imply that we encourage its practical use. Indeed, based on the above mentioned report its use should really be banned mainly because of the higher harmonic signal levels generated as a result of transmitter output mismatching.

Regenerative SW Receiver

A shortwave receiver with very interesting characteristics

Design by B. Kainka
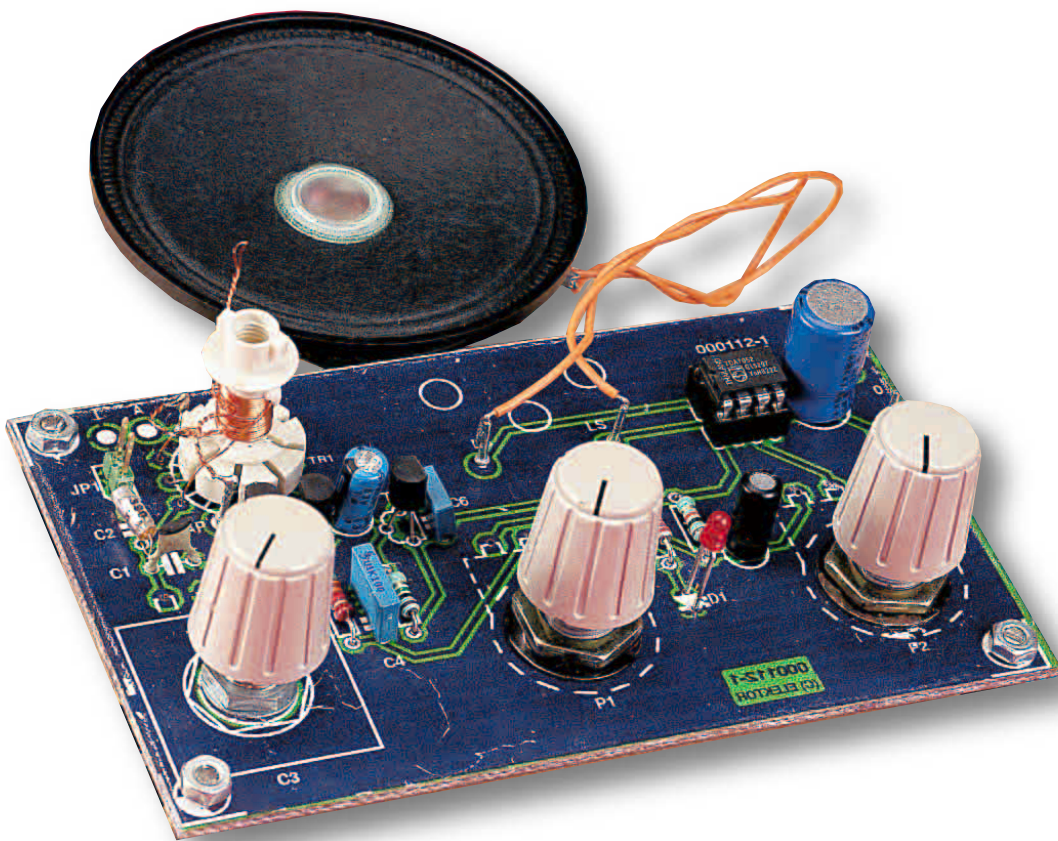
Building radio receivers is the classic introduction to electronics, usually by constructing simple detector type receivers for medium wave reception. However during the day there is not much to listen to. Almost as simple to build but much more interesting is the classic direct-conversion type short-wave receiver. Not only can it receive stations from around the world; this set pulls in SSB and CW transmissions as well.
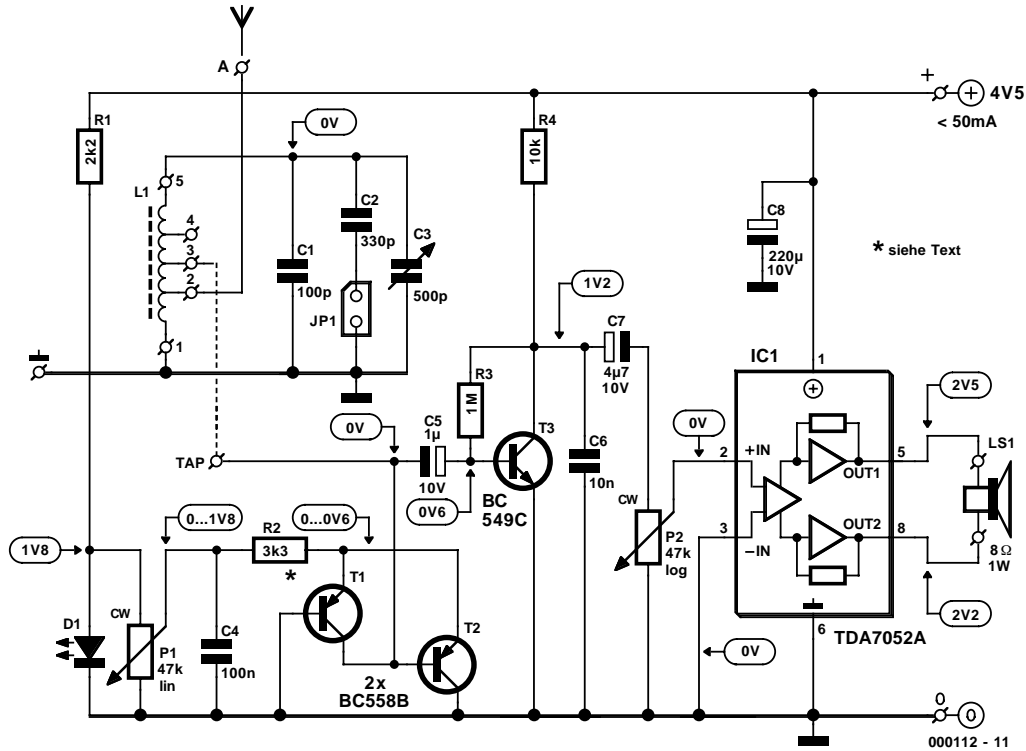
Figure 1. Circuit diagram of the Direct-Conversion Receiver.

Back in the mists of time when radio communication was still in its infancy, the earliest radio sets used just one valve, either a triode or pentode, and were based on the direct conversion design, often employing 'Audion' demodulators. Apart from the tuning knob there would be a second knob that controlled regeneration in the tuning circuit. Those skilled at using the radio set were able to draw down signals from the ether: The BBC Home Service, Radio Luxembourg…

Nowadays in the age of the superheterodyne it is all too easy to overlook the merits of those early designs. Using modern components it is much simpler to build such a radio, not only simpler but also the resultant set is better! With just one coil, three transistors and an integrated amplifier you can build a simple short wave receiver that has remarkable performance.

Principles

The direct conversion type of receiver simply amplifies the received signal at its antenna, and demodulates it. Unlike the super-

heterodyne receiver there is no frequency converter using a fixed intermediate frequency (IF).

The disadvantage of the direct conversion receiver design is its poor selectivity. It usually has one or two tuned circuits that must be tuned to the desired transmitter signal. With a superhet, its fixed IF means that the IF filter does not need to be adjusted to change frequency. Here you can use a filter with almost ideal characteristics since it does not need to be adjustable e.g., a ceramic filter

By use of a simple trick in the direct conversion receiver we can overcome its shortcomings. The amplified output signal from the tuning loop is coupled back to the input of the circuit. This positive feedback loop has a regenerative effect and boosts the Q or quality factor of the tuned circuit, thereby greatly increasing the selectivity of the radio and reducing the tuned circuit's damping loss. The optimal operating point for the circuit is just when the circuit is on the verge of oscillating, i.e. the positive feedback is just less than damping effect of the circuit. Increase the feedback anymore and the circuit starts to oscillate, the

receiver has turned into a transmitter! You may think this effect is a disadvantage but for receiving SSB and CW signals it becomes an advantage: the oscillating tuned circuit acts like a BFO and regenerates the missing carrier frequency, allowing these signals to be demodulated.

The Circuit

The circuit in **Figure 1** shows the circuits clear layout. The receiver consists of a resonant loop, a two stage HF amplifier (T1 and T2) with variable gain and feedback (regeneration circuit). Transistor T3 demodulates the signal and an integrated circuit amplifier drives the speaker.

The resonant loop is a parallel resonant circuit consisting of a coil in parallel with some capacitors. In this circuit, there are three capacitors in parallel to the coil C1, C2 and C3. For tuning the radio there is a variable capacitor, while the other capacitors are connected in parallel to the coil to give the tuning range. C2 is connected via a jumper, when the jumper is in place C2 is also in parallel with the coil and alters the tuning range of the receiver.

A variable capacitor is used for tuning the radio. If you take a look at most modern receiver designs, you will find varicaps are generally used for tuning. The capacitance of
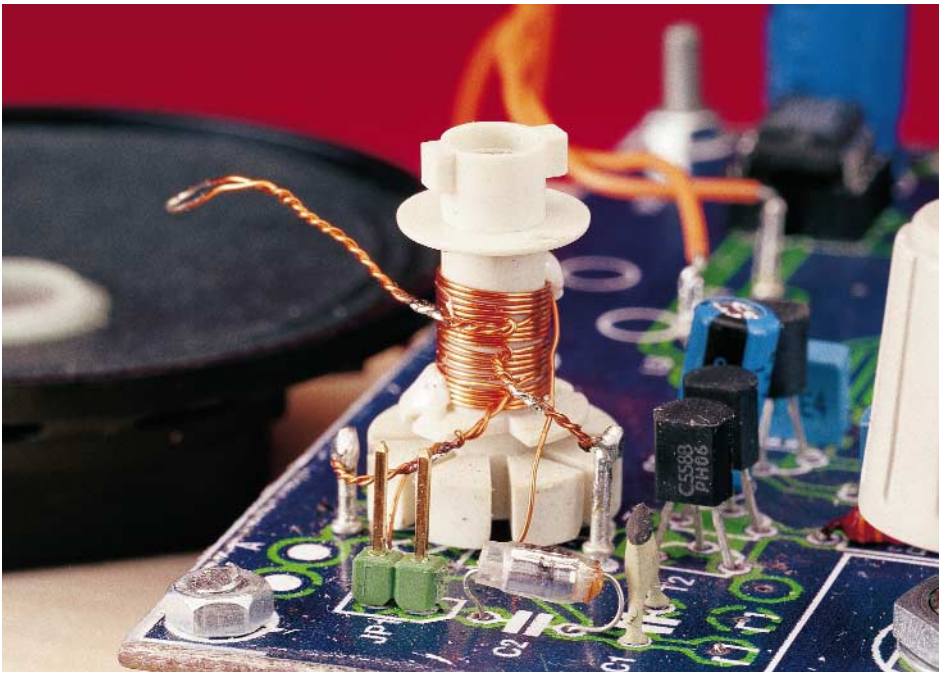
Figure 2. The single coil is simple to build.

a varicap is a function of the voltage across it. These devices are fine if you are using a PLL for the frequency tuning but they are not ideal for manual tuning using a potentiometer. Their operating voltage needs to be very stable and they cannot match the specification of a good air-spaced variable capacitor.

The coil winding has three taps to enable the connections of the antenna and the regeneration circuit to be adjusted.

The regeneration circuit itself looks very simple but requires closer inspection to fully appreciate its workings (see the text box). The stage employs feedback, the input (base of T2) and output (collector of T1) are connected together at the coil at point 'TAP'. The overall configuration works like a negative dif-
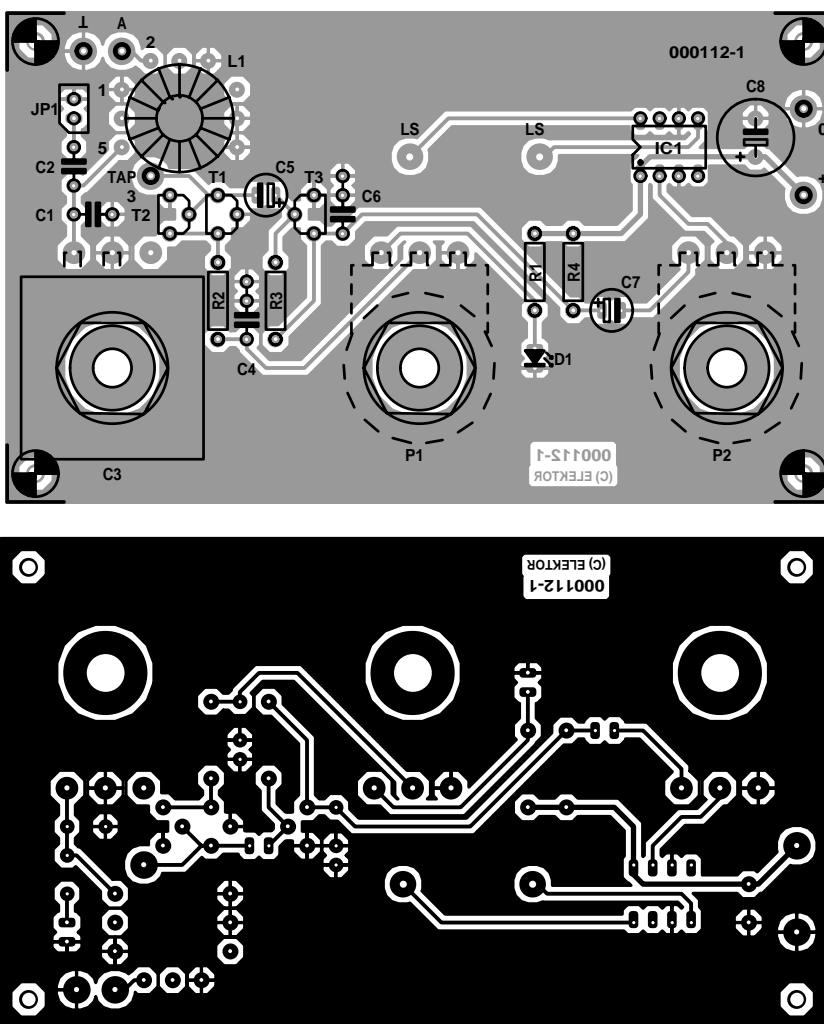
Figure 3. Layout of the single sided PCB.

COMPONENTS LIST

Resistors:
R1 = 2kΩ2
R2,R4 = 10kΩ
R3 = 1MΩ
P1 = 47kΩ linear potentiometer
P2 = 47kΩ logarithmic potentiometer

Capacitors:
C1 = 100pF
C2 = 330pF
C3 = 500pF tuning capacitor
C4 = 100nF
C5 = 1 F 10V radial
C6 = 10nF
C7 = 4 F7 10V radial
C8 = 220 F 10V radial

Semiconductors:
D0 = LED, red (high efficiency)
T1,T2 = BC558B
T3 = BC549C
IC1 = TDA7052 (Philips Semiconductor)

Miscellaneous:
JP1 = 2 solder pins with a jumper
PC1-PC6 = solder pins
LS1 = loudspeaker 8Ω 1W
L1 = coil on former (6mm dia., see text)
8-pin IC socket
3 knobs
PCB, order code **000112-1**

ferential resistor and causes regeneration in the tuned circuit. The regeneration circuit can be connected to the 'hot' end of the coil or to a tap point. If the tuned circuit has a relatively high damping factor, it is possible that the lowest tap point will have too low an impedance and it will not be possible for the regeneration circuit to compensate for this. The aerial also introduces some damping. A good setup is to use a long aerial connected at a low tapping point. Theoretically, the tuned circuit will be at optimum when the damping impedance is cancelled by the (negative) generator impedance of the circuit. The emitter current through T1 and T2 controls amplification and regeneration in the tuned circuit. The control current is supplied from the wiper of potentiometer P1 through the emitter resister R2. Capacitor C4 ensures that the emitter resister is shorted to earth at high frequencies. The potentiometer is in parallel with the LED D1 and is used to stabilise the voltage.

The coil tap point 'TAP' forms the connecting point for the regeneration circuit, which is also coupled to T3 via capacitor C5. T3 amplifies and demodulates the HF signal. C6 together with the output impedance of T3 form a low pass network that filters out the radio frequency components in the signal. The resulting audio signal is coupled to the volume control (P2) by capacitor C7, which also blocks any dc voltage that may be present on the signal. P2 is used to adjust the input signal to amplifier IC1. This amplifier is connected in a bridge configuration and can supply 1 W into the 8 Ω loudspeaker with a supply voltage of 4.5 V.

Coil winding

The coil L1 is the only component in this radio that needs to be made at home.

Before you wind the coil you need a coil former with a diameter of approximately 6 mm. This can be can be made of plastic, paper or card. The coil is wound using 0.3 mm (30 swg) diameter lacquered copper wire, and consists of four equal sections each comprising 5 turns. After winding each section of 5 turns, a small loop is formed in the wire and the loop is tightly twisted to make a tap point. The finished coil is shown in **Figure 2**. Altogether it has 20 windings with three tap points, one connection at the start and one connection at the end. All five connections to the coil must be carefully tinned (after first removing the lacquer). If you find that the connections are a little too long after tinning then it's a simple job to trim them using sidecutters.

On the circuit board (**Figure 3**) are some pads for mounting the coil. The bottom end of the coil is connected to point 1, this is at ground. The top end of the coil is connected to point 5 so that the coil is on this side of C1 and C2. The "TAP" connection on the PCB links a tap point on the coil with the regeneration circuit. The connection "2" links another tap point on the coil with the aerial (at connection "A"). Both of these PCB connection points should be fitted with solder pins to make it easier to change tap positions on the coil during experimentation.

Fitting the rest of the components is fairly straightforward, the only point to watch out for is to ensure that all connections made in the RF part of the circuit (everything to the left of C7 on the circuit diagram) should be kept as short as possible.

The best type of capacitors to use for C1 and C2 in the tuned circuit is polystyrene film or NPO type ceramic capacitors.

These days it is not so easy to find a good tuning capacitor. Ideally, a good solidly built air-spaced capacitor from an old radio would do the job admirably. Easier to come by but not quite so good would be a tuning capacitor with a film dielectric like the ones that are found in transistor radios. In an emergency, you could use a trimmer capacitor with a spindle glued to the adjustment screw.

The connections between the variable capacitor, PCB, and the coil must be kept as short as possible. If these components are not firmly attached, any movements will alter the coupling between them and lead to unreliable operation. Using a coil former with an adjustable ferrite core for winding L1 gives an additional method of tuning the loop.

Using the coil described above it is recommended to use the two lowest coil connections to attach an aerial and the middle tap or one above for connection to the regeneration circuit. If the regeneration effect is insufficient, even after adjusting P1, it is possible to alter the value of R2. During tests of the prototype using the PCB it was found that the stated value of 10 kΩ for R2 was too high (the sensitivity was too low). The optimal value for R2 was found to be 3.3 kΩ, this gave P1 the best adjustment range. BC550B transistors can be used in place of the BC558B for T1 and T2.

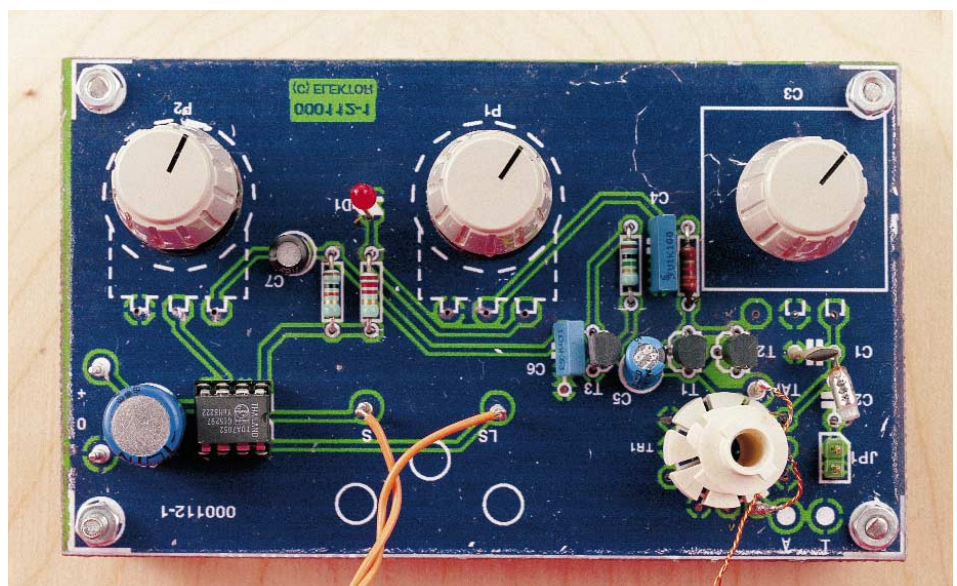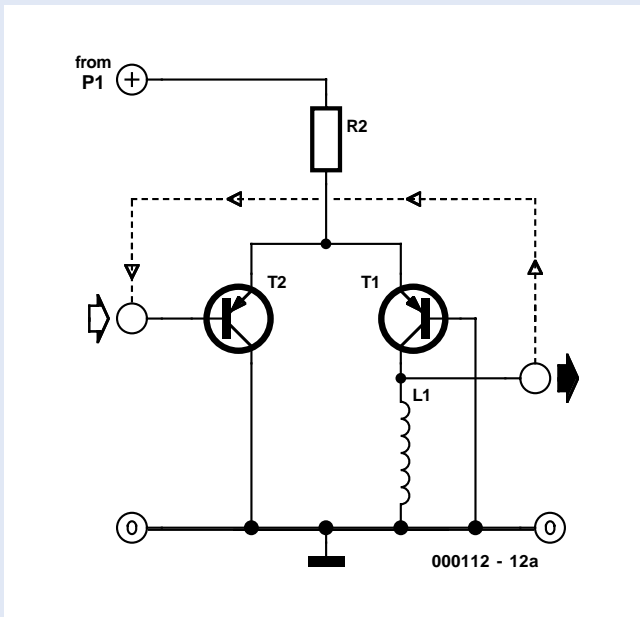## Tuning in

The circuit operates on a supply from 4 to 7 V.

Figure 4. PCB with components fitted. The grid of holes can be used to try out different coils.

The Regeneration circuit

000112 - 12a

T1 and T2 in the regeneration circuit form a two stage RF amplifier configured as a long tailed pair, a configuration that is often used in integrated RF amplifiers. In **Diagram A** the basic principles of design are shown. At first sight T1 and T2 appear to form a differential amplifier but on closer inspection you will notice that the collector of T2 is connected to ground along with the base of T1. From this we can see that T2 is used as a common-collector configuration while T1 is used in the common-base configuration, both transistors share the same emitter resister. To an input signal applied to the base of T2 the transistor acts as an impedance converter (emitter follower), the input signal appears at the emitter of T2 unamplified but in phase with the input signal and with a lower source impedance. This signal at the base-emitter junction of T1

now controls the collector current of T1 (also in phase). The ratio of low emitter impedance to high collector impedance (L1) of T1 gives this configuration its voltage amplification, in which the output signal at the collector of T1 is always in phase with the input. Linking the output of the amplifier back to the input (dotted line) causes the negative feedback to behave as a positive feedback. **Diagram B** shows the regeneration circuit as it is used in the Audion-based receiver. Positive feedback occurs at the connection of the collector of T1 and the base of T2. Both are connected to the coil that forms a resonant circuit with the tuning capacitor. The aerial is also connected to the tuned circuit through a tap on the coil. Received signals are amplified and positive feedback at the input to the regeneration circuit is used to boost the tuned circuit

000112 - 12b
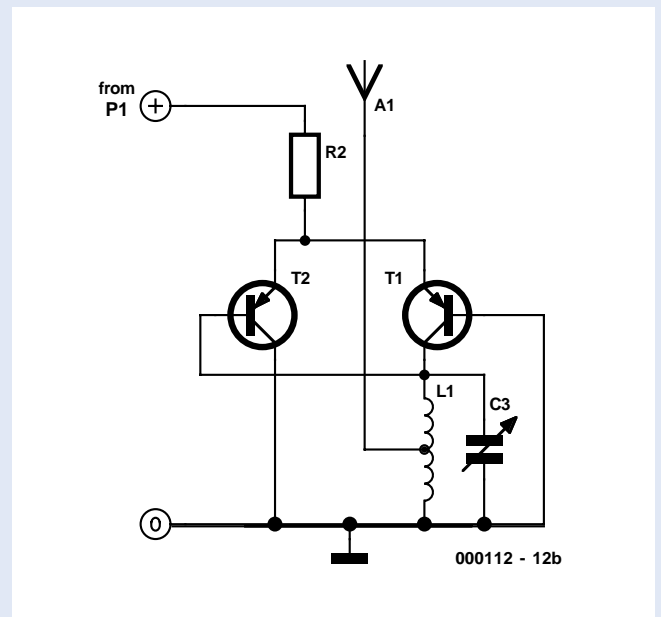
The normal frequency range of the radio goes from 6 MHz to 9 MHz, the actual range depends on the value of capacitors in parallel with the variable capacitor and the number of windings in the pick-up coil. Capacitor C2 can be linked into this circuit to extend the frequency range down to the 80 m amateur band where there are good possibilities of picking up SSB and CW transmissions.

Tuning the radio is best done with both hands, one hand on the tuning capacitor to find the station and the other on the feedback control (middle knob), adjusting the regeneration for best signal strength. With too much feedback (P1 turned clockwise) the regeneration circuit will suddenly start oscillating. This condition is useful to enable the reception of SSB and CW stations. For AM reception however, P1 is adjusted so that the level of regeneration is not quite enough to cause oscillation of the circuit. You will know oscillations have begun when you hear a roaring sound from the speaker and the received signal disappears. Roaring or whistling sounds may also be caused by external sources of interference, for wexample, fluorescent lamps, in this case the roaring will not be quite so loud and the received radio signal will still be audible.

When the feedback is optimally adjusted this circuit offers good sensitivity and selectivity. Some problems which afflict other types of receiver design, for example, blocking due to large input signals and intermodulation problems do not occur with this design because the regenerator only amplifies the desired frequency.

In practice, the clarity and sensitivity of this simple circuit can put some commercial super-PLL General Coverage receivers in the shade. To provide an aerial you will need a length of wire at least 50 cm long but

3 m would be better. The design of this radio will allow reception of many stations in the 49 m and 41 m band, even the 40 m Amateur band (CW) and SSB transmissions on the 80 m band (with the jumper in place to switch in C2) are possible. One refinement that can be made to the design is to use a geared motion tuning capacitor in place of C3. The circuit can also be modified to incorporate switched coil sections in L1 to make this into an All-Band or receiver.

000112e

XICOR X9258T, 9250T

Digital Controlled Potentiometers
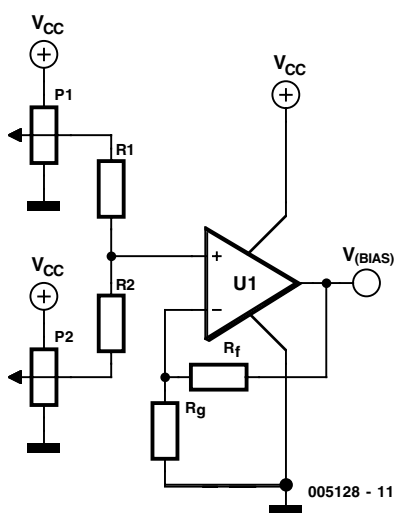
By P Gareth Lloyd

pglloyd@iee.org

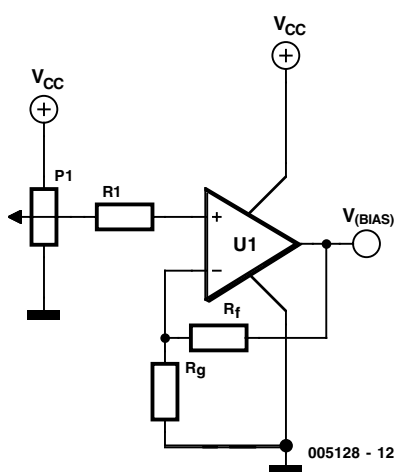Figure 1. XDCP-based wide range bias driver for RF power amplifiers.

Figure 2. High resolution biasing of LDMOS transistors.

One of the most important aspects of PA design is the biasing network. It is important for the bias network to reject RF power. Using high impedance sources where possible accomplishes this. Where low impedance sources are used, it is imperative to maintain a good decoupling regime, to maximize the transistor's performance.

At the FET drain (GaAs or LDMOS), it is necessary to use a low impedance bias supply. For transistors not biased class A, the current versus output power characteristic is dynamic, and any residual power supply impedance will cause amplitude modulation of the drain voltage.

Most commercial power amplifiers have a bandwidth typically of a maximum 10%, and therefore it is possible to supply drain current using a RF shorted quarter wave section (which will transform to an open circuit at the feed point). For wideband applications (octave plus), it is generally better to use an inductor to feed bias to the drain.

The bias voltage may be fed onto the transistor gate-matching network via a surface mount resistor. Typically, the resistance would be of the order of a few hundred ohms to ensure that minimal RF power leaks through the resistor into the biasing network. As the gate is extremely high impedance and therefore the current requirement is negligible, it is possible to use the smallest package size readily available (typically 0603). This will reduce the effect of any package parasitic resonance, maximizing stability and performance.

For LDMOS applications, thermal compensation would be done using either a simple analogue compensation scheme or using DSP to control the XDCP. The gate voltage change with respect to temperature (for constant drain current) is around -2mV.K^{-1}. Normally, the compensation constant would be a slightly different to this to maintain a constant gain versus temperature response. The biasing (quiescent current) requirement varies between applications, but for a typical SCPA (single carrier power amplifier) a quiescent current tuning resolution of 1% of Idq_opt is all that is needed. Idq_opt is the typical bias condition, which offers maximum dynamic gain flatness and almost optimum two-tone third order intermodulation distortion when a device is biased class AB. This is easily achieved using an 8-bit XDCP, X9258T or X9250T with 256 wiper positions.

Application	Resolution
MCPA (Multi Carrier Amplifier)	8-bit or 2 x 6-bit
Large Dynamic Conduction Angle Variation	2 x 6-bit
SCPA (Single Carrier Amplifier)	6-bit or 8-bit

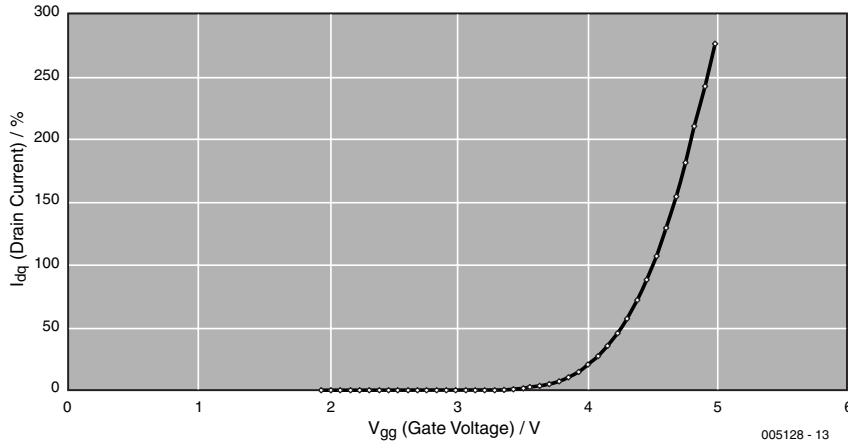Some applications, for example MCPA (multicarrier power amplifier)

Figure 3. LDMOS DC operating characteristic, drain current (% of Idq_opt) as a function of gate voltage.

may require finer bias control or greater dynamic range to optimize dynamic gain flatness. In some cases, it may be desirable to actually change the bias class (conduction angle) completely, from A through AB to B and possibly beyond.
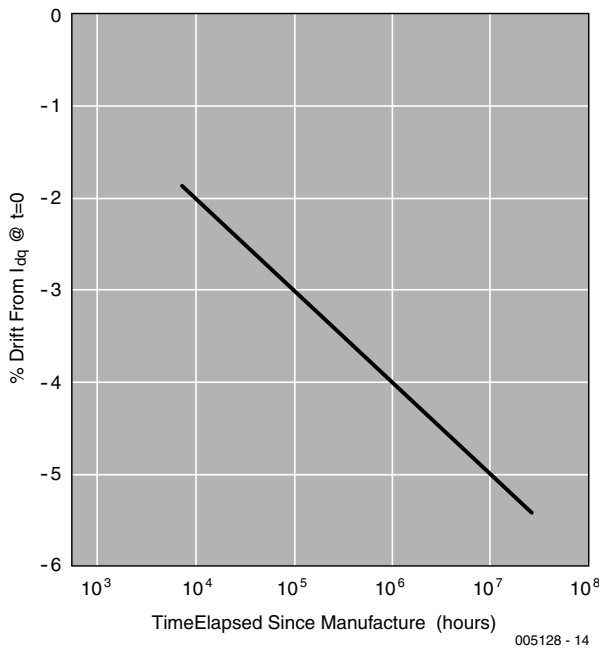
As shown in **Figure 1**, this can

also be easily achieved using two XDCPs and a weighted summing network at the buffer op-amp input … effectively doubling the bit resolution. Two combined 6-bit (64 positions) XDCPs can achieve 12-bit (4096 positions) resolution.

By selecting the ratio R1/R2 to be the same as the number of tap points (in this case 6 bits = 64 positions), it is possible to achieve a dividing resolution of more than 4000 wiper positions. This arrangement is more than adequate to provide high resolution biasing of LDMOS devices, while giving maximum flexibility to bias the transistor in any class of operation.

In the circuit shown in **Figure 2**, The X9250 8-bit potentiometer will generally give the required voltage resolution, especially when the range of voltage outputs is conditioned. This can be done by selecting upper and lower limits for the high and low side of the potentiometer.

Additionally, the op-amp buffer allows further flexibility for range adjustment and the introduction of an offset.

A typical LDMOS transistor requires a change of approximately 2.5mV in gate voltage to effect a 1% change in drain current. (**Figure 3**). It is therefore possible to use a single 8-bit potentiometer to tune over a range of 0.6V with 1% resolution. Using the 2 x 6-bit potentiometer example highlighted earlier, gives the potential for 1% resolution over a 10 V range, though normally the range would be reduced to allow greater resolution.

On-chip memory is another feature incorporated in most of the XDCP range. This allows the designer to load a set of four values for each potentiometer, and dynamically assign the memory register to the potentiometer at any point in time.

Generally, it is not necessary to use these memory settings. The settings would nor-

Figure 4. Typical LDMOS drift characteristic.

mally be stored and controlled by an external processor and memory. Reloading new values to the wiper register doesn't result in any spurious noise at the wiper.

This allows the PA bias setting to be dynamically reprogrammed while 'hot' with RF power, with no detrimental (or even detectable) effect.

This is theoretically the worst time possible to change bias conditions on the transistor, as any spikes on the bias supply could result in large amounts of current drawn by the transistor, enhanced by the RF power, with possibly terminal consequences.

The memory settings are most likely to be utilized for many power amplifier design features.

Digital thermal compensation

Thermal conditions are monitored by the system microcontroller. This can use a look-up table or algorithm to calculate the best operating point for the transistor. A preset list of discrete values can be loaded into the memory at production time, and loaded into the wiper register when necessary.

Vg/Id drift compensation

LDMOS transistors suffer from performance drift over time. The net effect is that a slightly increased amount of gate voltage is required to maintain a given drain current. LDMOS processes are being refined continually, and current drift figures are typically 5% over 20 years. Most of this drift occurs while the amplifier is undergoing test in the factory; effectively burning the device in, before delivery. Drift is also proportional to the process cutoff frequency. A typical drift characteristic is shown in **Figure 4**.

Other RF Applications – An Example

The XDCP can be used in a wide variety of other RF applications. A good example would be the vector modulator.

The purpose of the vector modulator is to manipulate an arbitrary signal, allowing it's amplitude and phase to be varied in a controlled manner. Recently, it has become a popular method for complex gain adjustment in linearized amplifier systems, both feed forward and predistortion.

The vector modulator consists of a 3dB 90-degree hybrid, an in-phase combiner, and two variable attenuators, realised either with a pair of mixers or two further 3-dB 90-degree hybrids with diodes. Analysis of the vector modulator is straightforward, and is not detailed here.

The advantages of using a XDCP over a DAC are the same as for the power amplifier application. The vector modulator example serves only to highlight another of the numerous applications where significant benefit can be derived.

Summary

The XDCP offers the reliability and flexibility of the DAC for the cost of the mechanical potentiometer, giving the designer the rare opportunity to make a win-win design improvement.

The new software interface allows easy prototyping of a dynamic programming environment with a minimum of hardware.

Flexibility of the XDCP is such that it may also be used in the PA periphery and control circuitry, not only for biasing of transistors. Additionally, it may supersede the use of the DAC in other cost critical RF subsystems.

(005128-1)

Xicor XDCP devices are available through Kanda Systems Ltd., Unit 17-18, Glanyrafon Enterprise Park, Aberystwyth, Ceredigion SY23 3JQ, United Kingdom. Tel. (01970) 621030, fax (01970) 621040.
Email sales@kanda.com,
website http://www.kanda.com

CORRECTIONS&UPDATES

537 'Lite' Computer
January & February 2000, 990054
The chip select lines address the following memory ranges:

CS0\	E000 - E7FF
CS1\	E800 - EFFF
CS2\	F000 - F7FF
LCD	F800 - FFFF

8-bit I/O Port
July/August 2000, 994077
Due to logic level contention, this interface can only operate as an 8-bit input or an 8-bit output. Using the PCF8574 to monitor input logic levels on K4 will result in driver logic reflections on K5. Conversely if using the PCF8574 to drive the output of K5, the dc logic level on K4 will adversely affect the correct operation of the PCF8574.

EEDTS Pro Super Loco Decoder
October 1999, 990071
The circuit of the decoder programmer, Figure 5, contains two transistors 'T2'. One of these should be labelled 'T3'. The correct type numbers of T2 and T3 are BD680, not BD560 as shown. The value of C4 should be 2.2nF, not 1 nF as shown.

HotKeys Keyboard (1 & 2)
April & May 2000, 002006
If hard to find localy, the 8-MHz ceramic resonator for this project may be replaced by a quartz crystal. The crystal wires are then connected to the outer two holes originally provided for the resonator. Two 27pF capacitors are connected between the crystal wires and the central solder pad.
The parts list in part 2 of the article contains an error. The correct type number of the caps for S1-S16 is 707023-01.

3-Volts Car Adapter
July/August 2000, 000014
A capacitor (C2) of 100nF (0.1 μF) should be fitted between R2 and ground.

PIC17C Processor Board
September 2000, 000061
Contrary to what is stated in the Components List, the -A version of the PIC processor is suitable for use in this circuit. The PIC17C756A is a 'shrink-wrap' version of the 'C756. The standard PIC17C756 is no longer produced.

CORRECTIONS&UPDATES

537 'Lite' Computer
January & February 2000, 990054

The chip select lines address the following memory ranges:

CS0\   E000 - E7FF
CS1\   E800 - EFFF
CS2\   F000 - F7FF
LCD   F800 - FFFF

8-bit I/O Port
July/August 2000, 994077

Due to logic level contention, this interface can only operate as an 8-bit input or an 8-bit output. Using the PCF8574 to monitor input logic levels on K4 will result in driver logic reflections on K5. Conversely if using the PCF8574 to drive the output of K5, the dc logic level on K4 will adversely affect the correct operation of the PCF8574.

EEDTS Pro Super Loco Decoder
October 1999, 990071

The circuit of the decoder programmer, Figure 5, contains two transistors 'T2'. One of these should be labelled 'T3'. The correct type numbers of T2 and T3 are BD680, not BD560 as shown. The value of C4 should be 2.2nF, not 1 nF as shown.

HotKeys Keyboard (1 & 2)
April & May 2000, 002006

If hard to find localy, the 8-MHz ceramic resonator for this project may be replaced by a quartz crystal. The crystal wires are then connected to the outer two holes originally provided for the resonator. Two 27pF capacitors are connected between the crystal wires and the central solder pad.

The parts list in part 2 of the article contains an error. The correct type number of the caps for S1-S16 is 707023-01.

3-Volts Car Adapter
July/August 2000, 000014

A capacitor (C2) of 100nF (0.1 μF) should be fitted between R2 and ground.

PIC17C Processor Board
September 2000, 000061

Contrary to what is stated in the Components List, the -A version of the PIC processor is suitable for use in this circuit. The PIC17C756A is a 'shrink-wrap' version of the 'C756. The standard PIC17C756 is no longer produced.

Lego Robotics Invention System (5)

Final part: your own robot

By L. Lemmens

In the previous parts of this mini-course, we have devoted our attention to the hardware elements of the Lego Robotics Invention System and the question of how to control them using the accompanying software or a high-level programming language, such as Visual Basic. Naturally, it's a lot more interesting to look at a real robot, and that is what we do in this final part.

Describing components is of course informative, regardless of whether it is Lego blocks or the hardware and software that are used to build and control the models. However, really 'playing' is a lot more fun. Practical experience teaches that many people first make something, and only after that do they start looking at what is actually inside the RCX block, in order to see what else they can do besides copying the pre-cooked examples.

Nevertheless, we will employ the Lego manual for the mechanical construction of the model described here.

If we had to publish the full assembly instructions, this article would be much too long. The program for the robot will be developed using both the software in the RIS package and Visual Basic v.6. With a few small modifications, it is also possible to use Visual Basic v.5. Programmers that prefer to work in Delphi or C should not have much trouble adapting the source code to their development environments. The robot in this article is so simple that it is actually not necessary to employ high-level programming languages. The RIS software is a lot simpler in this case. However, in the earlier instalments we have mentioned that certain things that are indispensable for serious applications (such as using variables) are possible in high-level languages, and that we have to do without them in the Lego environment. In addition, as you will see, the structure of the Visual Basic program is actually extremely similar to that of the Lego program. For quickly setting up and testing the rudimentary functions of a robot, you can thus start with the RIS environment, and then switch over to a high level language only when you want to add refinements.
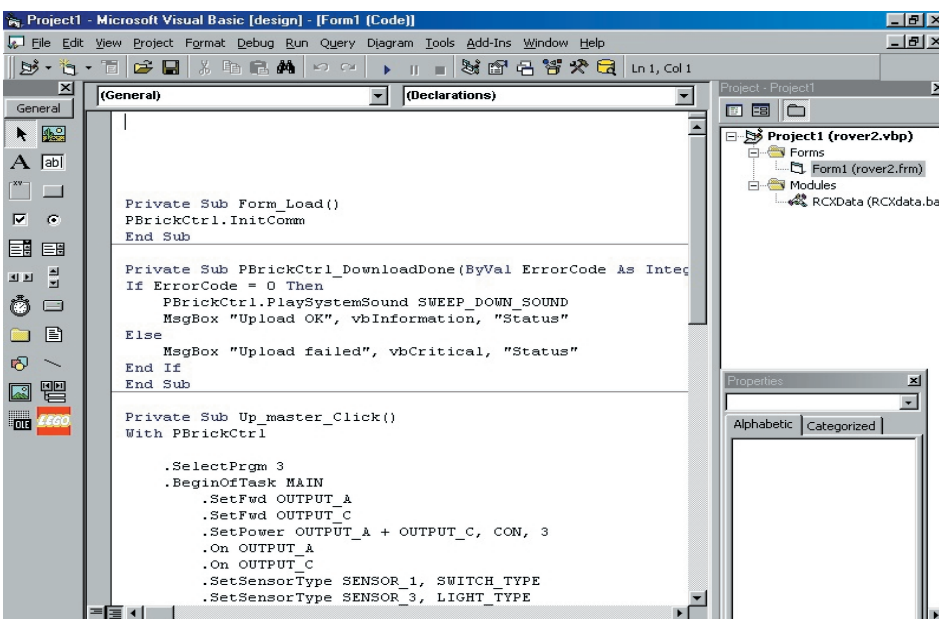

Figure 1. The program in the Robotics Invention System development environment.

What can our robot do?

Our robot can ride over a tabletop, briefly touching objects before changing directions, and turn around if it reaches the edge of the table.

A 'table bumper', located at the front of the robot, is used to detect obstacles and the edge of the table. If this is pressed in, the robot moves a short distance backwards and then changes its direction of travel. The light sensor on the rear side looks to see whether the robot moves too far backwards while it is turning around. It all sounds simple, and in fact it is simple.

Hardware

As already mentioned, we use the Lego assembly instructions for the Roverbot on page 10 of the Constructopedia, together with the wheel sets according to the instructions on page 17. The table bumper is mounted on the front side (see page 90). Finally, the light sensor must be fastened to the rear side, as described on page 34 and further. This is a simple model that should not cause any problems with its construction. However, it sometimes takes a lot of searching to find the necessary items in the large box of parts. Pay careful attention to the orientation of the motor leads. If these are improperly connected, the motor may turn in the wrong direction. The switches of the table bumper are connected to a single sensor input for convenience. At a later stage, it is possible to provide a separate port for each switch, so that the robot can distinguish between right and left.

Software in the Robotics Invention System

In the program bank, you will find a program called 'Robot2'. You can use this as a starting point for your own program. In contains all the program elements that are necessary for handling the table bumper. You only have to add the light sensor (see **Figure 1**). The routine that is necessary for this is very simple and quite similar to that for the table bumper. The only difference is that the robot does turn away, but it does not turn around.

In some cases, it may be necessary to adjust the setting of the light/dark threshold to match the table. The 'testing tools' of the Lego software prove useful here, since they allow the values that the sensor provides for a particular surface to be seen while the program is being developed. Another option is to press the 'View' button on the RCX block three times in succession. The display will then show an arrow next to sensor input 3, along with the sensor value.

Software in Visual Basic

Listing 1 shows what this application can look like in Visual Basic. You can see that it contains more than just the program code for the RCX module. A 'shell' has been placed directly around this code, so that the Visual Basic program can also look after sending the program code to the Roverbot (which is called 'downloading'). For this purpose, the InitComm method is added to the start-up routine of the VB program (Form Load), in order to make communications with the RCX possible. Once the VB program is started, you will see a window with a button that you can press to send over the code. **Figure 2** shows how this appears in the Visual Basic development environment.

Under ideal conditions, subroutine 'PBrickCtrl_DownloadDone' would be redundant, but it is essential to have feedback regarding the success of the communications process between the PC and the RCX. If this routine is missing, something will of course still happen, but you cannot be sure that the program has been properly stored in the RCX. If everything has gone properly, the IF statement triggers a happy little tune from the RCX and a message on the PC screen announcing that everything went as it should. Otherwise, all that appears is an error message on the PC.

However, what we are naturally most interested in is the program for the RCX. Let's start with the structure. The program is made up of three tasks. The first task, 'Main', sets the motors in the right direction and starts them, looks after the proper configuration of the sensors and starts two other tasks. Each of these tasks monitors a sensor and, if necessary, responds to the signals from the sensor in the appropriate manner. The main task thus only performs a certain amount of 'housekeeping', namely the initialisation of the robot, and then stops. After this, the sensor tasks continuously monitor whether something has happened with the sensors, and ensure that the Roverbot does not roll off the edge of the table. Of course, the program could have been written as only a single task, since this application is not all that complicated, but this structure makes everything easier to understand and easier to adapt to other applications.

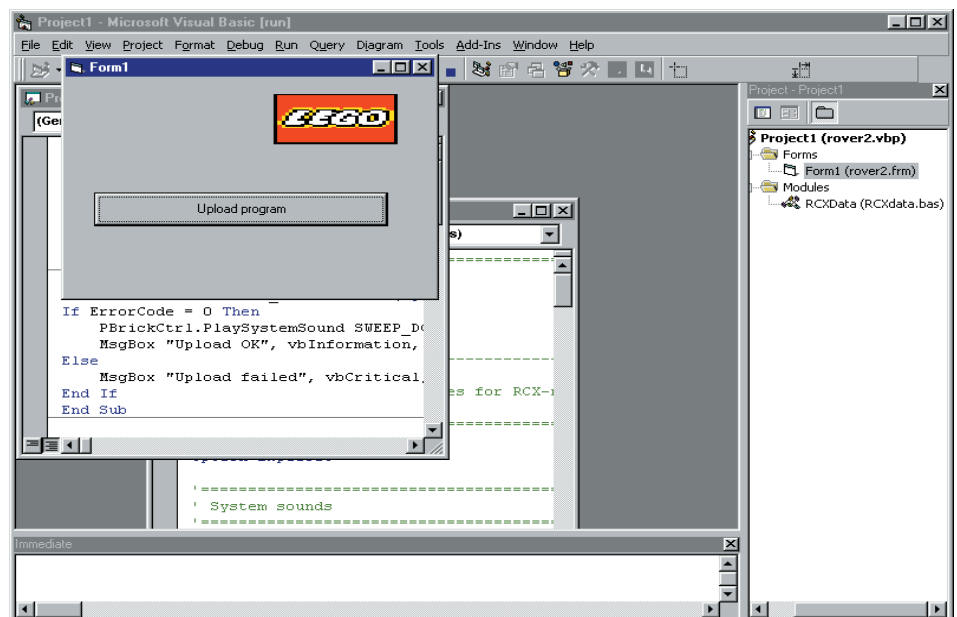A small warning is in order here: as your

Figure 2. The Visual Basic program is ready to upload the program code to the RCX.

```
Listing 1.

Private Sub Form_Load()
PBrickCtrl.InitComm
End Sub

Private Sub PBrickCtrl_DownloadDone(ByVal Error-
Code As Integer, ByVal DownloadNo As Integer)
If ErrorCode = 0 Then
    PBrickCtrl.PlaySystemSound SWEEP_DOWN_SOUND
    MsgBox "Upload OK", vbInformation, "Status"
Else
    MsgBox "Upload failed", vbCritical, "Status"
End If
End Sub

Private Sub Up_master_Click()
With PBrickCtrl

    .SelectPrgm 3
    .BeginOfTask MAIN
        .SetFwd OUTPUT_A
        .SetFwd OUTPUT_C
        .SetPower OUTPUT_A + OUTPUT_C, CON, 3
        .On OUTPUT_A
        .On OUTPUT_C
        .SetSensorType SENSOR_1, SWITCH_TYPE
        .SetSensorType SENSOR_3, LIGHT_TYPE
        .On SENSOR_1
        .On SENSOR_3
        .StartTask 1
        .StartTask 2
    .EndOfTask
```
```
    .BeginOfTask 1
        .Loop CON, 0
        .If SENVAL, SENSOR_1, EQ, CON, 1
            .SetRwd OUTPUT_A
            .SetRwd OUTPUT_C
            .Wait CON, SEC_1
            .Off OUTPUT_C
            .Wait CON, SEC_1
            .Off OUTPUT_A
        .Else
            .SetFwd OUTPUT_A
            .SetFwd OUTPUT_C
            .On OUTPUT_A
            .On OUTPUT_C
        .EndIf
        .EndLoop
    .EndOfTask
    .BeginOfTask 2
        .Loop CON, 0
            .If SENVAL, SENSOR_3, LT, CON, 35
                .SetFwd OUTPUT_A
                .SetFwd OUTPUT_C
                .Wait CON, SEC_1
                .Off OUTPUT_C
                .Wait CON, SEC_1
                .On OUTPUT_C
            .EndIf
        .EndLoop
    .EndOfTask

End With
End Sub
```

Listing 1. The program listing in Visual Basic version 6.

robots become more complex, you must take care that the various tasks do not interfere with each other, since they are executed in parallel. For example, it could happen that after one task has just stopped the motors, another task immediately resets them to maximum speed. In the present application, it is nearly inconceivable for the robot to teeter on the edge of the abyss on the front and rear sides at the same time, but in cases where it is possible for two sensors to be 'operated' nearly simultaneously, you will certainly have to pay attention to this possibility. It is reasonably simple to solve such conflicts by having one task suspend the other task using a 'StopTask' instruction or by using semaphores, as discussed in Part 3, so that (for example) only one task at a time can control the motors. Once a task has finished its work, it can reactivate the other task(s) or release the blocked resources. In the present application, however, it would not be a good solution to allow one task to completely block the other one, since what we want is to prevent the robot from running off the edge of the table while it is turning around. However, a possible option would be to activate the light sensor task only within the IF statement of task 1. After all, this sensor will not find itself

looking over the edge of the table when the robot is travelling forwards.

The two companion tasks are simple and do not need further explanation. The only fairly unusual elements are the IF statements for determining the sensor values. The first argument indicates that a sensor value must be compared, while the second argument specifies the sensor input in question. The third argument contains the relational operator. In the case of the switch, this is 'equals' (EQ), while with the light sensor it is 'less than' (LT). After this, the final two arguments specify that the sensor value must be compared to a constant (CON).
Note: the symbolic names used in this application (EQ, LT, CON, OUTPUT_A etc.) are defined in the module RCX-Data.bas, which is linked to this project. This module is located in the project GetStart.vbp, which we have already met in Part 3 of this course.

Both programs perform similar functions, and this case it was simpler to

use only the software from the RIS package instead of Visual Basic. However, if you want to have total control over what the program does and to understand precisely how the robot works, you will want to use other programming languages.

Conclusion

In the five parts of this course, you have been introduced to the Lego Robotics Invention System, but this cannot be considered to be anything more than an introduction. You can find an enormous amount of information and documentation regarding this system on the Internet, including sample programs, construction diagrams and so on – all too much to name and describe. We do hope that this series has made you enthusiastic about this 'toy', which can be used by people of all ages. Maybe it will turn out to be the latest of the toys that fathers buy 'for their children', only to keep them for themselves.

(000040-5)

e-Key Secure Access System

Based on iButton™ ICs

Design by P. Gros
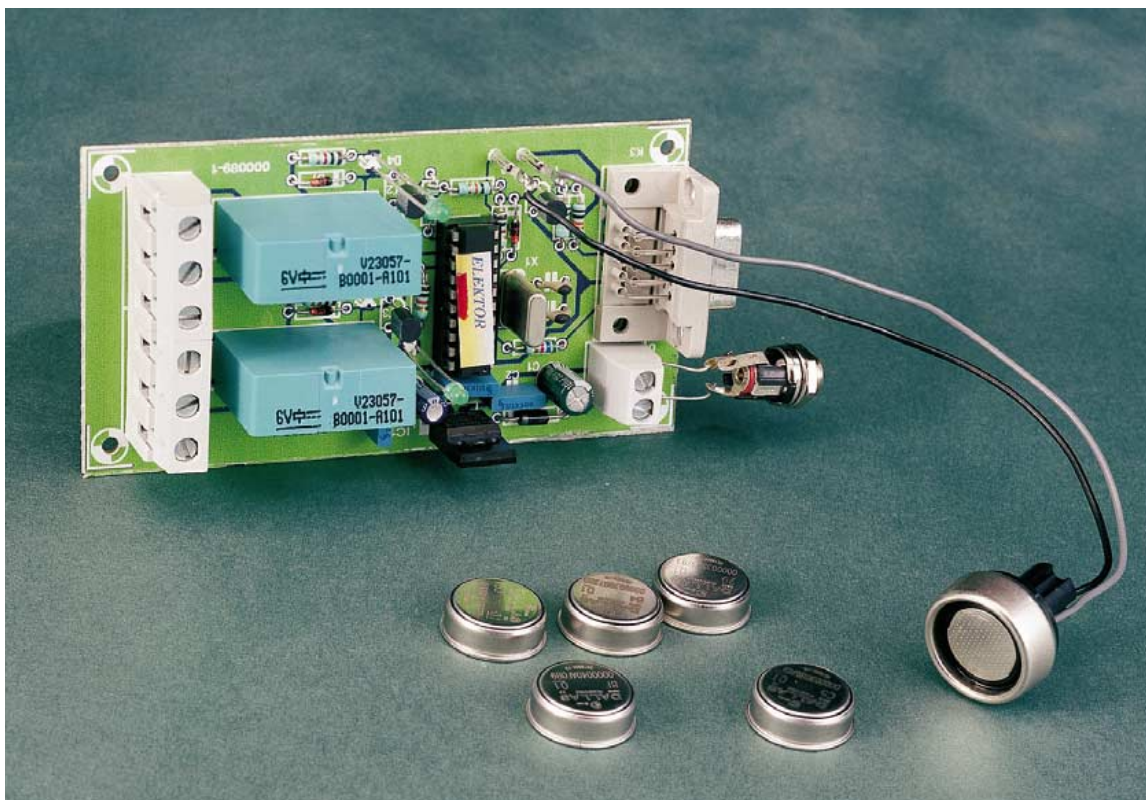
In this day and age it is trendy to put the letter *e* (for 'electronic') in front of many words, names and concepts, for example, e-business, e-life etc. We jump the bandwagon and describe *e*-Key, a controlled-access system based on *i*Button integrated circuits from Dallas Semiconductor.

The circuit described in this article allows two relays to be controlled with the aid of electronic keys. These keys are based on components manufactured by Dallas Semiconductors, and go by the name '*i*Button'.

Designed in the first place to switch alarm systems on and off, the '*i*Button' component can have many other applications like controlled access to a PC, electronic door openers, etc.

This type of lock with electronic key con-

e-Key Main Features

– Max. number of keys recognized:	7
– Outputs:	2
– Max. distance between circuit and key reader:	15 m
– CRC on codes read from keys	
– System Watchdog	
– Power supply:	7 - 15 V dc
– Current consumption:	max. 50 mA depending on relay state

trol has many advantages over traditional systems. The electronic version consists of three components: user interface, processing unit and control interface.

In order to afford maximum security, it is essential to physically separate the user interface from the processing unit, because the latter is subject to sabotage, vandalism and, of course, malfunctions. Most key boxes and number-code boxes used with traditional controlled access systems contain the necessary electronic parts as well as the relay, all in one and the same case. Once the case is vandalised, a simple short circuit or the cutting of a few wires is enough to disable the alarm or security system. Moreover, the access code may be easy to find inside the case.

The electronic key system described here allows the user interface to be removed a few metres from the control electronics (processing unit). The user interface consist of nothing but a two-way connector. The result is a higher degree of security. Even if the reader unit is torn apart, allowing a vandal to short-circuit the wires, the alarm system will remain armed.

The key

The *i*Button' component from Dallas Semiconductor looks like a button cell, having a diameter of about 17 mm and a thickness of 3 to 5 mm.

The 5-mm thick version of the *i*Button' may be secured in a special holder (designed by Dallas) to make a key which is not only easily handled on its own but also suitable for clipping on a key ring, alongside traditional, mechanical keys (see the illustration at the start of this article). As illustrated in **Figure 1**, it may be even be secured to a watch.

Two connections (including ground) give access to all functionality crammed into the *i*Button'.

The *i*Button' family consists of a great many devices, of which a number have been specially designed for use in controlled access systems. Within the family there are simple devices with an identifier of just 6 bytes (48 bits), but also components with memory structures of which certain zones remain inacces-

sible until the correct password is supplied.

Once the *i*Button is in contact with reader socket, it is powered and indicates its presence to a microcontroller which starts to exchange data and commands.

The present *e*-Key project is based on the simplest device in the '*i*Button' family, the DS1990A. It contains:

– A 'family' code, encoded in 1 byte;
– A Unique identifier, encoded in 6 bytes (48 bits);
– A check byte (CRC).

The *i*Button data exchange protocol

The '*i*Button' supplies its internal data when an electrical contact is established between it and a suitable reader device.

Once the iButton is connected up, it is powered by the reader circuit. In order to inform the system of its presence, the *i*Button pulls a system line to logic Low (see greyed-out line, **Figure 2a**). This event triggers the start of the internal initialisation of the device. When the initialisation is finished, the Low level is removed, allowing the internal pull-up resistor in the circuit to take over. Once the time slot t_{RSTH} is over, it is possible to send a command code. You can see the time slot available for the device initialisation sequence in the diagram shown in Figure 2a. The sequence is preceded by a 'Master Reset Pulse' sent out by the reader to re-initialise the *i*Button. In our case, the connection of the *i*Button to the reader contacts corresponds with the slot 't_{RSTH}', or 'Master R_x Presence Pulse'.

Principle of data transmission with the *i*Button

The internal memory of the DS1990A *i*Button is accessed by means of a one-wire connection. The protocol defines the way in which data and commands are exchanged. There are three types of data exchange: writing a logic High level ('1') (**Figure 2b**); writing a logic Low ('0') (**Figure 2c**) and reading a data bit (**Figure 2d**). The protocol defines

Figure 1. Example of an iButton electronic key secured on a wristwatch strap.
(photograph courtesy Dallas Semiconductor)

time slots during which the relevant logic levels are maintained, to allow transmitted data to be correctly latched by the receiving device.

At the end of the reset phase, the DS1990A goes into command-entry mode. Once a command is received, the DS1990A returns data as appropriate for a particular command. Every data transmission is subject to a cyclic redundancy check (CRC) operation. The CRC is based on an 8-bit polynomial ($X8 + X5 + X4 + 1$).

The data exchange flowchart for the DS1990A is shown in **Figure 3**.

Operation and use

The microcontroller starts by loading (registering) the identifier of one or more keys in its EEPROM area. Once the AT90S1200 used here contains 64 bytes, we employ 7 areas of 6 + 2 bytes. This enables the reader circuit to recognise up to 7 different keys.

For each of the 7 keys, 6 bytes are registered containing the serial number plus 2 bytes that serve to specify the 'on' time of each of the output relays.

In this way it is possible to define different keys to activate the first relay, the second relay or both at the same time. The aim should be to have the system perform two or three different actions depending on the keys used. In an alarm system, that allows one key to be defined for the proprietor, and others for (trusted) neighbours, household staff, the cleaning lady, etc. The latter keys could, for example, disarm a section of the alarm system only.

The eight remaining bytes allow us to store counters keeping track of, for example, the number of watchdog reset actions, or the CRC of the relevant EEPROM area.

The system parameters may be loaded using an RS232 terminal or a PC running a communication program (HyperTerminal is adequate for the purpose). The commands you may use are listed in **Table 1**.

Be sure to get the commands right as you type them (in upper case only) as the command processor, due to it being run in confined ROM space, is not particularly intelligent.

The first command to type could be **D** which allows you to check that the EEPROM areas do not contain code.

Command **S** allows the system to 'get acquainted' with a new key. Type the command followed by an number between 1 and 7. Next, apply the key to the reader. Its internal identifier will be saved at the specified location (1 - 7).

By default, the two relays are energized for 5 seconds. This may be modified to suit your requirements by means of command **A**.

Command **C** may be used to clear the identifier of a particular key stored at location 'n'.

The last command, **Z**, clears all EEPROM areas.

It is normal for LED D2 to remain off initially. The EEPROM area being empty, the auto-CRC will produce an error. This is automatically corrected however by using command **A**, **C**, **S** or **Z**.

The circuit

The circuit diagram of the *e*-Key Secure Access System is shown in **Figure 4**. As you can see, the reader unit consists of very few parts indeed. The circuit is built around an AT90S1200 microcontroller from Atmel clocked at 4 MHz. This relatively low speed is more than adequate for our application.
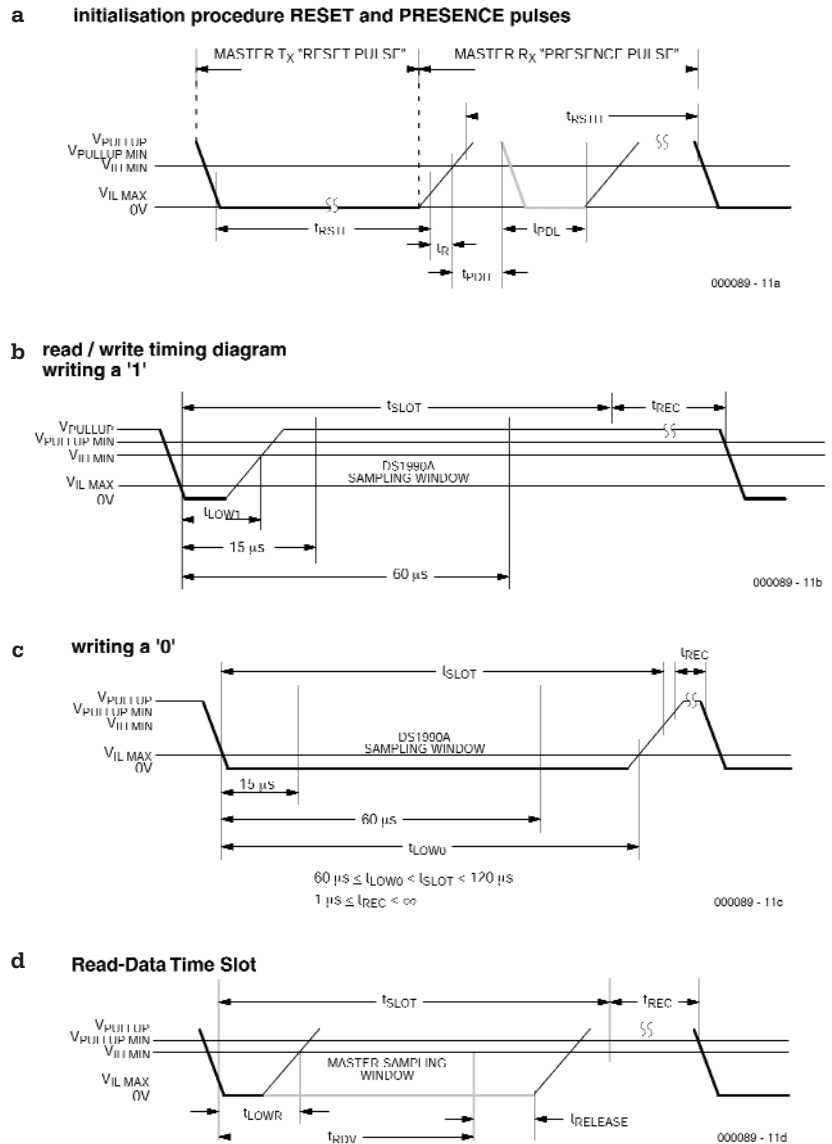
Figure 2. Timing diagrams. (a) Initialisation sequence; (b) writing a logic 1; (c) reading a logic 0; (d) waiting for data to arrive. (source: Dallas Semiconductor)

Table 1. e-Key Commands and Actions

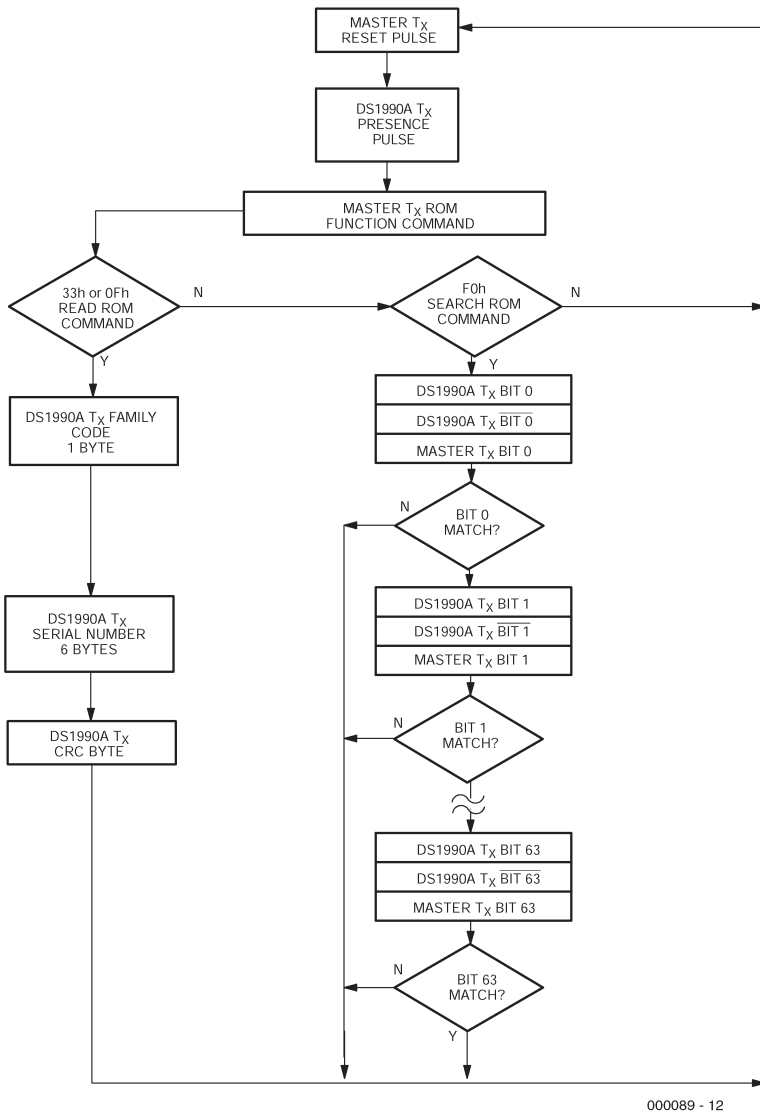| Command	Name	Action
AnXXYY	Action	n=key number, XX= relay-1 action, YY= relay-2 action, XX=00 no action, increment every 1 s (approx.)
Cn	Clear	Clear identifier of key 'n'.
D	Dump	Clear entire EEPROM area
Sx	Set key	Acquire identifier of new key, store in EEPROM zone reserved for recognized keys. x is key number (1 - 7). Default 'on' time for relays is 5 seconds (approx.).
Z	Zero	System reset and clear all EEPROM data.

```
        ┌─────────────────┐
        │   MASTER Tₓ      │◄──────────────────┐
        │   RESET PULSE    │                   │
        └────────┬─────────┘                   │
                 │                             │
        ┌────────▼─────────┐                   │
        │   DS1990A Tₓ      │                   │
        │   PRESENCE        │                   │
        │   PULSE           │                   │
        └────────┬─────────┘                   │
                 │                             │
        ┌────────▼─────────┐                   │
        │  MASTER Tₓ ROM    │                   │
        │  FUNCTION COMMAND │                   │
        └──┬──────────┬─────┘                   │
           │          │                         │
     ┌─────▼───┐   ┌──▼──────┐                  │
     │33h or 0Fh│   │  F0h    │  N               │
     │READ ROM │ N │ SEARCH  ├──────────────────┤
     │COMMAND  ├─► │  ROM    │                   │
     └────┬────┘   │COMMAND  │                   │
        Y │        └────┬────┘                   │
```

Figure 3. Flowchart showing command processing and dataflow.

000089 - 12

handler determines the source of the request (PD1 or PD2).

The communication with the circuit by way of the RS232 interface allows the following:

– registering of new keys;
– disabling of keys;
– visualisation of identifiers read from recognized keys;
– displaying of the code read from the key on every key 'insertion'. If the CRC is wrong, a hash character (#) is displayed.

A command is available to specify the 'on' time of the relays for each key.

Port PB2 allows a LED to be controlled, in this case D2, which should light when the circuit is working properly, that is, after completing the initialisation procedure, and a correct result for the CRC on the EEPROM.

Ports PB0 and PB1 control output relays 2 and 1 respectively. Each of these has an indicator LED, D4 and D5 respectively.

The power supply is based on the availability of a dc source capable of supplying 7 to 15 V at the required current. Diode D1 acts as a polarity reversal protection and a three-pin voltage regulator, IC1, steps down the input voltage to +5 V for the circuit to operate from.
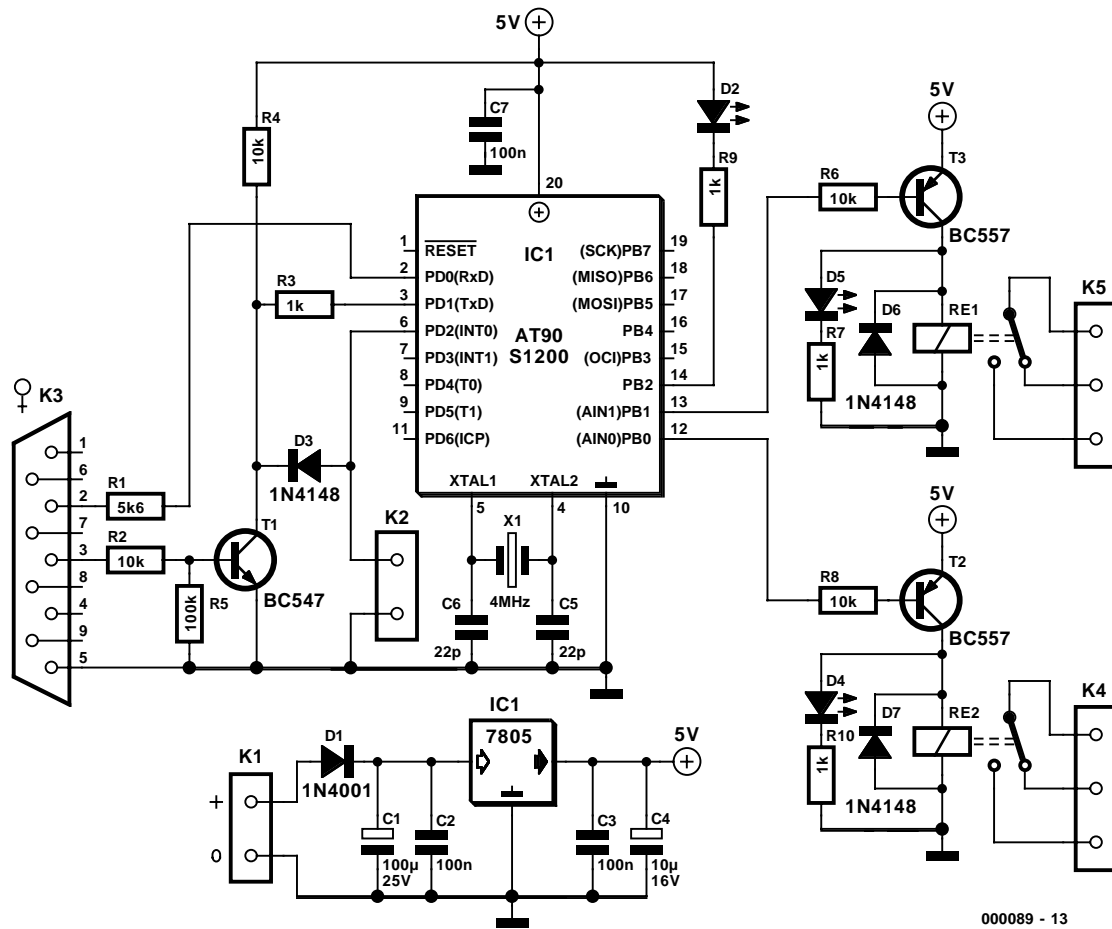
The microcontroller's RESET input does not have to be connected because the power-on reset circuitry is available inside the case.

Construction

Thanks to the availability of a ready-made printed circuit board whose design is shown in **Figure 5**, building the e-Key project should not pose practical problems. As usual, you start with the wire links, in this case, there's just one, you'll find it clearly marked between C3 and C4. Fitting the 'standard' components like resistors, capacitors, diodes and transistors should not require further explanation here. Regarding the terminal blocks and the 9-way sub-D connectors, you first mount them on the PCB to make sure they do not get in each other's way. Next, you solder the pins.

Before inserting the ready-programmed microcontroller (item **000089-41**) in its socket (we recommend one with turned pins), you should first check the presence of the circuit supply voltage at a number of relevant points in he circuit. When no apparent faults are found, switch off the supply and only then insert the controller into its socket (observing the orientation of the IC).

Those of you having an Atmel AT90 programmer available may want to burn their own chip for the project. To be able to do so

It may be useful at this point to briefly recap the main features of the AT90S1200: 1,024 bytes of Flash program memory, 32 bytes of RAM organized as 32 registers, 64 bytes of EEPROM, one interrupt input, input/output ports and a watchdog reset.

Reading an *i*Button is carried out via port line PD2 which also acts as the interrupt request input. It is necessary to program a '1' to activate the internal 1-kΩ pull-up to +5 V, and so provide a 'phantom' power supply for *i*Buttons when in contact with the reader. A close look at the timing diagram reveals that the *i*Button key, once powered,

forces a logic Low of about 470 µs. This change in the logic level on PD2 triggers an interrupt request which, in turn, launches the 'read' procedure.

A (TTL-level) RS232 serial interface is implemented using port lines PD0 and PD1. PD0 transmits the data (9,600 bits/s, no parity, 1 stop bit) with resistor R1 protecting the interfaces by limiting the current to a safe value. Port line PD1 is used as the receive line for data converted to TTL level by R2, R5 and T1. Resistor R3 in combination with diode D3 allows an interrupt request to be generated when characters arrive on the serial input line. The interrupt

Figure 4. The electronics in the e-Key reader is really down to a single microcontroller type AT90S1200.

you require the project source code file which is available either on disk number **000089-11** supplied through our Readers Services, or from the Free Downloads pages on our website at http://www.elektor-electronics.co.uk. The source code file may be assembled into executable code using Atmel's program AVRASM.EXE which may be downloaded free of charge from the Atmel website.

The program

When the circuit is powered up, the following elements are initialised: ports, timer and watchdog. At the same time, an automatic CRC is performed across the EEPROM memory. If the verification process is correctly finished, LED D2 lights and the circuit waits for an interrupt request to arrive. Once that arrives, the program finds out the origin of the interrupt (i.e., key read or RS232 data arriving). Each of these is discussed briefly below.

Key Read Interrupt

First, the command code is transmitted. Next, the bytes supplied by the key are read into the system and the checksum is verified. The result should be zero. If not, the # character is transmitted over the serial line and the normal sequence of events is abandoned. If the CRC reads zero as it should, all bytes read from the key are transmitted on the serial line. Next, the code is looked up in the EEPROM memory. If the code is not found, the sequence is abandoned again and the system returns to waiting for an interrupt. If the code read from the key is present, the output relays are actuated depending on EEPROM resident values of the bytes associated with the key code. When the relay actions are finished, the circuit returns to waiting for an interrupt. Note that keys can not be recognized while any of the relays is actuated.

COMPONENTS LIST

Resistors:
R1 = 5kΩ6
R2,R4,R6,R8 = 10kΩ
R3,R7,R9,R10 = 1kΩ
R5 = 100kΩ

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

Semiconductors:
D1 = 1N4001
D2,D4,D5 = LED
D3,D6,D7 = 1N4148
T1 = BC547
T2,T3 = BC557
IC1 = 7805
IC2 = AT90S1200 (programmed,
   order code **000089-41**)

Miscellaneous:
K1 = 2-way PCB terminal block,
   raster 5mm)
X1 = 4MHz quartz crystal
RE1,RE2 = PCB mount relay, 6 V,
   1 changeover contact, e.g.,
   V23057-B0001-A101 (Siemens)
K3 = 9-way sub-D socket
   (female), PCB mount
K4,K5 = 3-way PCB terminal
   block, raster 7.5mm)
Keys = Serial Number iButton™
   DS1990A (Dallas Semiconductor,
   RS Components,
   Farnell # 790-461)
Optional: key support DS9093A
Contact Reader for iButton™
   DS9092 (RS Components,
   Farnell # 790-473)
PCB, order code **000089-1** (see
   Readers Services page)
Optional: project source code files
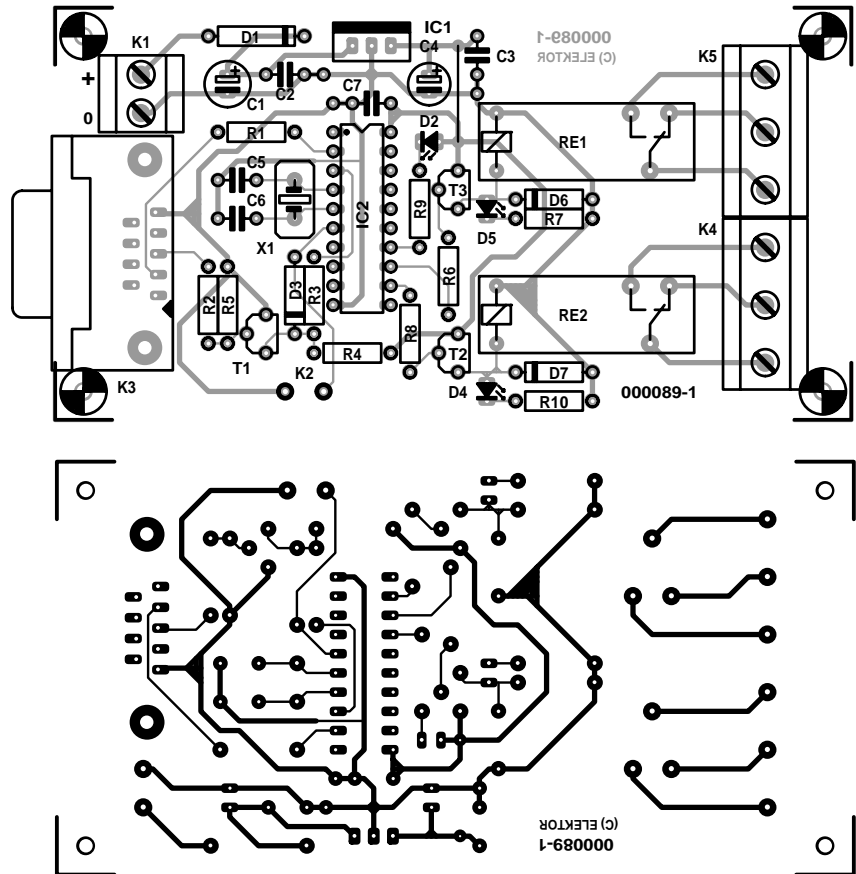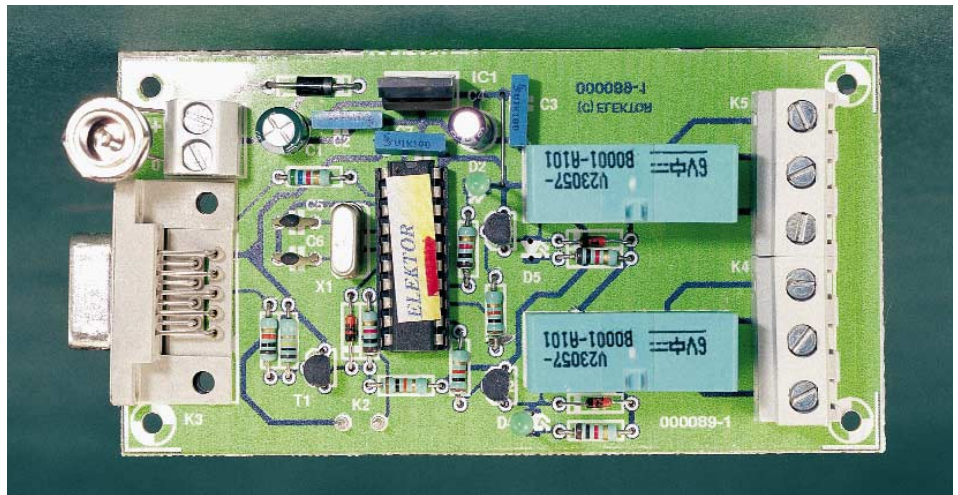   on disk, order code **000089-11**.

Figure 5. Copper track layout and component mounting plan of the PCB designed for the e-Key project (board available ready-made).

RS232 Interrupt
When a character is received from the PC or terminal, it is immediately scrutinised by the command processor. If the character is valid, the relevant command action is launched. Invalid characters cause the system to return an asterisk (*) to the PC or terminal.

(000089-1)

On the Internet

If you want to know more about the DS1990A, the iButton chip or Atmel's freeware assembler mentioned in this article, pay a visit to these websites:
http://www.ibutton.com
http://www.dalsemi.com
http://www.atmel.com

Camera on Model Train

view the track from the proper perspective

Design by S. van de Vries

Without doubt, one of the secret wishes of many train fans is to be able to step into the role of the engine driver on a real train. With this project, you can at any desired moment consider yourself to be the master of your own model train, and you can direct it over the model train layout from the perspective of the engine driver.

In order to display the view from the model train on a television set or monitor, you will need a video camera, a transmitter and a receiver. Since these components are readily available at reasonable prices, they are not particularly interesting as DIY projects.

However, one thing that you will have to devote some attention to is the power supply for the entire setup. In order to ensure reliable transmission of the picture, the delivery of power to the camera and transmitter must be ensured at all times. Temporary loss of contact with the supply rail must not cause picture information to be lost. A mini-UPS (uninterruptible power supply) ensures that this does not occur.
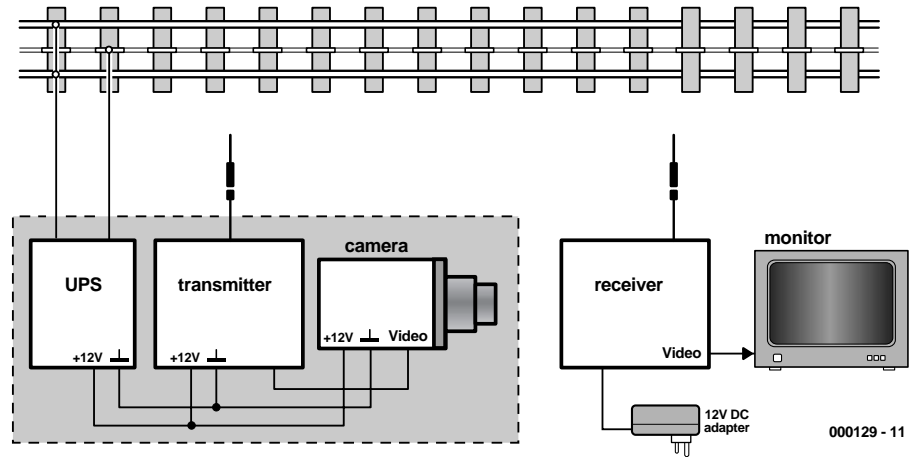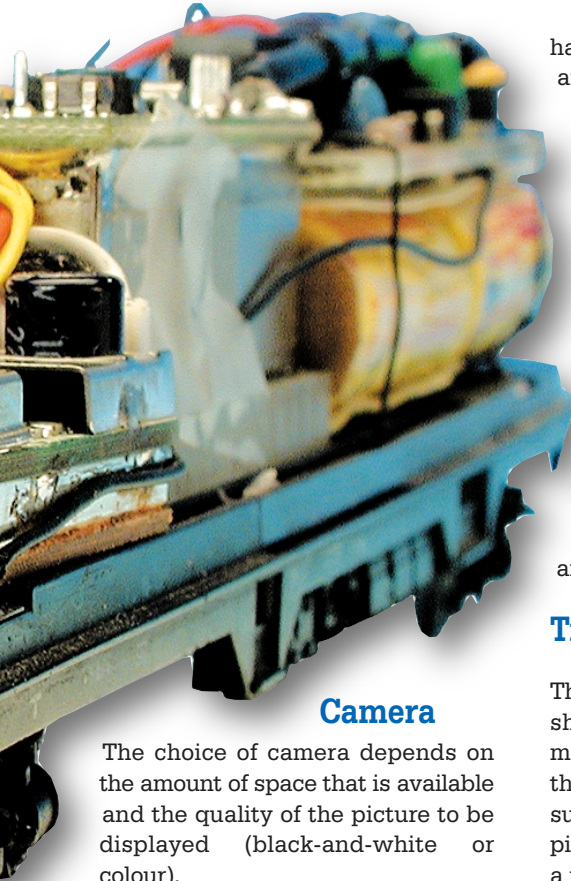
Figure 1. The complete installation consists of a camera, a transmitter, a UPS, a receiver and a monitor.

be used, and a brown ceiling joist in the model-train attic can more easily be interpreted as a green hill on the horizon.

All modern miniature cameras have automatic diaphragm controls, and the capabilities of these small technical marvels are extraordinary.

A typical camera has three leads:

- ground
- supply voltage
- composite-video output

Many cameras require a supply voltage of 12 V, but the latest generation needs only 5 V. With the 12-V types, the current consumption is around 80 mA, while the more recent 5-V types are happy with 20 mA or less.

Transmitter

The only type of transmitter that you should consider is an (approved) model that emits a signal in one of the allowed 2.4-GHz channels. If such a transmitter is used, noise-free picture transmission is possible over a range of several tens of meters.

For H0-gauge trains, the H0 OEM transmitter (available from Conrad Electronic) is very suitable. This transmitter, with dimensions of 62 × 22 × 18 mm, can be built into an H0 carriage without too many difficulties.

Receiver

Although there is a matching receiver for the H0 OEM transmitter, we decided to use the Marmitek Gigavideo 30 instead, since it is available as part of a set at a lower price than a separate H0 receiver. In addition, the Marmitek receiver comes in a nicely finished case.

The Marmitek 30 receiver has a composite-video output, so it can be connected to practically any television set. Several different adapter cables are provided with the receiver.

If your television set only has an HF aerial input, then you can use the version of the receiver that has a modulated HF output. The video signal can be found on UHF channel 36.

The channel frequencies of the H0 OEM transmitter differ somewhat form those of the Marmitek receiver, but good reception is possible on channels 1, 3 and 4 of the Marmitek unit. The following table summarises the usable settings when the Marmitek receiver is used with the H0 OEM transmitter:

Marmitek receiver	H0 OEM transmitter
Ch. 1: 2.411 GHz	Ch. 1: 2.4145 GHz
Ch. 3: 2.453 GHz	Ch. 4: 2.4565 GHz
Ch. 4: 2.473 GHz	Ch. 5: 2.4705 GHz

Camera

The choice of camera depends on the amount of space that is available and the quality of the picture to be displayed (black-and-white or colour).

A colour camera has the advantage that the model landscape is presented more realistically, and a red signal lamp is readily visible. However, a black-and-white camera also has certain advantages. For instance, it allows IR headlamps to

Important Notice

The use of the 2.4-GHz video transmitter module mentioned in this article is subject to type approval and radio regulations and may not be allowed in all countries in which *Elektor Electronics* is published.
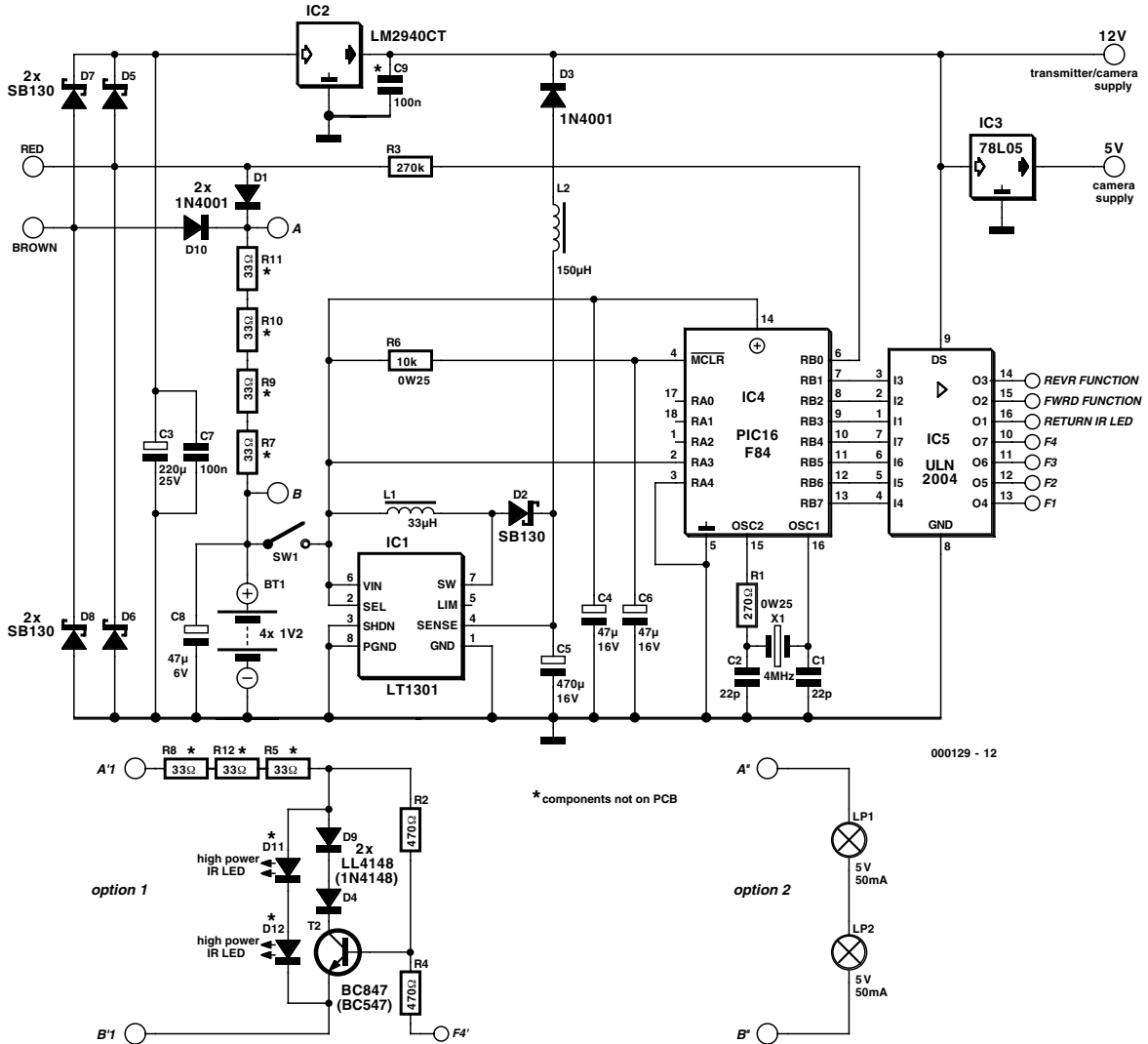
Figure 2. Schematic diagram of the UPS with the super locomotive decoder.

Although the components just described are some of the smallest commercially available modules, you can't just pop a camera together with its transmitter right behind the cab window of an H0 locomotive. A large part of the available space in the locomotive is taken up by the motor, so it is practically impossible to fit in the camera and transmitter. In some cases, it will be possible to fit only the camera in the locomotive, with the transmitter and associated electronics located in the carriage just behind the locomotive.

Another option is to build the camera and transmitter into a driving trailer carriage. A carriage that is especially suitable for this is the first version of the German 'Silberlingen' driving trailer. It is very well suited for housing a camera and transmitter module, since the camera can nicely look through the small window in the aisle door, and the carriage body has sufficient room for building in the camera, trans-

mitter and power supply.

Model railroad fans that only allow running stock on their tracks that has also run on a real railway in a particular configuration need not have compunctions about using this driving trailer, since it was actually used in combination with a BR212 or BR216 diesel, together with several second-class cars, in traffic running in the Dutch/German border region.

Electronics

Since so many ready-made modules are used, the amount of DIY electronics is very limited.
You could even consider omitting the fairly extensive backup power supply and powering the camera and transmitter directly from the rail voltage, via the 12-V regulator. However,

since the contact with the rail is quite frequently interrupted, the video picture will have a lot of interference. Consequently, there is a provision to compensate for these voltage dropouts.

It is also possible to keep the mechanical modifications to the carriage to a minimum by using only the NiCd cells as the power source. Of course, if the battery is not charged via the rail voltage, it is necessary to add connections to the carriage so that the cells can be charged. In this case, the red and brown leads must be brought to the outside, and the battery can be charged using a 12-V AC or DC mains adapter (such as that for the Marmitek transmitter or receiver). If power is supplied only by the NiCd cells, then the PIC, the ULN, C1, C2,

X1, R1, C6, C4, R6, D5, D7 and IC2 may be omitted.

On digital model railways, the rail voltage can serve as the primary power source. It is connected to the red and brown leads, and then rectified by D5–D8. Schottky types are used for these diodes, in order to keep the voltage drop across them to a minimum. Especially on track sections where EEDTs Pro signalling modules are used, the available voltage can drop to around 15 V.

Following the rectifier, a 220-μF capacitor and a ceramic capacitor filter the supply voltage. The camera module in particular is very sensitive to disturbances on the supply voltage.

The fact that low supply voltages can be present on the track is also the main reason for using a low-drop voltage regulator to stabilise the supply voltage. With this solution, the supply voltage can be drawn from the rails in almost all situations. If you do not intend to use to use NiCd cells in the power supply, you can use these parts alone to provide power to the camera and transmitter. In this case, however, it is recommended to make C3 as large as possible (for example, 4700 μF/25 V).

On the other side of D1 and D10, we find the rectified rail voltage for charging the NiCd cells. Do not try to omit these diodes by drawing power directly from C3. Due to the protection diode between the input and output of the 12-V regulator, this would allow a charging current to flow from the backup source to the NiCd cells when the backup source is active.

Battery

Penlight (AA) cells are a good choice for the four NiCd cells. If the camera and transmitter depend entirely on this battery for their operating power, 700-mAh cells should be used. With this capacity, the camera and transmitter together can be provided with power for approximately 1.5 hours.

If you choose to draw primary power from the rail voltage, smaller-capacity cells may be used. In this case, you could also use the smaller AAA cells.

Do not use NiMH cells, since they cannot supply the high currents demanded by the step-up regulator.

A charging current of 70 mA has been chosen. This can be realised using a series resistance of around 130 Ω (R7 and R9–11). Since the power dissipation is approximately 1 W, the heat dissipation is shared by four 0.25-W resistors. Cut the leads of the resistors to 5 mm and solder them to each other. Then solder two flexible leads to the ends of the assembly, and insulate it with a length of heat-shrink tubing. The heat dissipation is now spread over the resistor chain, and the string of resistors can be placed nicely between the two rows of NiCd cells.

Part of the charging current can also be used for the IR headlight. The two high-power LEDs can be placed at the front of the driving trailer carriage at the level of the coupling, which thereby can be removed (see Option 1 in the schematic diagram).

If F4 of the locomotive decoder is not active, then R2 will drive T2 into conduction, and the charging current for the battery will flow through T2, D4 and D9. The voltage drop across the two diodes and the transistor lies below the threshold voltage of the IR LEDs (1.1 V), so they do not emit any IR light.

By contrast, if the F4 output of the ULN2004 is active, transistor T2 is blocked. The charging current then flows through the IR LEDs, and these illuminate the track.

The components in Option 1, with the exception of the IR LEDs, can be mounted on printed circuit board C (SMD), but the circuit can also be build using conventional compo-
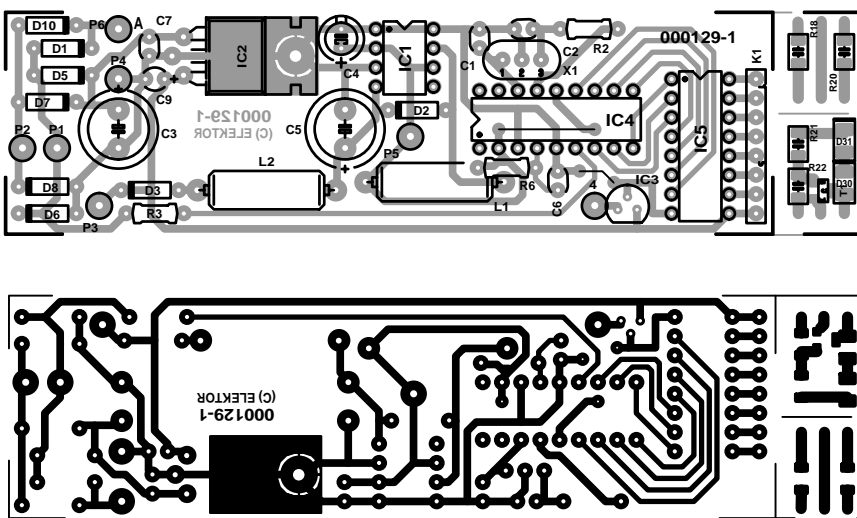

Figure 3. The associated printed circuit board matches the width of the carriage (board available from Readers Services).

COMPONENTS LIST

Resistors:
R1 = 270Ω
R2,R4 = 470Ω (option 1)
R3 = 270kΩ
R5,R8,R12 = 33Ω (option 1)
R7,R9,R10,R11 = 33Ω
R6 = 10kΩ

Capacitors:
C1,C2 = 22pF ceramic
C3 = 220μF 25 V radial
C4 = 47μF 25V radial
C5 = 470μF 16V radial
C6 = 47μF 16V radial
C7,C9 = 100nF
C8 = 47μF 6V radial

Inductors:
L1 = 33 μH (40 turns. 0.25 mm diam./SWG32 enamelled copper wire on ferrite rod, 4 mm dia., 15 mm long)
L2 = 150 μH miniature choke

Semiconductors:
D1,D3,D10 = 1N4001
D2,D5-D8 = SB130
D4,D9 = 1N4148 (option 1)
D11,D12 = high-power IR-LED (option 1)
T1 = not fitted
T2 = BC847 of BC547 (option 1)
IC1 = LT1301CN8 (Linear Technology)
IC2 = LM2940CT
IC3 = 78L05 (only with 5V camera)
IC4 = PIC16F84 (programmed, for Super-Loco Decoder, # **996523-1**, see Readers Services, items October 1999)
IC5 = ULN2004

Miscellaneous:
X1 = 4 MHz quartz crystal
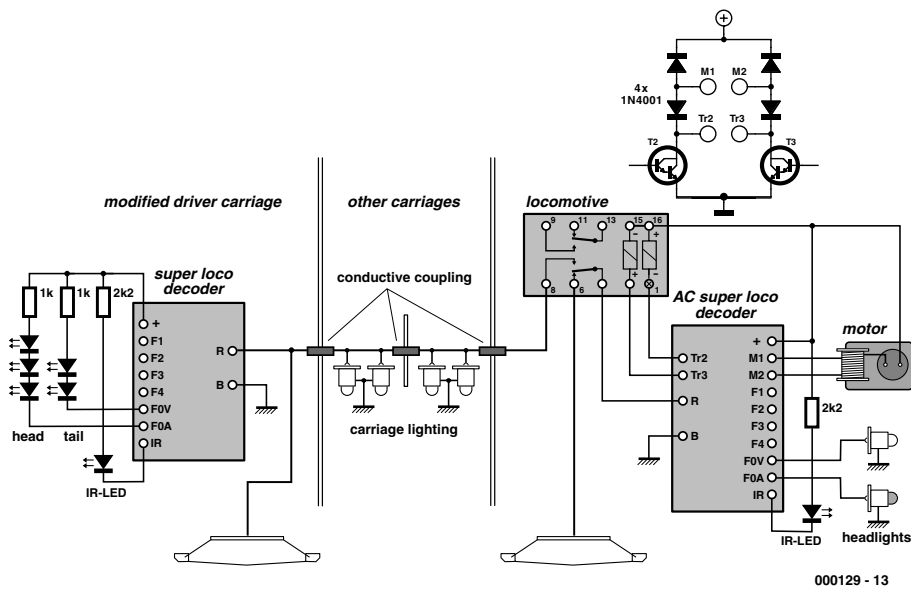L1,L2 = miniature bulb 5V/50mA (option 2)
PCB, order code 000129-1

Figure 4. Sample connections for a Märklin system.

sense input of the regulator. This allows the voltage to be held very closely to 12 V.

L2 is added to the circuit to filter out the last remnants of HF ripple in the supply voltage. In this case, a ready-made component may be used.

D3 forms the switch between the supply voltage from the rails and the backup supply. If the voltage at the output of the 12-V regulator drops below 11.3 V, the step-up regulator will take over the supply to the camera and transmitter, without any visible effect on the video image.

Locomotive decoder

The right-hand part of the schematic diagram consists of a stripped-down super locomotive decoder (**996523-1**).

The motor control logic is entirely omitted, the low-voltage detection circuit is simplified and hardware address selection using diodes is omitted. However, all functions and the IR address-transmission output are still available via the ULN2004.

The three yellow LEDs for the front running lights are connected to the REVR (reverse) output via a 1-kΩ resistor, and the two red LEDs of the rear signal lamps are connected to the FWRD output. The (SMD) resistors can be mounted on circuit board B.

The return IR LED output can drive a LED mounted underneath the carriage body, so that the address can be detected when the train is being pulled and pushed.

Using the EEDTs-Pro software, the address of the locomotive decoder is set to the same value as address of decoder in the locomotive at the other end of the train.

Modifications

Mounting the components on the printed circuit board should not present very many problems. However, C8 and C3 should be mounted horizontally instead of vertically, in order to save height. Some space can also be saved by soldering the ICs directly to the circuit board, instead of using sockets.

If the driving trailer carriage with the camera is used on a model railway with stop sections for the sig-

nents (using the part numbers in parentheses).

Option 2 yields a design with two small incandescent lamps, which can be used for interior illumination.

Step-up regulator

The step-up regulator is completely integrated into the LT1301CN8. This IC manages to convert the 4.8-V voltage from the NiCd battery into 12 V at a maximum current of 200 mA.

Inductor L1 is an important part of the

step-up regulator. Although it is very tempting to use a ready-made, colour-coded inductor here, such components cannot handle the high current level (around 0.5 A). Winding the coil yourself, however, is not especially difficult. Forty turns of 0.25-mm diameter enamelled copper wire on a ferrite rod (4 mm thick and 15 mm long) will make a satisfactory inductor.

The rectified voltage is found across C5, and it is fed back to the
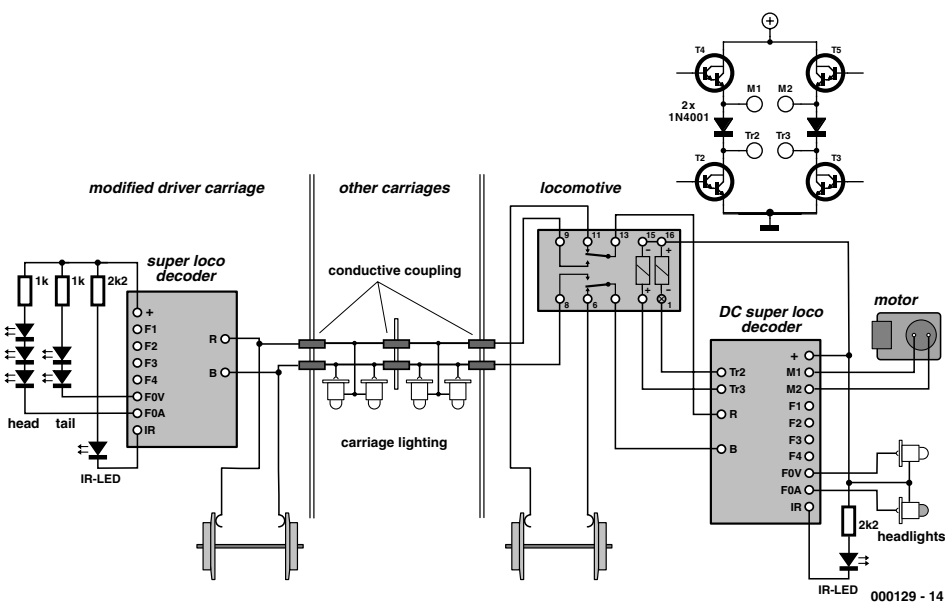
Figure 5. Sample connections for a two-rail system.

nals, then a sliding contact must be mounted under the carriage to prevent the entire train from coming to a halt after passing the signal. In addition, the decoder in the locomotive must receive its power from whichever slider is at the front of the train.

The locomotive should preferably be fitted with a super locomotive decoder, which can decode the new Motorola format, so that both the decoder in the driving trailer carriage and the locomotive decoder know which direction the train is travelling. This ensures that the front and rear signal lamps will always be illuminated correctly.

Another advantage of the super locomotive decoder is that is can easily drive the switchover relay for the slider. In order to ensure reliable operation of the bistable relay when the super locomotive decoder is controlling a Märklin-series motor, two diodes have been included in the motor control stage (see **Figure 4**). If necessary, these diodes can be soldered on the printed circuit board in place of D10 and D11 (but with the opposite polarity!), with D10 and D11 replacing the wire bridges.

In addition to these modifications, C4 on the locomotive decoder circuit board must be changed to 220 μF/25 V.

Figure 5 shows the situation for a two-rail track.

Replace the SMD electrolytic capacitor C4 on the super locomotive decoder in the locomotive with a normal electrolytic capacitor with a value of 220 μF/25 V. Since there are already diodes on the circuit board in the DC version, no additional measures are necessary to allow the bipolar relay to be connected. The relay coils are connected to the collectors of T2 and T3, which are the connection points for the field coils in the AC version.

Cutting and breaking

When we looked for a carriage that was suitable for housing the camera, transmitter and power supply, our choice fell on a Fleischmann model. However, Roco also has a suitable type in its assortment.

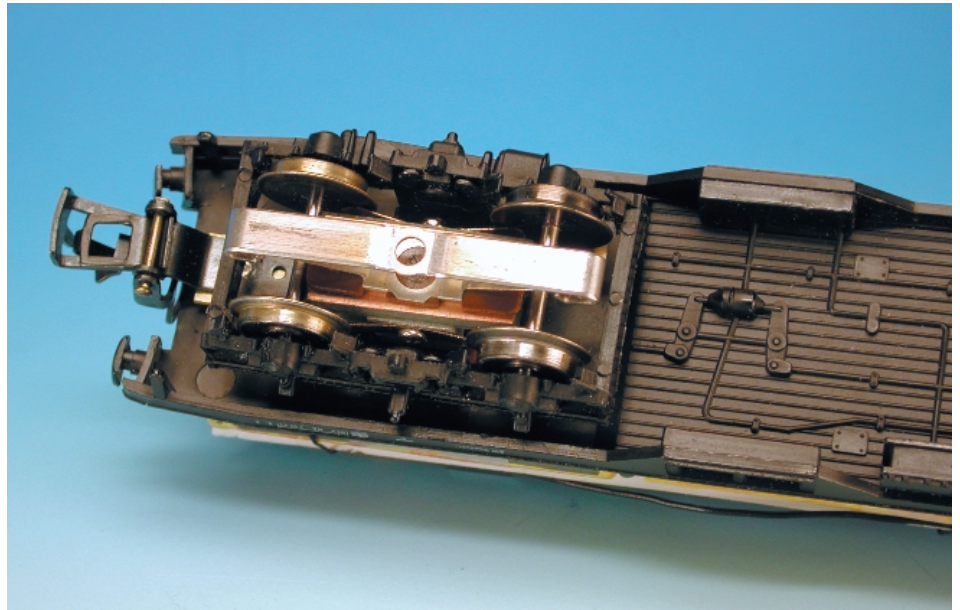Don't use a metal carriage, such the Märklin models, since there is a

Figure 6. The slider under the driving trailer carriage.

good chance of a short circuit, and the transmitter will also be inside a Faraday cage.

The first thing to do is to remove the interior elements of the carriage. After this, turn your attention to the lamp holders and the diodes for switching over the front and rear lamps.

The lamp holders for the interior lighting must also be broken off. Grasp each one with flat-jawed pliers and rock the pliers back and

forth until the lamp holder breaks off.

There is no longer any reason to illuminate the interior of the carriage, so you can dispense with interior lighting.

In general, the pivots for the bogies will present problems, since they protrude around half a centimetre above the floor of the carriage. Make new pivots, using (for example) flat-head M2 screws and a few washers. Make sure that the bogies turn smoothly, and that the pivots protrude above the floor of the carriage as little as possible.

If the carriage is used on a Märklin system,

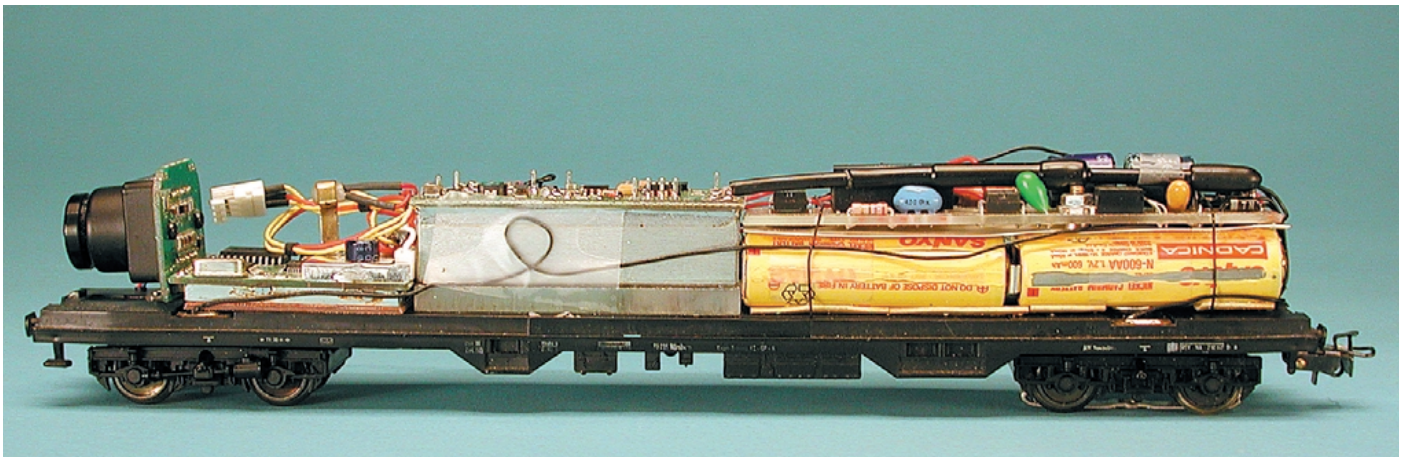Figure 7. Connecting the front and rear signal lamps.

Figure 8. Placement of the components in the driving trailer carriage.

it is better to replace the insulated wheels with uninsulated types, since this makes for better contact with the rails, and contact rails will react properly when the carriage passes over them.

The Fleischmann carriage does not have a NEM standard shank, so the Fleischmann coupling cannot be directly replaced by a Märklin coupling. However, if you use a small strip of 0.5-mm thick brass to extend the Märklin coupling, it is possible to attach the carriage to a Märklin train.

If the camera driving trailer is used on a Märklin system with stop sections for the signals, a sliding contact must be mounted under the driving trailer carriage to prevent the entire train from coming to a halt after passing the signal. A connection must be made through the length of the train between this contact and the switchover relay in the locomotive. This can be done using conductive couplings, Roco multiple-lead connective couplings or a thin piece of wire running through the train.

If you use a piece of wire for the connection, it is practical to use pin-and-socket connectors at the couplings, so the cars can be stored individually. The turned pin sockets of a good-quality IC socket are a very good choice for such connectors, due to their compact dimensions. Solder on the wires as shown in the draw-ing, and slide a short piece of heat-shrink tubing over the pin, to provide insulation and prevent the wire from breaking off so quickly.

The supply current must switch between the slider under the loco-motive and the slider under the dri-ving trailer, depending on the direc-tion that the train is travelling. A small, bipolar 12-V relay located in the locomotive is used for this (Takamisawa RALD12W-K.

If the rail voltage is used to sup-ply power to the camera and trans-mitter on a Märklin railway, a slider must also be mounted under the bogie. The best choice here is a
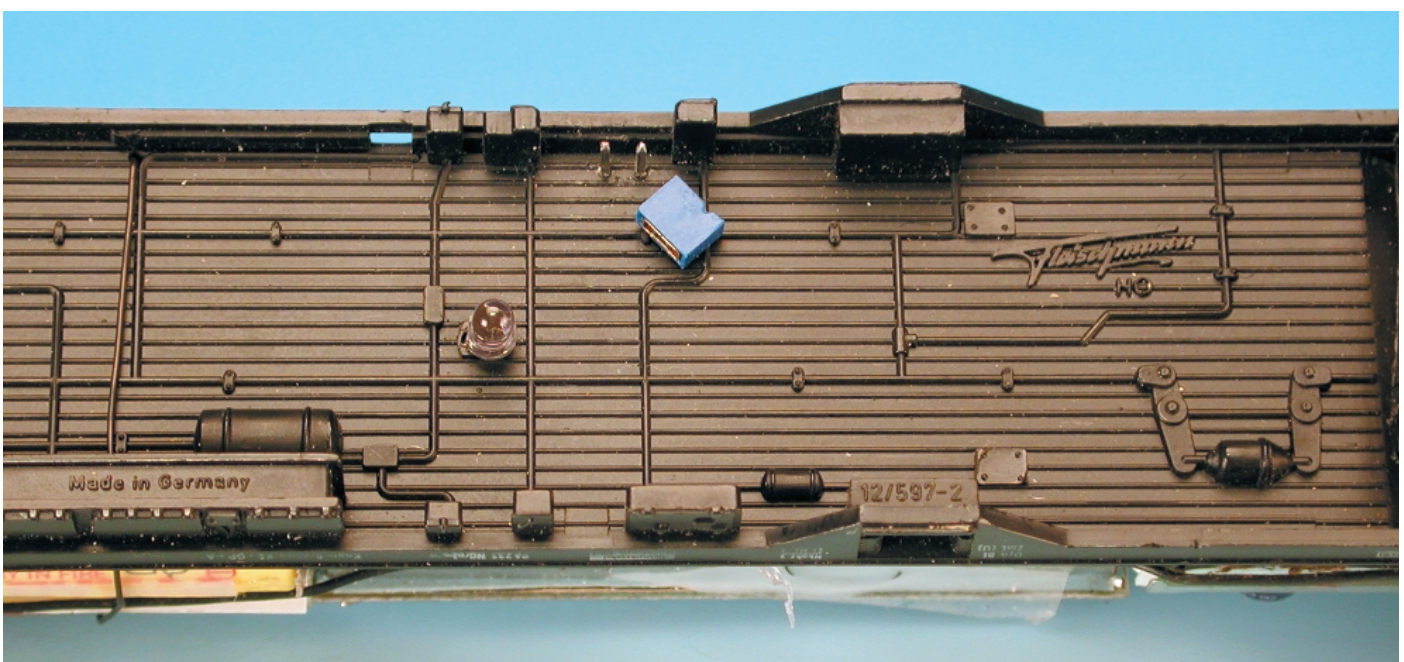

Figure 9. The IR LED and jumper switch in the middle of the carriage body.

Märklin type 7198 sliding contact, which should be placed under the trailing bogie. This reduces the chance of derailment.

In order to make the video picture as clear as possible, it is a good idea to remove the small plastic window in front of the camera lens. This can be easily done using a small multi-purpose drilling tool and a routing bit.

Refitting the carriage with head and taillights is a finicky little job. A true model builder will not have any

serious problems with this, but if you don't fall in this category, you can do without it.

The Siemens type TLUY 2400 and TLUY2401 yellow LEDs are very suitable for the headlights, while red 3-mm LEDs can be used for the tail lights. For an attractive result, file the 3-mm LEDs flat.

The three yellow LEDs are fastened with a bit of crazy glue. Apply a very small amount of glue to the inside surface of the carriage body around the lamp opening, and then press the LED into the opening. The collar of the LED will then embed itself in the glue.

The red LEDs for the taillights are attached by first applying glue to the LED and then pushing the LED into the lamp opening. The openings for the lights are actually a bit too large, so it is a good idea to use a void-fill-

ing crazy glue.

In order to avoid problems with the carriage body during disassembly, it is best to use a pin-and-socket connector on circuit board B for the supply leads of the LEDs. A three-pole SIL header can be used as the connector. It is also possible to butcher the previously mentioned IC socket with turned sockets to produce a socket strip with three contacts. Insert three pieces of wire (left over from mounting wire-wound resistors) into the connector and cut off the free ends 4 mm from the connector.

Leave the wires in the connector, and solder them longitudinally onto the printed circuit board. Mount the two current-limiting resistors on the circuit board, and file the portion of the board without components into an arc that matches the roof of the carriage. Fasten the circuit board under the roof of the carriage using crazy glue, after first checking that the connector can be slid on.

The connections between the LEDs and the small printed circuit board are made using thin pieces of wire (wire-wrap wire), as shown in **Figure 4** or **Figure 5**.

Now it's time to mount the camera. A right-angle type is mounted on the undercarriage, while a surface-mount type gets a place in the carriage body. In any case, it is

important to mount the camera firmly.

The transmitter is placed in the middle of the undercarriage. In order to position the aerial nicely above the NiCd cells and the printed circuit board, lay it on a piece of 4-mm thick Plexiglas and secure it with contact cement.

If optical address recognition is used, a notch for the connecting leads of the IR LED must be made in the Plexiglas, since the transmitter is located just above the IR LED. Incidentally, this LED can be mounted very simply by drilling two 1-mm holes 0.1 inch (2.5 mm) apart in the undercarriage, and inserting the LED from the bottom.

In order to prevent the NiCd cells from being completely discharged, it must be possible to disconnect them when the carriage is not on the track. A jumper 'switch', such as commonly used in PCs, can be used for this purpose.

Here again, drill two small holes 2.5 mm apart. Pass two small pins through these holes from the top side of the undercarriage and secure them with a drop of glue. This 'switch' can now be closed with a jumper.
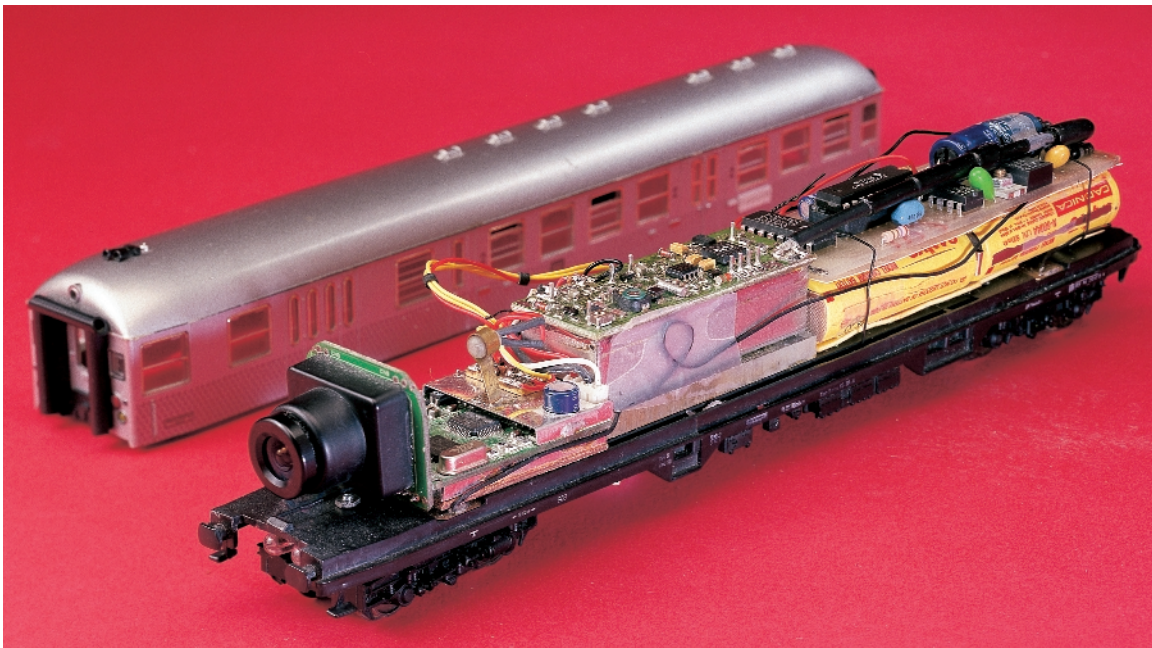
The final step is to mount the NiCd cells along with the power-supply circuit board. The four cells are connected in series by soldering small wires to their terminals. Avoid heating the cells for too long. You can also use cells with solder tabs, but these are generally much more expensive.

The power-supply circuit board and the NiCd cells can be secured to the undercarriage using silicone glue. However, before doing this, you must first verify the proper operation of the circuit board and check that it fits into the carriage body.

Hopefully, these extensive instructions will provide an adequate basis for finding solutions in many individual situations.

Nearly all of the components used are stock items from Conrad Electronic (http://www.conrad-electronic.com), so availability should not be a problem.
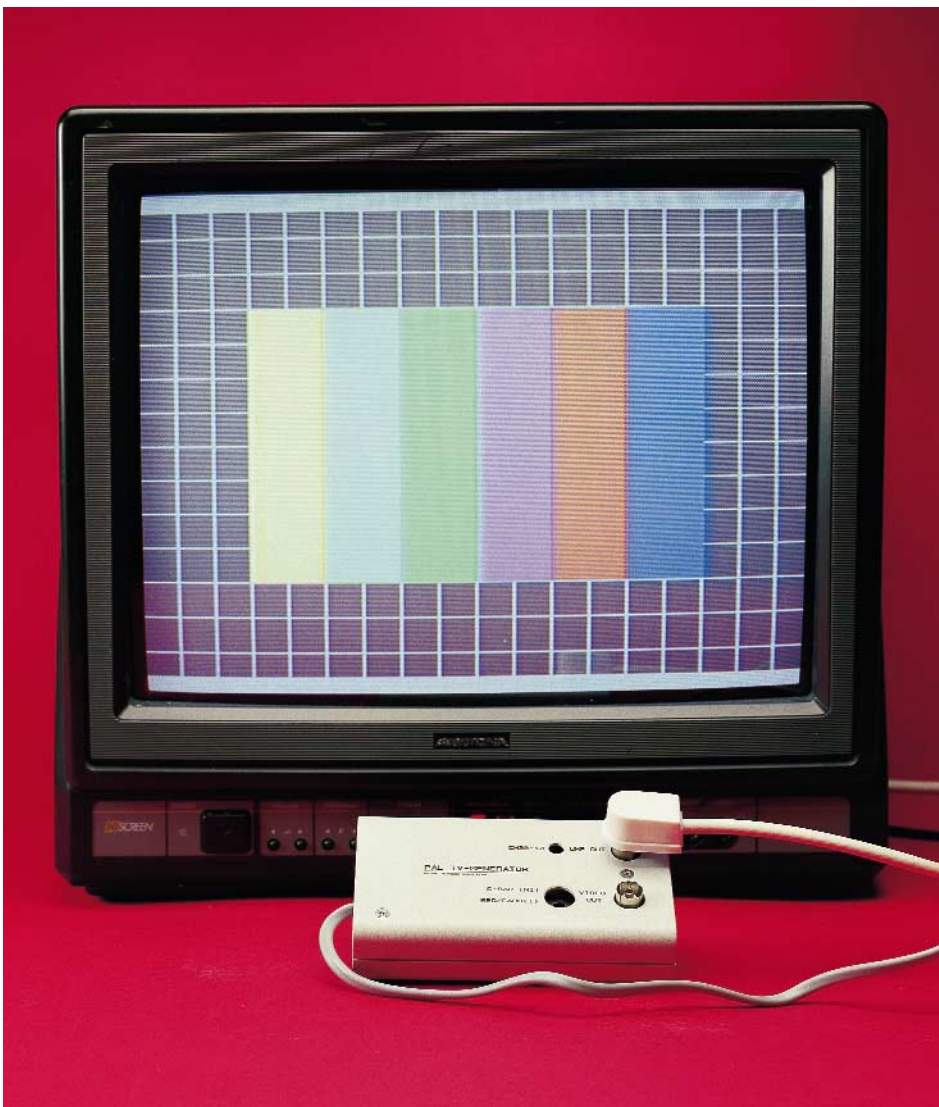
(000129-1)

PAL TV Pattern Generator

prototype board layout using a PC

Design by W. Foede

Email: foede.koeln@gmx.de

In spite of digital television, an analogue test pattern generator is still part of the basic equipment of every electronics technician who works with television and video signals.

This device is an extension of the PAL Test Pattern Generator published in the January 1993 issue of *Elektor Electronics*. The GAL and the two counter ICs that were used at that time have been replaced by an EPLD with 64 I/O cells. The generator produces two test patterns: a colour bar pattern with a grid and a red microgrid. These are adequate for checking all important settings, such as picture position, picture geometry, convergence, grey balance, colour purity, colour and focus. In contrast to the original project, the generator described here includes a UHF modulator, so that the test signal can be fed to the television set not only via the video input sockets, but also via the antenna socket.

The subject of this article is not just the TV signal generator itself. A large part of the assembly instructions is devoted to the development and construction of the circuit. This is because a specific printed circuit board layout has not been developed for this article. Instead, we describe how the circuit can be built on a piece of perforated prototyping board (Veroboard) with a matrix of solder pads. Both the author of this article and the *Elektor Electronics* laboratory staff build most of their (initial) prototypes on such boards. This is because prototyping board
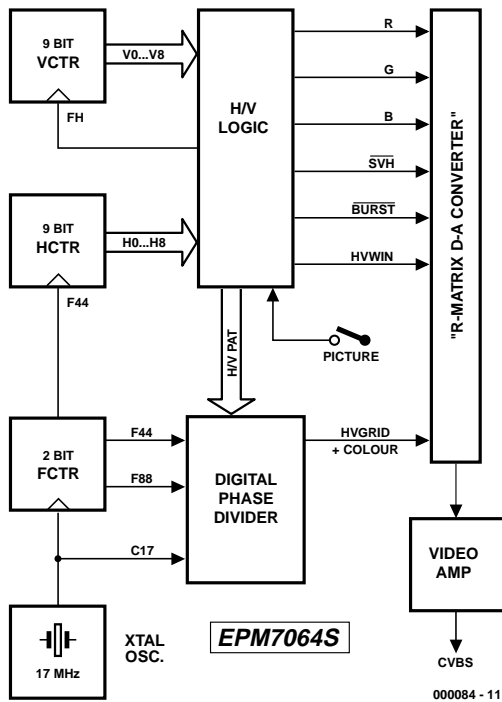
Figure 1. Internal block diagram of the EPLD.

assemblies are actually better than their reputation: they are easy to understand and easy to modify, the components can be inserted quickly, and the preparation of the board does not create any rubbish or additional effort.

There is also no reason why a circuit built on a prototyping board cannot be 'routed' using a PC. For many years, the author has been using a DOS-based, freeware CAD program for this purpose. The procedure will be described in detail later on, but first we provide an appropriately brief description of the circuit of the PAL TV Pattern Generator (since it works in the same way as the extensively documented version of 1993).

The logic: an EPLD

The PAL TV pattern generator con-

sists of only a few components. Apart from the oscillator and video amplifier assemblies, which are built using discrete components, as well as the modulator, all of its major functions are housed in a single programmable component, which is an EPLD. The block diagram in **Figure 1** shows the internal structure of the EPLD, as well as the connections for the oscillator and video amplifier. The operating principles can be easily explained using this diagram.

The discrete quartz crystal oscillator supplies the common clock C17 for all signals. It runs at four times the frequency of the colour subcarrier (CSC) (4.43361875 MHz $\times$ 4 = 17.734475 MHz). C17 clocks the 2-bit counter FCTR, which in turn generates the signals F88 (approximately 8.8 MHz) and F44 (approximately 4.4 MHz). If F44 is divided by 284 using the 9-bit counter HCTR, the result is the horizontal frequency FH. This means that the generator works with a full-line offset, in contrast to the PAL standard, which prescribes a relationship of FH = FHT ÷ 283.7516 = 15.625 kHz (quarter-line offset). If the oscillator is tuned to exactly 4 × FHT, the horizontal line rate is here FH = 15.611 kHz.

The vertical frequency FZ (50.036 Hz) is obtained from the horizontal frequency via the 9-bit divider VCTR. This yields 624 lines for a full frame and no interlacing, which is called 'progressive' operation. This is good for test pattern images, since a stable image can be observed without any stress. It does not have the flickering edges of a normal television picture, which are only eliminated in top-end equipment using 100-Hz technology and full-frame memories. The small deviations from the standard are not visible in the rest of the image, and can be completely ignored. In the H/V logic, all of the picture, blanking and synchronisation signals are digitally programmed using the two 9-bit counters and logical operations, with precise timing and TTL levels.

Special effort is necessary to generate the colours. For each colour, the CSC has different phase states (hues) and amplitudes (saturation). In line with the PAL standard, the phases for each colour alternate from line to line. This also applies to the colour synchronisation signal (colour burst) on the back porch following each horizontal sync pulse. For six colours and the colour burst, a total of 14 phases are needed. Using the principle indicated in **Figure 2**, it is theoretically possible to digitally generate all the phases in a 45-degree matrix. By selectively inverting F44 and F88, as well as clocking with the rising or falling edge of C17, there are even several options for each phase. In addition, the propagation times of the individual signals and
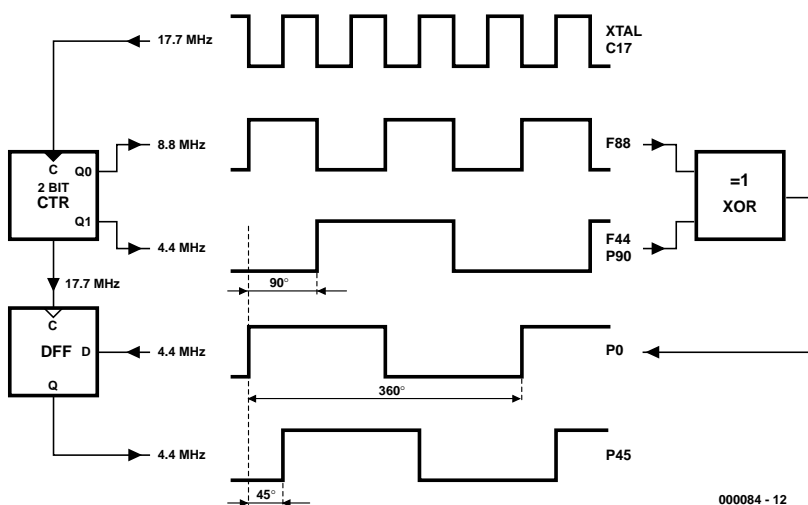

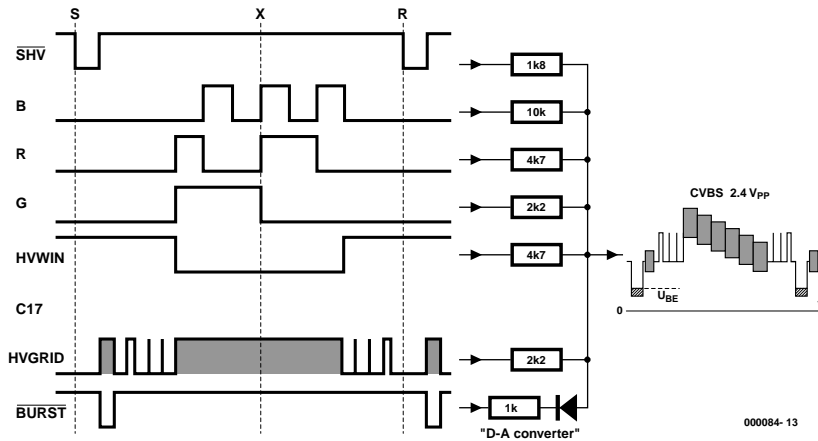Figure 2. The working principle of the digital 45° phase splitter.

Figure 3. A D/A converter made from discrete components gives form to the composite video signal.

position of the colour burst on the back porch.

Before and after the logic

Let's take another look at the assemblies outside the ELPD in **Figure 4**. The clock generator, consisting of the overtone crystal X1 with the resonance capacitors C9 and CT1, is buffered by a transistor stage with T1, so that the clock signal C17 can drive a reasonable load.

A video amplifier based on T2 is connected to the output of the EPLD. It provides a low-impedance output. The commercial UHF modulator is driven by the composite video signal (with frequency compensation provided by R14/C8) and by a heavily integrated square-wave signal from VCTR at around 500 Hz, which serves as the audio signal. In order to minimise the number of external components that have to be connected to the circuit board, the modulator is slightly modified so that its antenna input also serves as a video output and the test switch serves as a test pattern selector switch. The UHF antenna output of the modulator is also available.

The modulator contains a wideband amplifier with input sockets, for feeding through the antenna signal. This amplifier is not used, so the Vcc connection (pin 5) and the antenna socket are free. Pin 4 is either grounded or left open. The modulator is grounded via its case, so pin 4 can be made free, possibly after cutting an internal connection to ground. In this case, be sure to restore the ground connection inside the modulator with as short a lead as possible.

In order to modify the modulator as shown in **Figure 5**, first open the back cover of the modulator. The inner contact of the HF socket is always connected to an air-core coil and an SMD capacitor. Break this connection, and then pull out the free end of the coil and cut it off. Next, unsolder the capacitor. Now all that is missing is a wire to pin 4, which receives the composite video signal via R12. We can do without the test signal generated inside the modulator, which consists of two black vertical stripes and horizontal (but not vertical) sync pulses. The

the duty factor of C17 affect the results. The phase states that most closely match the PAL standard were empirically selected using a PAL vectorscope; that is, by repeated trial and error. The result is a visually very usable colour bar pattern in test pattern 1. The timing relationship between the colour signal (C) and the picture signal (Y) is also provided by the H/V logic. The resistor network R1/R5–R9

represents a digital-to-analogue converter that, for each relationship, combines the digital levels of the individual components to produce the composite video signal (see **Figure 3**). HVWIN adjusts the brightness of the colour bars to match the rest of the image content, and BURST adjusts the amplitude and
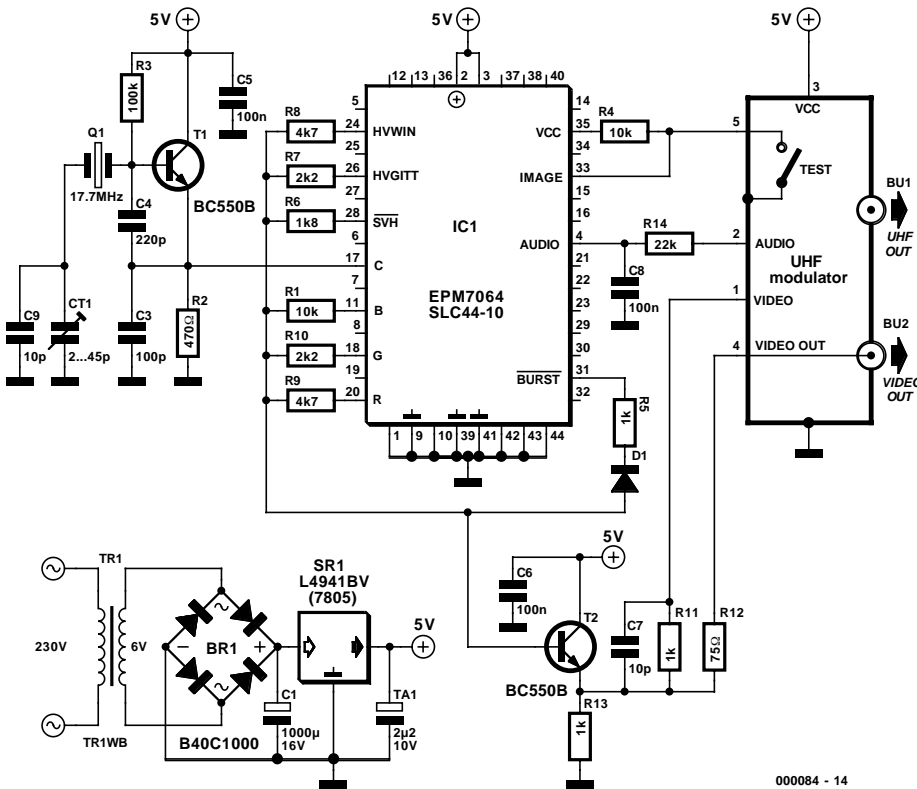

Figure 4. The EPLD needs only an oscillator and a buffer stage. The UHF modulator generates an HF signal, but in addition to an audio signal, it also provides the unmodified composite video image.

modulator works in normal mode when the contact point of the test switch is connected to ground. In the best case, one of the three contacts is grounded. When the switch is operated, the middle contact is connected to this grounded contact, and the third contact is free. If the two contact points are now bridged with a bit of solder, the free contact will be connected to ground when the switch is operated. After cutting the Vcc track to pin 5 inside the modulator, the switch contact that has been made free can be connected to pin 5. The SMD filter capacitor that is usually connected to pin 5 can be left in place, since the signal BILD is in principle a DC voltage. Before closing up the modulator, it is strongly recommended to carefully check the modifications with an ohmmeter.

Unfortunately, in some modulators the connections to the test switch are different, even though is serves the same purpose. Naturally, if you have any doubts about making the modifications, it may be better to use an external switch or an external video socket.

The modulator is soldered directly on top of the circuit board using four 1-mm solder pins. The electrical connections are extended using five solder pins.

From painful practical experience, we know that every circuit, no matter how nice, also needs an enclosure, and we must not overlook the power supply. The snap-together shell enclosure used here is very inexpensive and should be a stock item in every electronics shop. It consists of two half shells that are 15 and 25 mm deep, respectively, and it restricts the size of the circuit board to 117×61 mm.

The power supply consists of only a few components, so it can also be mounted on the main circuit board. This makes a mains adapter unnecessary. Any printed-circuit-board transformer with a capacity between 1 and 2.5 VA and suitable dimensions can be used. To be on the safe side, we have chosen a 5-V low-drop voltage regulator, but from 1.5 VA upwards a 7805 in a TO220 package can also be used.

Alignment

Before installing the EPLD, you should measure Vcc ($+5$ V) on pins 2 and 3 of IC1, on the collectors of T1 and T2 and on pin 3 of the modulator. In addition, it is recommended to use a continuity tester to check all ground connections (with no power applied to the circuit). You can verify C17 using an oscilloscope. The crystal should oscillate, and with a frequency counter connected to R2, you can take this opportunity to adjust C17 to 17.734475 MHz using the trimmer capacitor CT1.

With the power off, you can now install IC1. On the unloaded video output, you should find a composite video signal with a level of around 2 V_{pp}. The trimmer in the modulator can be adjusted to an UHF channel between 30 and 40. If you do not have a frequency counter available, adjust CT1 for the best colour reproduction on a television set. The test pattern with the red microgrid is suitable for checking and adjusting the focus with the colour contrast set to zero and increased black-and-white contrast. With low black-and-white contrast and maximum colour contrast, it can be used for testing colour purity. The main test pattern, with colour bars and a grid pattern, can be used for all other adjustments. When the picture position and geometry are properly adjusted, the broad white borders should fall just outside of the visible image area.

From concept to prototype

The development of a private project can be concisely described in the following manner. First you have an idea, and following this you sketch a design on paper and then construct a prototype, either in the form of a 'component sculpture' or using a socket-strip prototyping board. After a while, the circuit will actually work. Experienced constructors use the schematic editor of a layout program to prepare the schematic diagram, and then use the layout editor to produce the circuit board layout. The exposure mask is then glued and exposed or printed, and the circuit board is etched, drilled, stuffed and soldered. This is a lot of effort for a circuit board that in many cases
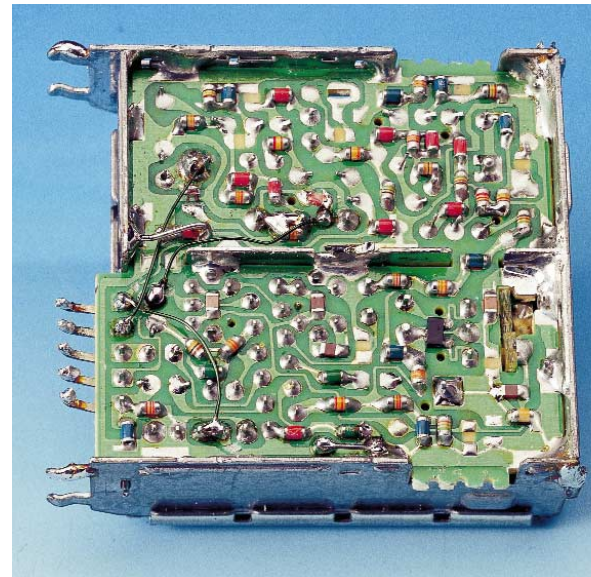

Figure 5. Modifications to the modulator (shown with the cover removed).

still has bugs, especially if you do not do it all that often.

Most of the circuits published by the author over the years have been built in the demonstration stage using perforated prototyping boards with a matrix of solder pads, according to the method described below. The advantages are no chemicals, no broken 0.8-mm drills, standard materials and no waiting. If you work reasonably carefully, the results are certainly quite presentable. Surprisingly enough, the final *Elektor Electronics* circuit boards are often no smaller than the prototype. A well-built circuit on a perforated prototyping board can also be very helpful when making the conversion to a 'real' circuit board; it is in a manner of speaking half the battle.

Prototype layout with a program

The best way to achieve an elegant arrangement of the components on a perforated prototyping board is to use a layout program to generate the schematic diagram and the layout. If possible, this program should cost nothing and still be legal — in other words, it should be freeware. Two possibilities are *Eagle light* from CADSOFT and *Target 2OO1!V8 discover* from Ing.-Büro Friedrich, both of which have Windows interfaces and are available via the Internet (see 'On the Internet'). For this circuit, the author has chosen *Easytrax*, which is a proven, free DOS program from Protel. It is especially suitable for beginners, and the included functions are fully adequate.

The program package consists of three zip

archives, which together amount to less than 1 MB (oh, for the blessed days of DOS!). They can be obtained from the Free Downloads page on the *Elektor Electronics* website (select November 2000 items).

EASYTRAX.ZIP

The file EASYTRAX.ZIP contains the PCB drawing program EASYEDIT, the plotter output program EASYPLOT with drivers, BOM (bill of materials) and several input and output converters for other Protel programs. EASYTRAX.ZIP is initially unpacked onto a diskette (but not automatically installed). Following this, you can start the installation routine with a mouse click, and the drawing program and its accessories will be stored in the predefined folder C:\EASYTRAX. During the installation, you must select a video driver; standard VGA with 640 × 480 pixels will always work. You can try out other drivers that look like they may be usable. The video driver is installed in a separate folder called C:\GRAPHDRV. A separate DOS driver must be loaded for the mouse. An English-language manual of around 25 pages is located in the READ.ME file. An extended component library is available on the Internet, as well as extensive installation instructions (in German).

The drawing program, which can be used to draw a schematic diagram or a layout according to the component library used, is started using EASYEDIT.EXE. This program is quite easy to use, so we do not need to provide any instructions here. Everything that you need to know can be found in the ReadMe file.

Generating suitable component libraries is unfortunately difficult, but it is nevertheless sometimes necessary to do this preparatory work. You have to draw each component on a suitable layout level (such as OVERLAY) with its outline and solder pads (PAD), and then define it as a BLOCK. The cursor position when the left button of the mouse is clicked the first time after the block has been finished defines the reference point, which determines where the component appears with respect to the cursor after being called up from the library. The reference point and the pads should be specified using a 100-mil (2.54-mm) reference grid. The component is stored using the hotkeys L/A/Y. Components from the library can be converted back into editable individual elements (PRIMITIVE) by pressing the L/P keys and clicking on the component, after which the elements can be modified. The diameter of a circle can be adjusted using the left and right cursor keys (snapping to the reference grid), and a circle
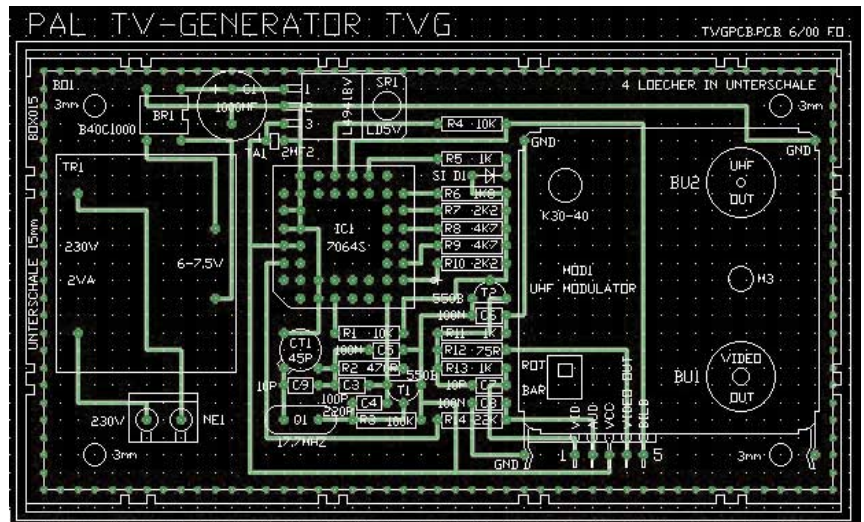

Figure 6. Screen dump of all circuit board layers under *Easytrax*.

can be divided into quadrants by clicking on it and then pressing the cursor keys. A new function can be called up only after the current one has been stopped by pressing <ESC> once or twice. It is always possible to change the reference grid to 100 mil (2.54 mm) for this project using G <CR>, in order to place components (PLACE COMPONENT) or lay down tracks (PLACE TRACK). Similarly, +/– zoom (PgUp/PgDn) and refresh (F9) are always available. The holes of the circuit board are located on a 2.54-mm grid, or

better put, on grid with a spacing of 100/1000 of an inch, or 100 mil. It is a good idea to set the default units to inches (IMPERIAL). Although this takes some getting used to if you are accustomed to working in metric, it makes sense, since almost all standard electronic components are based on a 100-mil grid. It's also easier to divide 100 mil by 2 or 4 than to divide 2.54 mm!

The circuit board uses only four of the available layout layers (LAYER), namely OVERLAY for COMPONENT and STRING, BOTTOM (solder side)
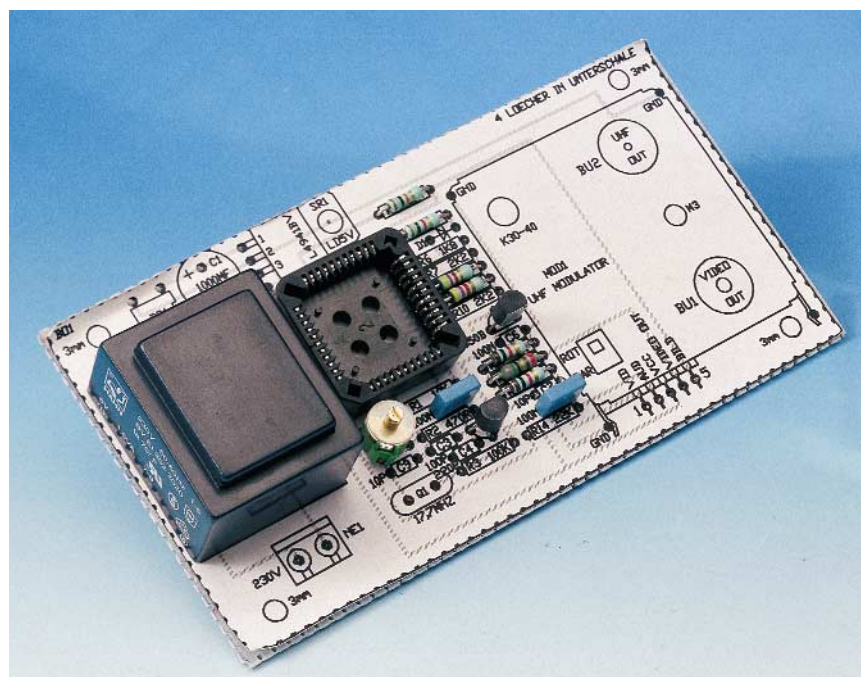

Figure 7. The 1:1 layout drawing is glued to the perforated prototyping board.

for TRACK, MULTILAYER for PAD and MIDLAYER 1 for mechanical elements. **Figure 6** shows a combined print of all four layers.

When the board layout is finished, you can use EASYPLOT to convert it into a plotter file (*.dft) and plot it. The plotter output provides the most options, since a different pen can be assigned to each layout layer. Each layer can be locked or flipped.

PRINTGL.ZIP

If you do not have a plotter, you must convert the dft file into a print file. The files located in the PRINTGL.ZIP archive can be used for this. You will find plotter emulators for Windows,

TVG.EXE (also available from the *Elektor Electronics* website) into the EASYTRAX directory and start it up before starting the program. This file contains the complete instructions, as well as the libraries and default settings. Any matching program modules that may already be present may be overwritten when the file is unpacked. TVGSCM.LIB is for the schematic diagram of the pattern generator, while TVGPCB.LIB is for the layout. Both libraries are located in TBG.EXE.

Solder-pad matrix

Now you can print the layout at 100% scale, cut it out and glue it onto

through the holes as usual. Pull their leads through as you would with a 'real' circuit board, bend them over on the solder side, cut them short and then solder them (see **Figure 8**). Lead wires are not well suited for making tracks. Only after all the components have been mounted should you start adding the interconnecting wires. For this the board should be held level, preferably firmly secured in a bench vice. You will need tinned or silver-plated hookup wire with a diameter of approximately 0.5 mm for the interconnections. Pull several pieces around 30 cm long straight using two smooth-jawed pliers. In order to avoid excessive warping with long connections, due to thermal expansion during soldering, it is best not to bridge more than 4 to 5 holes at a time. The use of a small bending gauge is highly recommended, including for the wire bridges. In order to make a connection 'around the corner', you must use two wire bridges. Very short connections can be made using solder alone.

The 1:1 printout can also be used as a drilling template for the 25-mm deep upper shell of the enclosure. The circuit board is firmly fixed to the 15-mm deep lower shell on the modulator side, using four 10-mm long threaded standoffs with 3-mm internal threads. The Euro mains cable can be fitted with a plastic strain relief clamp of suitable diameter.

(000084-1)

Note:
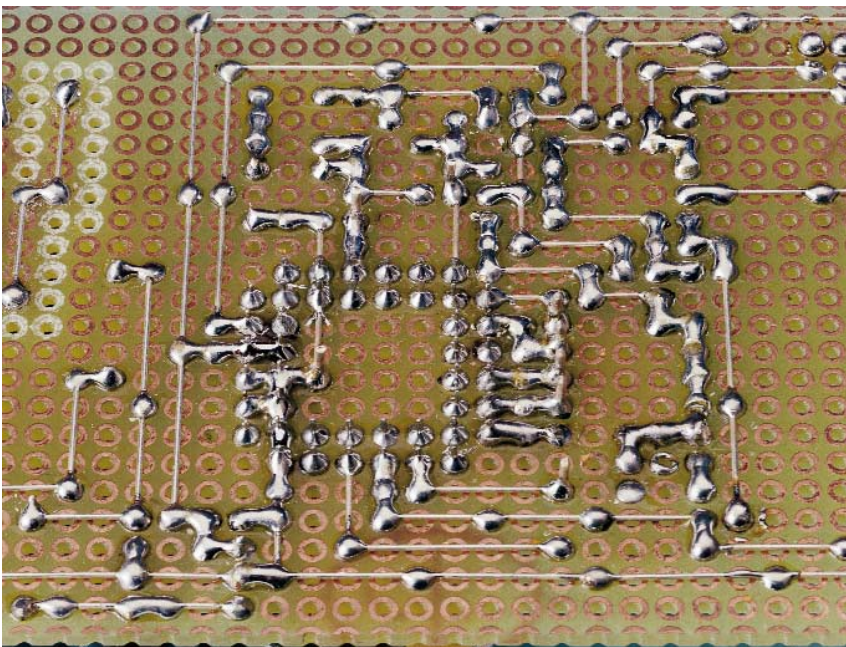The programmed EMP7064 for this project is available through our Readers Services as order code **000084-31**.

Figure 8. The components are first completely soldered…and the interconnecting wires are then attached.

a printer driver for DOS-CAD and, once again, an extensive ReadMe file. The files in the zip archive are unpacked and directly copied to C:\PRINTGL.

The plotter program is called using the user interface PMI.EXE. The line width and density can be individually selected for each pen.

TVG.EXE

If *Easytrax* is used especially for this construction project, it is easier if you load the self-extracting file

the perforated prototyping board (see **Figure 7**). This spares you the tiresome task of counting holes. If possible, you should use an epoxy-glass prototyping board for reasons of stability, but a Pertinax board can also be used. The cutting lines always run through the middle of the holes. You can score a Pertinax board on both sides with a pointed tool and then break it, while an epoxy board can be readily cut with a heavy shears. You can leave your saw in the drawer.

The components are inserted

Measuring with an NTC

temperature measurement using a multimeter

By Bob Stuurman

It is often desirable to know how hot a part is. The usual method is to use a thermometer to measure the temperature, but this may not always be practicable.
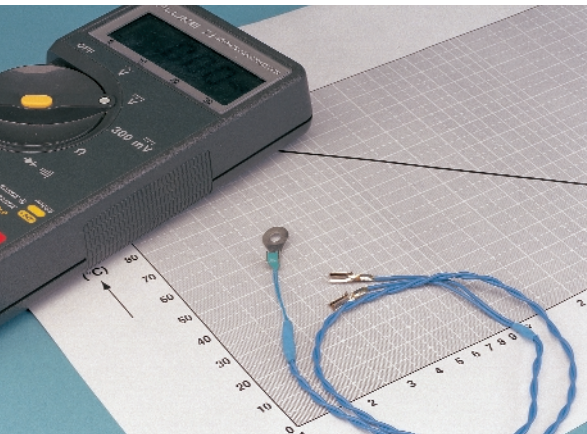
However, with the help of a small NTC and a multimeter it is just as easy. During the development of a speed controller with a final stage consisting of MOSFETs, it was necessary to measure the temperature of these devices. A normal thermometer is unsuitable for this purpose, so a search was made for a sensor that could be secured to a MOSFET.

We found an NTC resistor, type 46720055, in the Conrad Electronics catalogue that appeared eminently suitable. The NTC has a flange with a hole with which it can be secured using a screw. This was exactly what we needed. But how could the measured resistance be easily converted to temperature?

Graph

First, two flexible leads, each 30 cm long, were soldered to the NTC terminals. Next, the NTC was securely fastened to a normal glass thermometer with a measuring range from 0 to 110 °C. This whole assembly was submerged in an electric kettle filled with water. After switching on, the measured resistance was recorded at every 5 °C temperature rise, until the water boiled. At this point the kettle was switched off. While the water cooled down, the resistance was recorded again at every 5 °C fall in temperature. It was noticed that the temperature indicated by the thermometer fell steadily but that the resistance fluctuated. Apparently, the NTC reacts faster to turbulence in the water than to the thermometer does.

It was hoped that a graph could be generated showing the linear relationship between temperature and resistance. But this was not so, the relationship appeared to be a logarithmic one. The graph shown here is the result. The function is a straight line when plotted using a logarithmic resistance scale. Not all measured data points lie exactly on a straight line. Also, differences between individual NTCs can cause variations. However, we may assume that the error will be smaller than 5%. The nominal value of the NTC is 10 kΩ at 25 °C. From the graph, at 10 kΩ, we read a value of approximately 23 °C. This is sufficiently accurate for our purposes.

Applications

Using the NTC, a DVM with an appropriate resistance range and the graph it becomes very simple to measure the temperature of a part. Because the NTC is small, it has very little thermal inertia. It quickly settles to the temperature of its environment and contributes little heat. It is easy to attach to a TO-220 MOSFET, an electric motor, or something similar. The thermal conductivity is very good because the mounting flange is made from brass. The NTC is small and light. As a consequence, vibrations — such as from an electric motor — have no influence on the measurement.

The horizontal axis of the graph is the measured resistance value. Going straight up from this value until you hit the curve allows you to read the corresponding temperature on the left.

Examples: 1000 Ω corresponds to a temperature of 90 °C, 2000 Ω corresponds to a temperature of 70 °C.
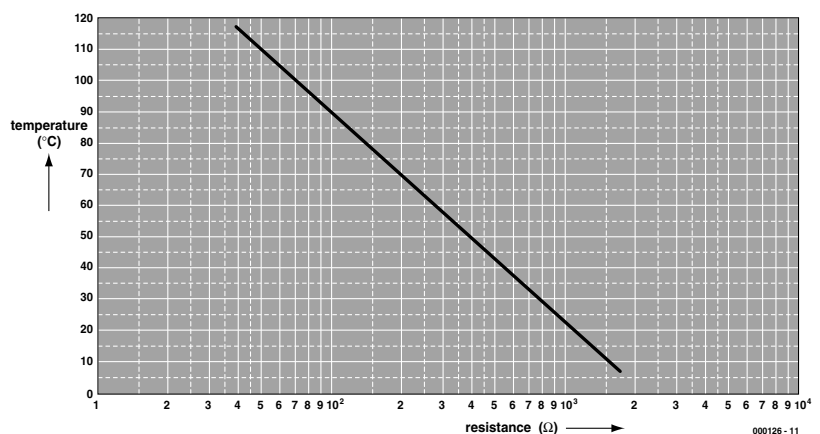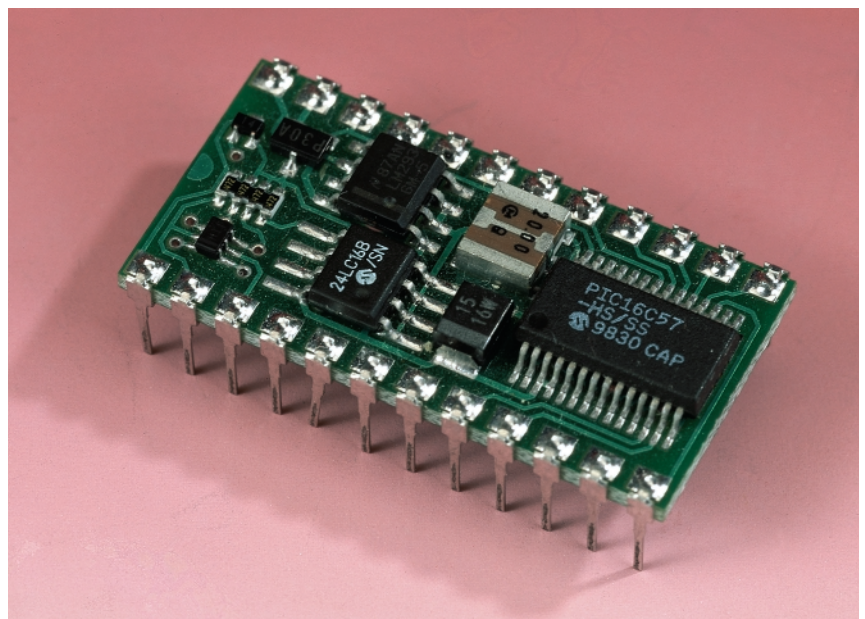
(000126)

Figure 1. The resistance characteristic of an NTC forms a straight line if we use a logarithmic resistance scale.

LCD Driver for BASIC Stamp II

## a serial-in, parallel-out (SIPO) module

Design by K. Burkhardt

This circuit needs only four connections to equip a BASIC Stamp II with an LCD module.

The BASIC Stamp II has 16 I/O lines. To connect an LCD module to a BASIC Stamp II board, you would need eight data lines and two control lines. Even if you split the data byte into two sequential four-bit packets, the LCD module still takes up six I/O connections of the BASIC Stamp board. With certain applications, this may mean that there are not enough I/O connections left over.

Two busses

The alternative control circuit described here makes do with only four leads. It employs the well-known 74HCT574 bus driver in an unconventional manner, as a serial-in, parallel out (SIPO) IC. As can be seen in **Figure 1**, the eight flip-flops of the bus driver are connected in series, so that it functions as a shift register. The serial input data reach the 74HCT574 via one lead (DATA), and a second lead (CLOCK) is required for the shift clock. The data traffic is similar to that on an I^{2}C bus.
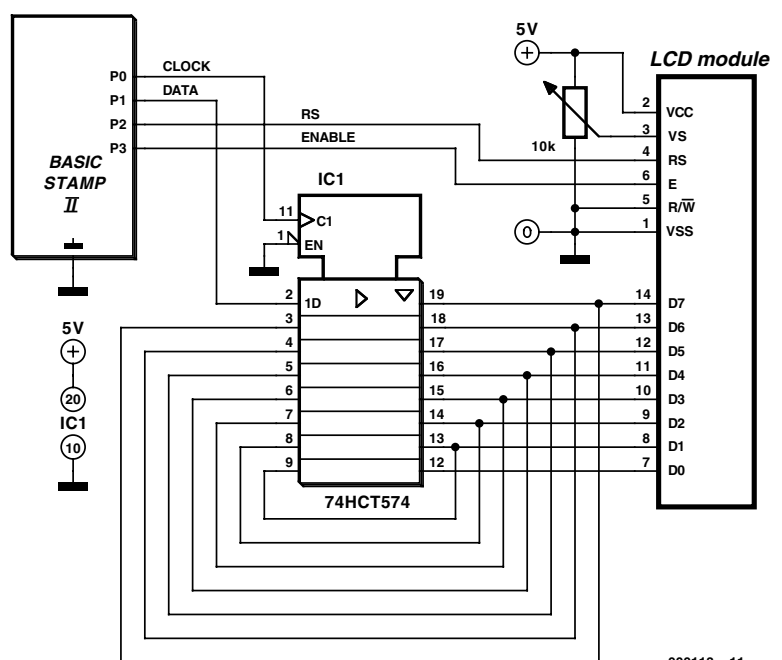
Figure 1. A bus driver sits between the BASIC Stamp module and the LCD module.

Whenever a complete byte is available on the outputs of the shift register, two additional leads come into play. The status of the RS (register select) lead determines whether the following byte is to be interpreted as a control command (Low) or as text to be displayed (High). The byte is transferred into the display memory on the falling edge of the BNA (enable) lead. We must do without the option of reading out the contents of the module. Consequently, the associated R/W̄ pin of the module (pin 5) is tied to ground.

Software

The program for driving the four relevant I/O leads of the BASIC Stamp module is shown in **Figure 2**. It is short, and thanks to the comments, it is not difficult to understand. Following the usual variable definitions, it consists of a main routine and two subroutines.

The `shift:` subroutine reads the eight-bit value `command` (control or text) from right (lsb) to left and passes it via P1 (out1) to the shift register, clocked a bit at a time by the `pulsout` instruction (SCL).

The second subroutine, ena:, consists of only one instruction. It generates an enable pulse for transferring the parallel byte from the 74HCT574 outputs into the module's memory.

The main routine `in_lcd:` takes care of the configuration of the display and switching between the first and second display rows. The comments in the listing are self-explanatory.

(000113-1)

The program can be downloaded at no charge from our website at http://www.elektor-electronics.co.uk. Select Free Downloads, November 2000, item 000113-11.exe.

Figure 2. The short program listed here can be downloaded from the Elektor Electronics website.

```
memory data "1st Line ——*2nd Line ——*"
charvar byte
sipovar nib
avar byte
commandvar byte
dirs = %0000000000001111
out0 = 0                    Clock (SCL)
out1 = 0                    Serial data (SDA)
out2 = 0                    Register Low = command mode /
                            High = data mode
out3 = 1                    High to Low edge = Enable


in_lcd:                     Initialise display
command = %00000001         Clear
gosub shift:gosub ena
pause 10
gosub ena:gosub ena


command = %00000011         Cursor home
gosub shift:gosub ena
gosub ena:gosub ena


command = %00111000         8 bit / 2 lines
gosub shift:gosub ena
command = %00001111         Display on/Cursor+Blink on
gosub shift:gosub ena
command = %00000110         Move to right
gosub shift:gosub ena
toggle 2                    Switch to data input
pause 100


for char = 0 to 15
read char,command           Text "1st Line....."
gosub shift:gosub ena
pause 50: next


toggle 2                    Switch to command
command = %11000000         Start of 2nd line
gosub shift:gosub ena
toggle 2                    Switch to data input
pause 100


for char = 16 to 30
read char,command           Text "2nd. Line....."
gosub shift:gosub ena
pause 50: next
stop                        End of subroutine


shift:
for sipo = 0 to 7
a = command & 1             Masked AND command reads LSB only
out1 = a                    Serial data (SDA)
pulsout 0,10                Shift Clock (SCL)
command = command / 2       Shift right,1
next:return


ena:
pulsout 3,10:return         Enable for data copying
```

PC Serial Peripheral Design (3)

By B. Kainka
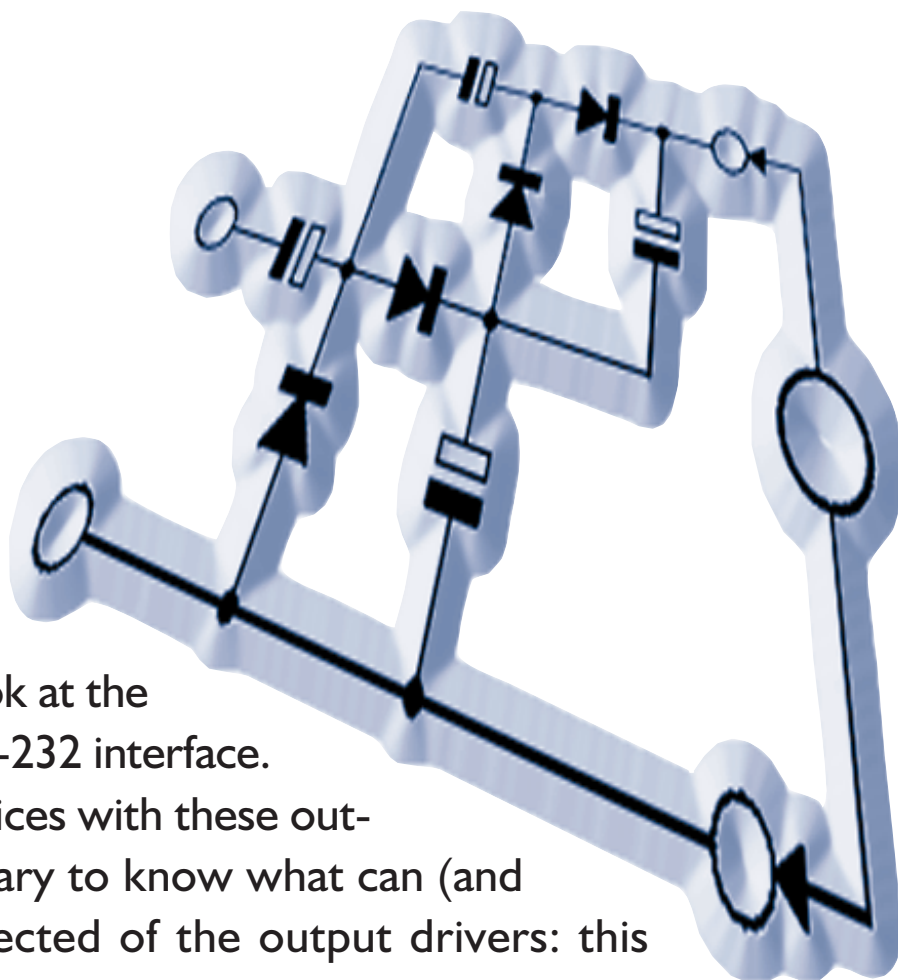
In this third part we look at the
output signals of the RS-232 interface.
In order to control devices with these out-
put signals, it is necessary to know what can (and
what cannot!) be expected of the output drivers: this
knowledge can then be used in our experiments.

We have already seen in this course that the output signals of the RS-232 interface swing between −10 V and +10 V. However, because the output current is limited, it is safe to connect an LED directly. But what exactly are the characteristics of the outputs? We shall attempt to answer this question now.

In general, manufacturers of PC equipment follow the RS-232 standard, in which the voltage levels used to send data are specified. It was originally specified that

the output voltages should be ±15 V, while at the inputs a signal of at least ±3 V is required. Voltages below −3 V are considered to be a logic '1', and voltages above +3 V are considered logic '0'. Since the outputs deliver ±15 V, and the inputs require only ±3 V, reliable data transfer is assured even over long cables. Noise is much less of a problem than it is with for example the TTL logic levels of 0 V and 5 V.

The standard in theory and practice

Modern PCs no longer adhere to the requirement to generate output voltages of ±15 V. The PC's power supply produces +12 V and −12 V, which are used instead. The ultimate voltage is somewhat lower than this again: this is due to the output drivers used. On separate interface cards the 1488 driver and 1489
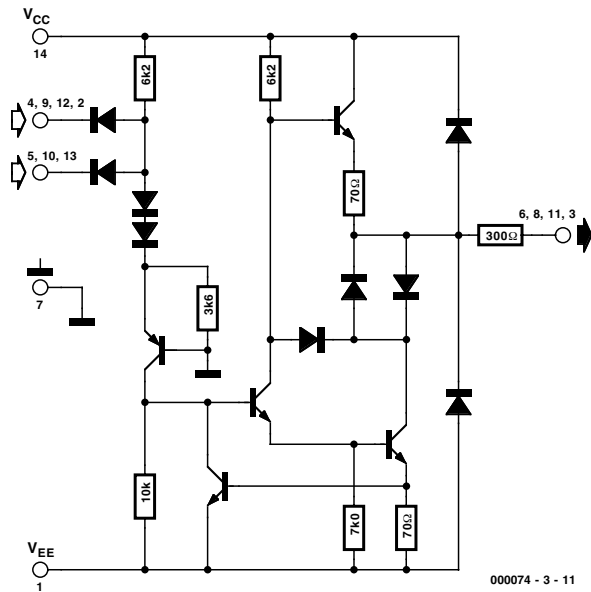
Figure 1. Schematic of the 1488 (source: Motorola).

Figure 2. Measuring the open-circuit voltage (2a) and the short-circuit current (2b).

receiver devices are generally used: these have set a *de facto* standard for the behaviour of RS-232 interfaces. **Figure 1** shows the circuit of the driver in the IC. It is clear how the current limiting (set at 10 mA according to the datasheet) is provided. If the output is short-circuited, no more than 10 mA can flow. It can also be seen that 12 V cannot be expected at the output even when a 12 V power supply is used: the voltage drop of the output stage is such that only about 10 V will be produced.

Many PCs are now built with more integrated components, with output drivers already included, which can produce rather different results. It is interesting to determine the exact voltages and currents available from a particular PC. The trend among PC manufacturers is always faster, bigger, better: that means, as far as the RS-232 interface is concerned, higher baud rates over longer cables with greater reliability. To ensure that the higher capacitance of longer cables does not have too great an adverse effect on the pulse shape, the maximum output current must be increased. The outputs of more recent PCs therefore are capable of delivering around 20 mA rather than 10 mA. A total of up to 60 mA can be drawn from the interface. That is handy for our experiments, and is another reason for wanting to make accurate measurements. On some PCs output voltages of ±12 V can indeed be found: these presumably use MOSFETs in their driver output stages.

Measuring the output characteristics

The output characteristics can be measured very roughly using, for example, a digital multimeter. **Figure 2** shows how to measure the open-circuit voltage and short-circuit current. 'Short-circuit' sounds rather dangerous, but because of its current limiting the RS-232 interface will not be damaged.

The author's PC measures as follows:

Figure 3. Measurements with variable load.
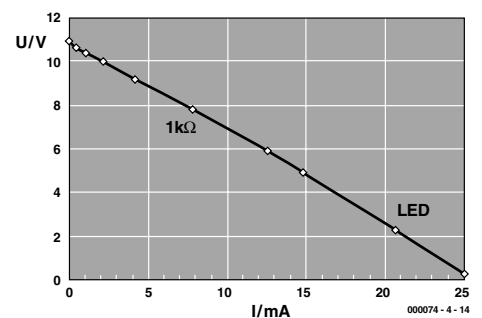
Figure 4. Characteristic curve for one output.

Table 1

R [kΩ]	I [mA]	U [V]
infinite	0	10.9
22	0.48	10.6
10	1,04	10,4
4.7	2.12	10
2.2	4.18	9.2
1	7.8	7.8
0.47	12.55	5.9
0.33	14.84	4,.9
0.01	25	0.25
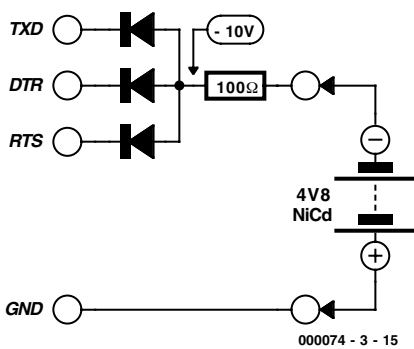
Figure 5. Charging a battery from the RS-232 interface.

Figure 6. Connecting a relay.

Figure 7. Connecting a transistor switching stage.

Open-circuit voltage: $U_0 = -10.9$ V (off), $U_0 = +10.9$ V (on)

Short-circuit current: $I_{max} = -22.4$ mA (off), $I_{max} = 24.4$ mA (on)

A number of measurements must be taken in order to get more exact data for a particular PC: the voltage and current must be mea-

sured for a range of loads. A potentiometer (say 10 kΩ) or a set of fixed resistors of various values can be used as a load. If two meters are available, the v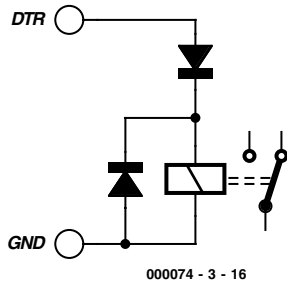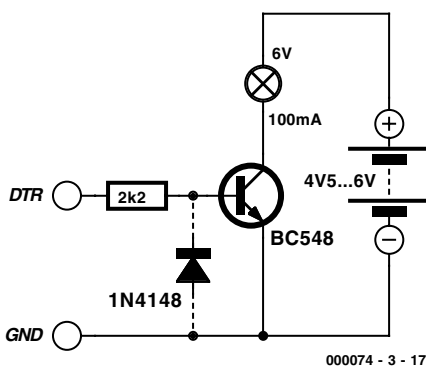oltage and current can be measured simultaneously (**Figure 3a**); if only one, the voltage can be measured, and then, as long as the resistor value is known, the current can be calculated (**Figure 3b**). For the example here, we used a set of standard resistors. The voltage was measured and the current calculated using the formula $I=U/R$. The results can be seen in **Table 1**.

Figure 4 shows how the output voltage decreases under increasing load. The lowest-valued resistor, at 10 Ω, gives practically a short-circuit, but a voltage can still be measured. The graph shows, to a first approximation, that the voltage falls linearly with increasing current. The internal resistance of the output can be calculated from the gradient of the graph to be about 430 Ω. A modern bright LED has a forward voltage drop of about 2.2 V. From the graph we can read off the current: about 20 mA. This is about the maximum allowable continuous current for a normal LED. So our measurements show that we can connect an LED without a series resistor.

We used Microsoft Excel to analyse the measurements. If you wish, you can carry out the corresponding experiments for your own PC, which makes a good exercise in measurement and analysis; or you can move straight on to the following experiments.

Uses for the serial interface

If the interface can drive LEDs directly, the current must also be enough for other purposes. As we have already stated, up to approximately 60 mA can be drawn from the interface. We look at a few applications here.

The following practical application is a small battery charger operating from the serial interface. In the circuit shown in **Figure 5** the charging current is about 30 mA. That is adequate for small batteries or for trickle charging. We will work with a negative output voltage: the

advantage is that the circuit works immediately the PC is switched on, without having to run a program. If it is desired to use the opposite polarity, the diodes can be reversed and the outputs switched to +10 V in software. You could also control charging automatically in software.

Another example of a device that can be driven directly from the serial interface is a small DC motor. A smooth-running motor, such as the ones found in cassette recorders, can be used, and will run satisfactorily on 30 mA. To obtain this current, several outputs are connected together to drive the motor. With a small modification to the 'flasher' program two outputs can be made to switch simultaneously. The motor can then be made to run in either direction.

Small relays can also be connected directly to the interface (**Figure 6**). A diode is normally required to ensure that the relay drops out when the polarity is reversed.

Transistor switching stages

Relays can be used to switch currents greater than that required by LEDs. Cheaper, more elegant and less extravangant is a transistor stage. **Figure 7** shows how a 100 mA bulb can be switched, using an external power supply. The transistor used is a BC548. The principle of the switching stage is very simple: the interface delivers a relatively small base current to the transistor which is amplified, so that the collector current is sufficient to drive the lamp.

How are the components for the switching stage selected? The most important considerations will be discussed briefly here. The operating current of the bulb is 100 mA. This can be provided by a BC548 without difficulty: the maximum collector current allowed is 300 mA. If the lamp current is measured at the moment it is switched on, it will be found that it is considerably greater. When the bulb is cold it has a resistance of about 1/10 of that when it is operating. In theory, then, an instantaneous current of 1 A will flow. In practice, however, the current switched by the transistor is limited.

The bulb filament warms up after only a few milliseconds and so the overload is brief enough to be withstood. If you are not sufficiently reassured by this, you can substitute a BC338 which can withstand a peak current of 800 mA.

The 2.2 kΩ base resistor will have a potential of around 10 V across it. When the output is on, the base current will be about 4.5 mA. The BC548 is available in three gain groups with gains of between 110 and 800. Usually the BC548C is used, with a gain of between 420 and 800. In the pessimistic case a base current of 100 mA/400 = 0.25 mA is required; the actual base current with a 2.2 kΩ base resistor is comfortably more than this. Note, however, that the gain falls at higher collector currents. In any case, the transistor will be driven well into saturation, guaranteeing the smallest possible voltage drop between emitter and collector and keeping power dissipation low both during operation and at the instant the transistor is switched on.

As can be seen, the choice of base resistor is not arrived at by exact calculation, but rather by estimation, since normally the gain of the transistor is not known precisely. It is interesting to try various base resistors to discover over what range reasonable results are obtained. With too high a value, the transistor will not be driven fully into saturation; then the voltage drop becomes greater and the transistor becomes noticeably warm. Also, a resistor which gives satisfactory results in the 'on' state can nevertheless not be able to provide sufficient drive at the instant of turn-on. The lamp appears to turn on slowly, during which time there is considerable power dissipated in the transistor. With too low a base resistor power is wasted in the control circuit, leading also to higher dissipation and possibly to overloading the base-emitter diode by exceeding the maximum allowable base current. The absolute maximum allowable base current is given in the datasheet.

In the circuit diagram a diode is shown connected in reverse between the base and emitter of the transistor. This prevents excessive negative voltages appearing at the base. The maximum reverse voltage of the base-emitter diode generally lies at around –5 V. Breakdown occurs at about –9 V, when a considerable reverse current flows. The transistor behaves like a Zener diode with a voltage of about 9 V. Since in the 'off' state the voltage will be around –10 V, it must be limited. With the diode fitted, the base voltage cannot fall below –0.6 V. It is a worthwhile experiment to investigate the effect of omitting the diode. A reverse current indeed flows, but the transistor nevertheless does not conduct: the lamp remains off. The circuit works even without the diode. It is said that a continuous reverse current over time impairs the noise performance of the transistor; but that will not be a problem here. As so often, it makes a difference whether one is experimenting or designing a circuit in earnest; in the latter case, the diode belongs in the circuit.

AC experiments

The flasher program (Flasher.vbp) produces an alternating voltage on the DTR and RTS outputs, whose frequency can be adjusted up to a limit of about 10 Hz. This lets us try some simple experiments with alternating current. As is well known, a capacitor appears as a resistor to alternating current, conducting the current better at higher frequencies. This can be demonstrated using the circuit of **Figure 8**. Here a capacitor is constructed from two electrolytics connected back-to-back to enable operation with an alternating voltage. This arrangement is sometimes used in driving loudspeakers.

If the flasher program is set to a low frequency, the LEDs alternately flash briefly. At each transition the capacitor is recharged. The current then falls to zero as the voltage across the capacitor approaches the voltage on DTR. If the frequency is increased, the flashes become more frequent and the average brightness of the LEDs also increases. The capacitor presents a lower resistance to the alternating current, and so the (average) current increases.

The alternating voltage produced has a peak value of about 10 V. The peak-to-peak voltage is around 20 V.
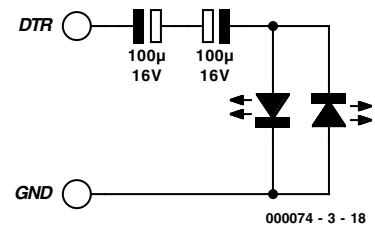
Figure 8. Capacitors as AC resistors.
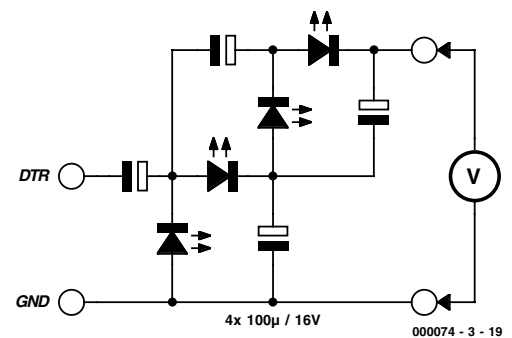
Figure 9. 40 Volts from the serial interface.

Using a special multiplier circuit, a DC voltage of about 20 V can be obtained; using a multiplier cascade a factor of 4 can be achieved, giving about 40 V. The circuit consists of four capacitors and four diodes (**Figure 9**). Here LEDs are used so that the circuit's operation can be seen directly.

When the program is first run, the LEDs flash relatively brightly. The brightness decreases gradually to practically nothing, when the capacitors have charged to their final voltages. A voltage of 40 V can be measured at the output of the circuit. If the capacitors are discharged using a 1 kΩ resistor across the output, the process starts again from the beginning.

This circuit is an example of how LEDs can be 'stressed' by high voltages. This is fine for our experimental purposes, since experience shows that LEDs can cope with the high voltages without difficulty. One should be aware, however, that such circuits hardly represent exemplary engineering practice; for professional applications, silicon diodes (such as the 1N4148) should of course be used.

(00074-3)

PC Audio Amp

2 x 180 W$_{PMPO}$ Mini Amplifier

By R. Badenhausen

This stereo amplifier uses a low cost, and widely available audio IC. The TDA2822M from ST Microelectronics. With the addition of a few passive components it is possible to build a low cost stereo amplifier featuring a good impulse response, ideally suited for connection to a PC soundcard.

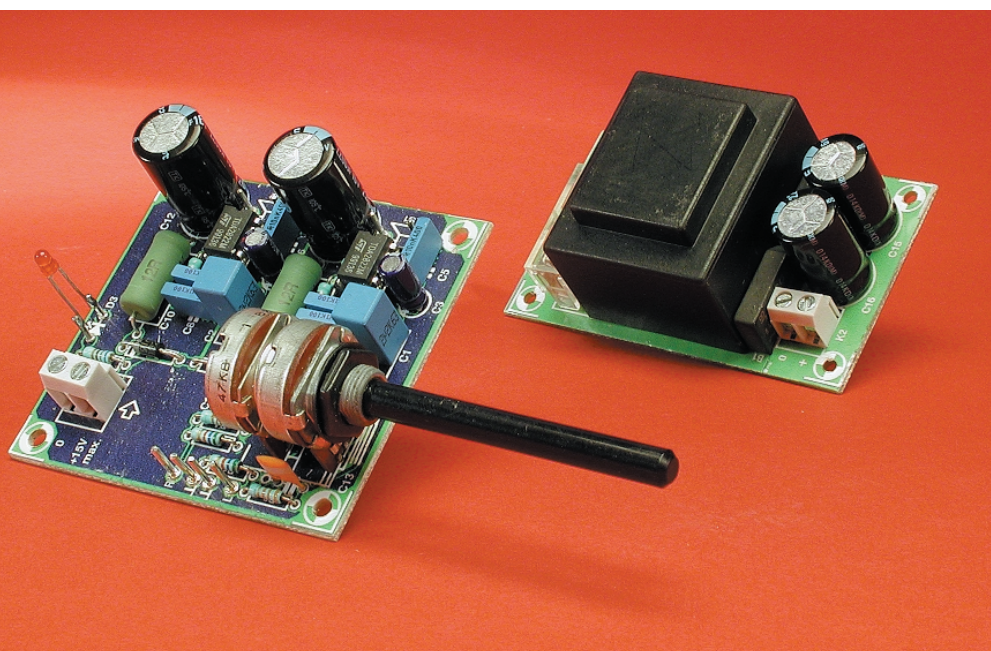Looking at today's compact active loudspeaker systems for PC's you can only marvel at the quoted power output that such small units can produce. A closer inspection reveals that the power quoted is not the generally accepted and well defined continuous power rating of the amplifier but rather its Peak Music Power Output (P.M.P.O.). This rating gives an indication more of the ability of an amplifier to reproduce impulses rather than its continuous output power rating.

Big reservoirs are best

Most amplifiers with a good impulse response employ large reservoir capacitors in their power supply circuits. Calculation of the *P.M.P.O* (see box) assumes that the conducting output transistor T1 can dump the total charge from the reservoir capacitor into the loudspeaker. In practice, a voltage drop across the transistor means that this is not pos-

sible. Moreover, the amplifier will have a minimum operating voltage below which it will cease to function. With many of the low cost PC active speaker systems available on the market, the design of the output stage results in further loss of performance when a capacitor is used between the output transistors and loudspeaker. These are switched in series with the power supply capacitor during conduction and effectively reduce the capacity of the discharge path.

Low Losses

An integrated amplifier was chosen for this design. The output stage exhibits a voltage drop of less than one Volt and according to the data sheet, can work with the supply voltage down at 1.8 V (!). The TDA2822M with its 8 pin mini DIP package outline provides a good solution for a stereo amplifier capable of driving loudspeakers of all the common impedances. **Figure 1** shows the internal circuit of the TDA2822M and also a typical application circuit. The RC network R3/C6 and R4/C7 serve to suppress any tendency to oscillate. This bipolar chip has a fixed voltage gain of

Test results

(1 kHz, 8 Ω, P1 max., both channels loaded and driven)

Sensitivity(1 kHz/500 mW)		120 mV$_{eff}$
Bandwidth (250 mW)	"cold"	12.5 Hz - 55 kHz
	"hot"	10 Hz - 52 kHz
P_{max} (1 kHz, THD+N = 1 %)		500 mW
THD-N (250 mW, B = 80 kHz)	"cold"	0.16 %
	"hot"	0.9 %
S/N at 500 mW (P1 min., linear 22 Hz - 22 kHz)		77 dB
(P1 max., linear 22 Hz - 22 kHz)		70 dB
(P1 min.)		80 dB(A)
(P1 max.)		78 dB(A)
Channel separation		>65 dB
Quiescent current (both ICs with LED)		43 mA
No load operating voltage		ca. 13 V
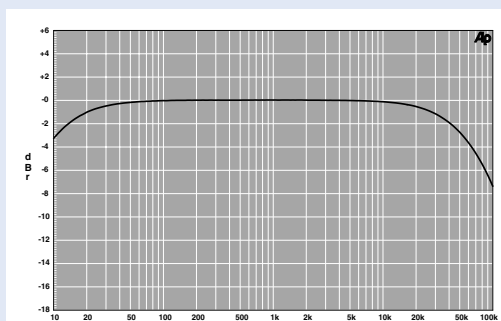
Frequency response
(250 mW/8 Ω,
B ≈ 10 Hz - 52 kHz)

40 dB. The quoted distortion is 0.2% with an output power of 0.5 watt at f = 1 kHz and into an 8 Ω load, however during testing (with the IC running hot) this was not achieved. Using the same output impedance and with a output power of 1 W, the data sheet indicates a bandwidth of 120 kHz but again as you can see, we measured a slightly lower value. The TDA2822X family of amplifiers were originally designed to be used in portable audio equipment (Mini-disc, Discman, Walkman etc.). The performance data applies across the whole family. An additional advan-

tage of this IC is the simple component selection for loudspeaker impedance matching at a fixed input signal level and operating voltage.

Bridge instead of Stereo

When the output capacitor is omitted from the output stage it is important to ensure that the other end of the speaker is not connected to earth. For this configuration, it is necessary to connect the two amplifiers in the chip in a bridge configuration to provide just one channel (**Figure 2**). A further IC amplifier is then necessary to produce the other half of the stereo amplifier. To optimise the amplifiers impulse response, the circuit does not have any external negative feedback components. The overall gain of the amplifier is set by the input divider (R1 - R4) and the volume control. The use of C3/C4 to couple the inverting inputs is suggested in the data sheet. The polarity of these electrolytic capacitors is not critical because the signal levels here are only in the millivolt range.

Many soundcards offer direct control of the output signal tone via the PC operating system so it was considered unnecessary to provide bass, treble or 3D controls for the amplifier. Between the input network and the tandem volume potentiometer are Anti Aliasing Filters formed by R3/C13 and R4/C14. The value of these filter components is determined by the value of the output load and can be found on **Table 1**. The output offset voltage is guaranteed by the manufacturer to be less than ±50 mV when the amplifier is used in a bridge configuration. The supply voltage to pin 2 has an absolute maximum value of 15 V. The output stage of the IC is not short circuit protected. For this reason it is important not to use a type of socket (e.g. stereo jack socket) which allows the output to be momentarily short-circuited during plugging or unplugging. This style of connector is however fine for the input connections. If you do not have in mind a loudspeaker (or headphones) for this amplifier then it is best to choose the components for the 8 Ω or 16 Ω version. The test results are given for operation into an 8 Ω loudspeaker. The plot shows the frequency response of the amplifier at its operating temperature (hot) driving 250 mW into an 8 Ω load. The bandwidth extends from 10 Hz to 52 kHz.
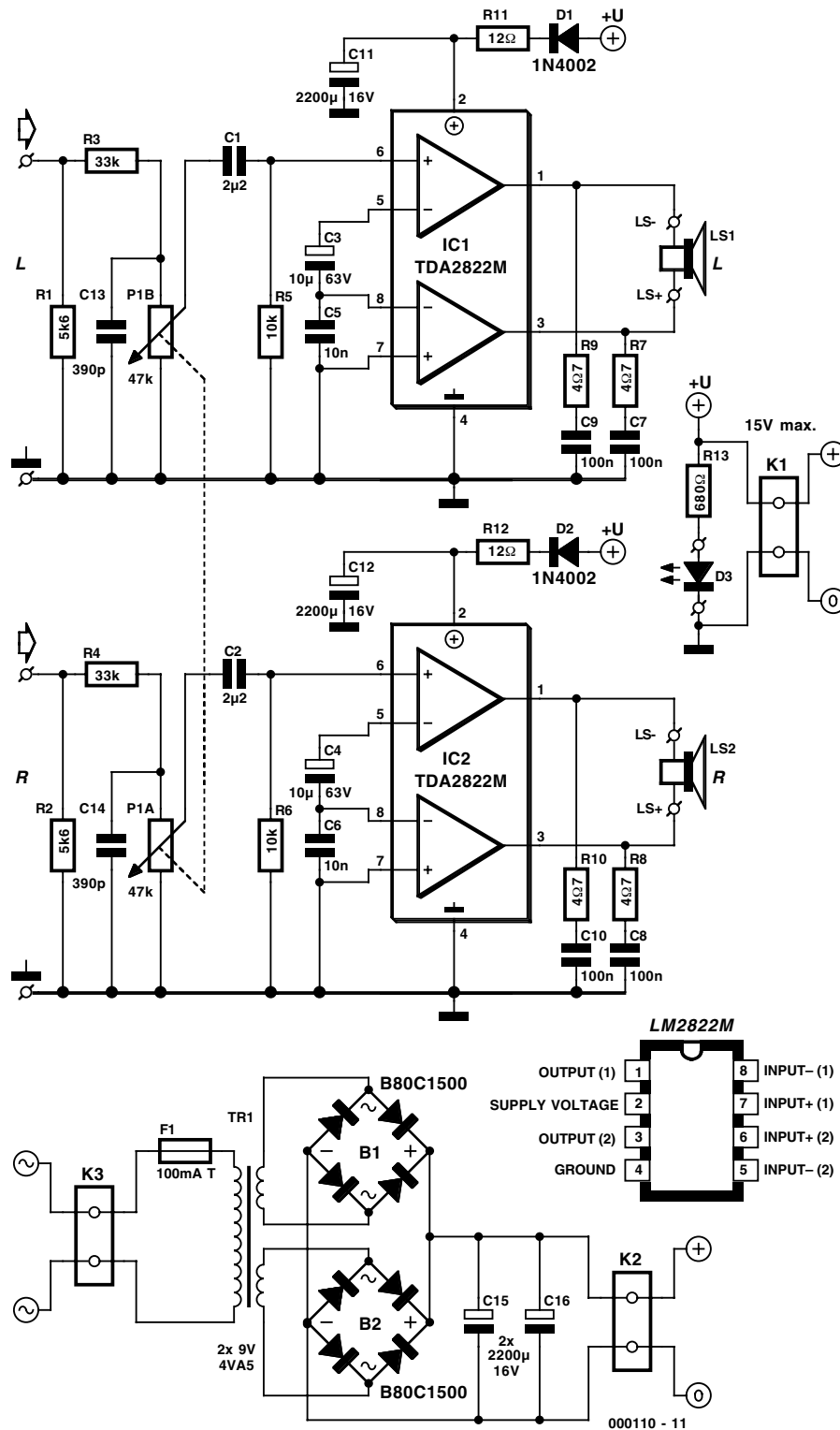
Heatsink? No Need!

Both channels of the amplifier are built onto a small single sided PCB with an extensive earth area to give good shielding. Component placement is relatively straightforward, it is
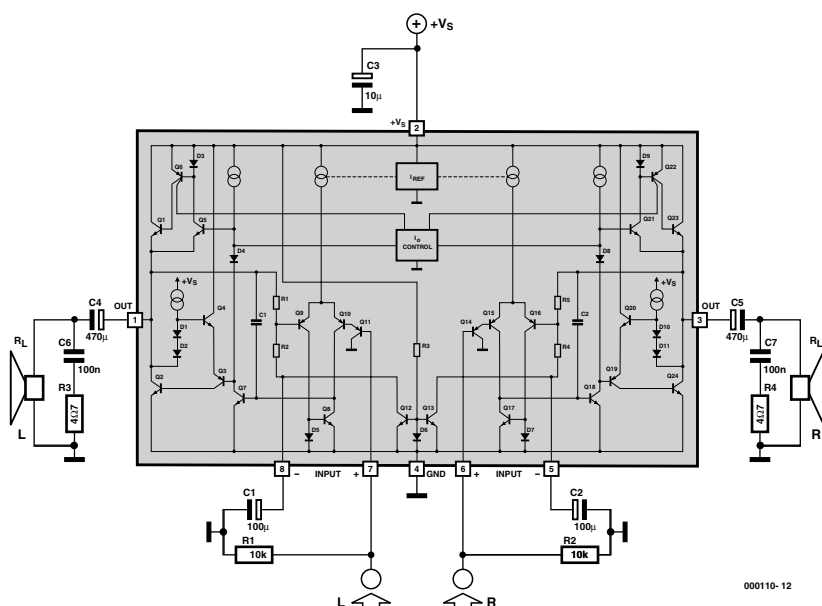
Figure 1. Internal diagram of the TDA2822M and a typical stereo application.

COMPONENTS LIST

Resistors:
R1,R2 = 5kΩ6
R3,R4 = 33kΩ
R5,R6 = 10kΩ
R7...R10 = 4Ω7
R11,R12 = 12Ω >2W
R13 = 680Ω
P1 = 47kΩ logarithmic, stereo

Capacitors:
C1,C2 = 2µF2 MKT, raster 5 or
   7.5mm
C3,C4 = 10µF 63V radial
C5,C6 = 10nF
C7-C10 = 100nF
C11,C12,C15,C16 = 2200µF 16V
   radial, dia. ≤12.5 mm
C13,C14 = 390pF

Semiconductors:
D1,D2 = 1N4002
D3 = LED, rot (not high-
   efficiency)
IC1,IC2 = TDA2822M (8-pin DIP)
   (ST Microelectronics) (Farnell)

Miscellaneous:
K1,K2 = 2-way PCB terminal
   block, raster 5mm
K3 = 2-way PCB terminal block,
   raster 7.5mm
B1,B2 = B80C1500 (80V piv, 1.5A
   peak) (rectangular case)
TR1 = 2x9 V/4VA5 (e.g., VTR4209
   (Monacor/Monarch)
F1 = fuse, 100mA, time lag, with
   PCB mount holder

Figure 2. The amplification factor of the TDA2822M is controlled by the tandem potentiometer.

only important to ensure that no bridges are formed between tracks during soldering. A bonus of this design is that no heatsink is necessary for the amplifier so you can leave those drills and taps in the toolbox where they belong. Fitting the finished amplifier into a PC should also be straightforward.

If the amplifier is to be fitted inside a PC it is possible to use the +12 V from the power supply unit (PSU) in the PC. In this case it will

not be necessary to fit the mains unit part of this design. It is important here to check the earth continuity between the PSU and the soundcard in the PC. To reduce the effects of interference it is advisable to fit the circuit inside a small grounded case, this will ensure that the body of the potentiometer is also grounded.

If the amplifier is to be used exter-

nally then the PCB shown in **Figure 3** includes a mains unit. It is a simple matter to fit the mains transformer, two in-line rectifiers, two capacitors and fuse holder.

In both cases the amplifier should be mounted as far as practicable from the power supply.

(000110-1)
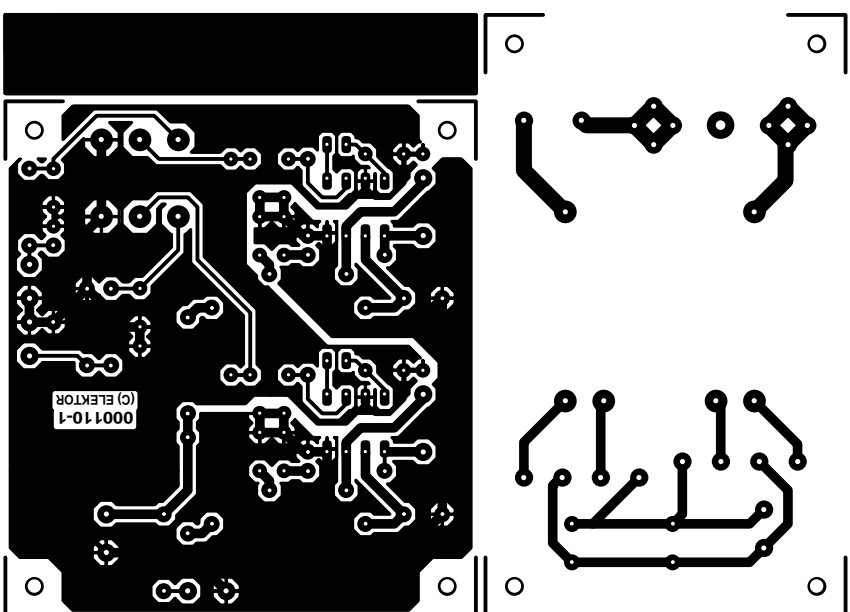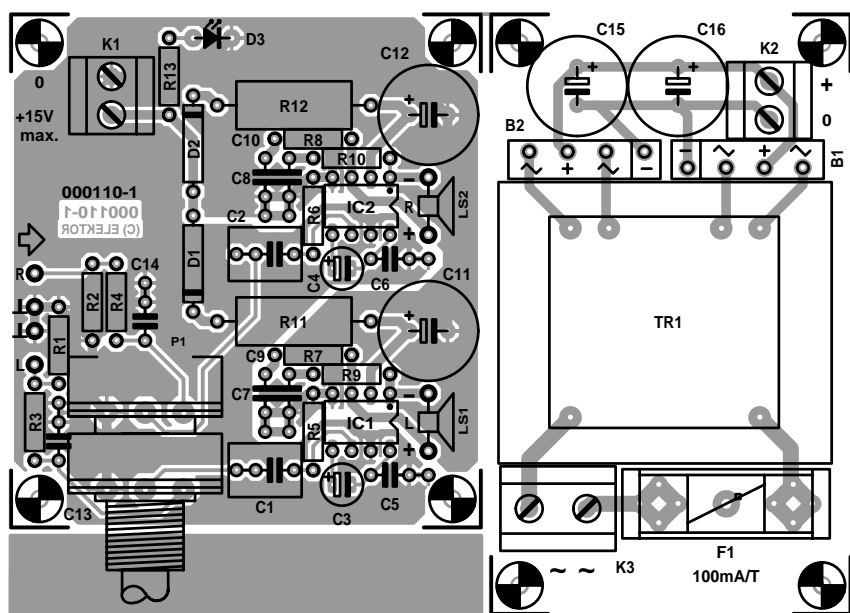
Figure 3. The PCB includes a layout for a mains power unit. Be sure to separate the two halves before the components are fitted. The board is not available ready-made.

Loudspeaker impedance	4	8	16	32	Ω
R3/R4	47	33	22	15	kΩ
C13/C14	330	390	470	560	pF
R11/R12	15 (2 W)	12 (2 W)	8.2 (1 W)	5.6 (1 W)	Ω
Output power (RMS)	1	1.4	2	1	W

Table 1. Correlation between anti-aliasing filter and output impedance.

Calculating the P.M.P.O.
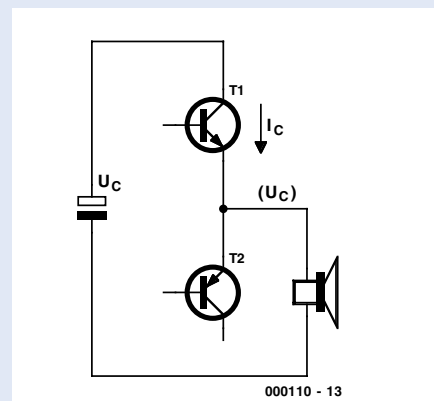
The energy W_c in a capacitor C with a voltage U_c is given by:

$$W_c = \int_{U_C} Q_c \, du$$

Where the charge

$$Q_c = CU_c$$

Integrating gives:

$$W_c = \tfrac{1}{2} \cdot CU_c^2$$

The power is defined as the differential of energy over the differential of time:

$$P = \frac{dW_c}{dt} \quad \text{or} \quad P = \frac{\Delta W_c}{\Delta t}$$

The power dissipated when the voltage on the capacitor falls from the level U_{c1} to the level U_{c2} in the time period Δt is given by:

$$P = \frac{\Delta C (U^2_{c1} - U^2_{c2})}{2\Delta t}$$

For the Peak Music Power Output "P.M.P.O." Δt is the signal period at 1 kHz, i.e. 1 ms. Generally U_{c1} is the no-load voltage output of the power supply while U_{c2} is the minimum operating voltage of the amplifier output stage (usually equated to zero).

Finding components and datasheets

Many readers phone and write us with questions about components. Typical questions include: who's the manufacturer of that IC, and where can I find a datasheet? Unfortunately we can not always help, mainly because of lack of time (who else would look after the magazine?). However, you may not have realized that with an Internet connection available you've access to extensive databases covering components and datasheets.

Although this month's subject was covered before on the Electronics On-Line page (see 'Semiconductor overviews' in the March 1998 issue) as well as on a datasheet (issue January 1999), some more coverage is apparently in order in view of the many requests we get every day.

One of the best websites to start your search for component data or datasheets is still the **Chip Directory** [1] run by Jaap van Ganswijk from the Netherlands. Since its first appearance on the web, the number of approved mirror sites has risen to about 25, so the site should have a good accessibility rate. Although the Chip Directory by itself already offers a substantial database of technical specifications of all kinds of semiconductor, on the homepage it also gives you an optional access to other powerful search engines like **ChipDocs** [2], **ECG** [3], **Questlink** [4], **IC Master** [5] and **Free Trade Zone** [6]. Note that the latter two are only accessible after registration. Most of these search engines start digging in the component archives run by semiconductor manufacturers, and then return information on where the relevant component (or its datasheet) may be found.

If you want to look a bit further and would like to know manufacturer contact addresses, a visit to the **Hardware Web** homepage [7] is recommended. The site contains long lists of electronics-related web addresses. There are several overviews: web addresses only for datasheets; addresses of semiconductor manufacturers; distributors. There's also a separate overview of passive components and connectors, plus a list of companies involved in electronics test and measurement equipment.
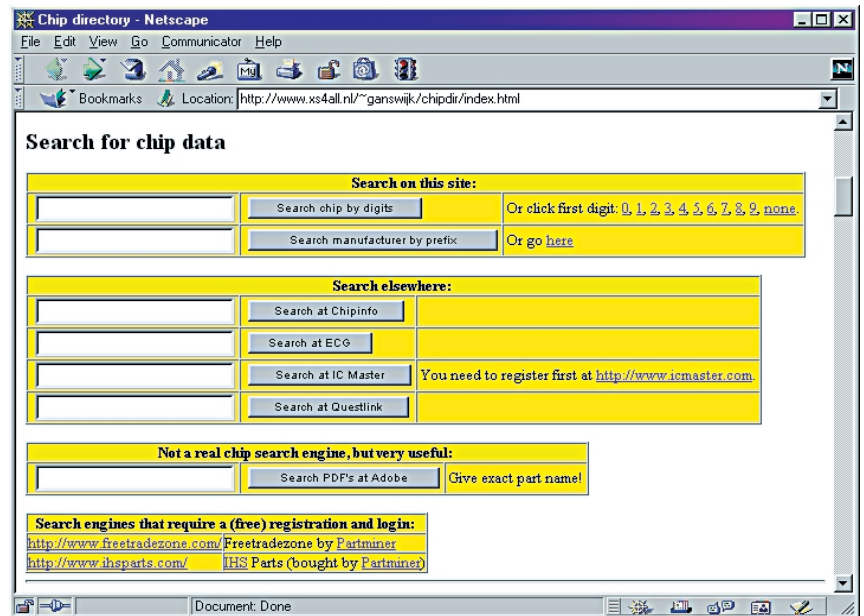
Finally, there's **EG3** [8], a web portal for electronics which not only contains a component search engine, but also information on lots of other electronics and computer-related subjects, including Internet protocols and robotics, to mention just two.

(005129-1)

Internet addresses:
[1] Chip Directory:
http://www.xs4all.nl/~ganswijk/chipdir/index.html
http://www.xs4all.nl/~ganswijk/chipdir/mirror.htm?index.htm
[2] ChipDocs:
http://www.chipdocs.com/

[3] ECG:
http://www.ecgproducts.com/ECGCrossReference/
[4] Questlink:
http://www.questlink.com/
[5] IC Master:
http://www.icmaster.com/login.asp
[6] Free Trade Zone
http://www.freetradezone.com/
[7] Hardware Web:
http://www.nctnico.cistron.nl/index.htm
[8] EG3:
http://www.eg3.com/home/index.htm

Note:
urls maintained by EE webmaster,
http://www.elektor-electronics.co.uk

MAX114/118

Integrated Circuits
Special Function

DATASHEET   II/2000

Electrical Characteristics
(VDD = +5V±5%, REF+ = 5V, REF− = GND, Read Mode (MODE = GND), TA = TMIN to TMAX, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
ACCURACY						
Resolution	N		8			Bits
Total Unadjusted Error	TUE				±1	LSB
Differential Nonlinearity	DNL	No missing codes guaranteed			±1	LSB
Zero-Code Error					±1	LSB
Full-Scale Error					±1	LSB
Channel-to-Channel Mismatch					±1/4	LSB
DYNAMIC PERFORMANCE						
Signal-to-Noise Plus Distortion Ratio	SINAD	MAX11_C/E, fSAMPLE = 1MHz, fIN_ = 195.7kHz	45			dB
		MAX11_M, fSAMPLE = 740kHz, fIN_ = 195.8kHz	45			dB
Total Harmonic Distortion	THD	MAX11_C/E, fSAMPLE = 1MHz, fIN_ = 195.7kHz			−50	dB
		MAX11_M, fSAMPLE = 740kHz, fIN_ = 195.8kHz			−50	dB
Spurious-Free Dynamic Range	SFDR	MAX11_C/E, fSAMPLE = 1MHz, fIN_ = 195.7kHz	50			dB
		MAX11_M, fSAMPLE = 740kHz, fIN_ = 195.8kHz	50			dB
Input Full-Power Bandwidth		VIN_ = 5Vp-p		1		MHz
Input Slew Rate, Tracking			3.1	15		V/ms
ANALOG INPUT						
Input Voltage Range	VIN_	GND < VIN_ < VDD	VREF−		VREF+	V
Input Leakage Current	IN_					µA
Input Capacitance	CIN_			32		pF
REFERENCE INPUT						
Reference Resistance	RREF		1	2	4	kΩ
REF+ Input Voltage Range			VREF−	VDD	VREF+	V
REF− Input Voltage Range			GND		VREF+	V

MAX114/118

Integrated Circuits
Special Function

DATASHEET   II/2000

MAX114/MAX118
+5V, 1Msps, 4 & 8-Channel, 8-Bit ADCs with 1µA Power-Down

Manufacturer
Maxim Integrated Products. Internet:
http://www.maxim-ic.com

Application Example
Gameboy Digital Sampling Oscilloscope (GBDSO),
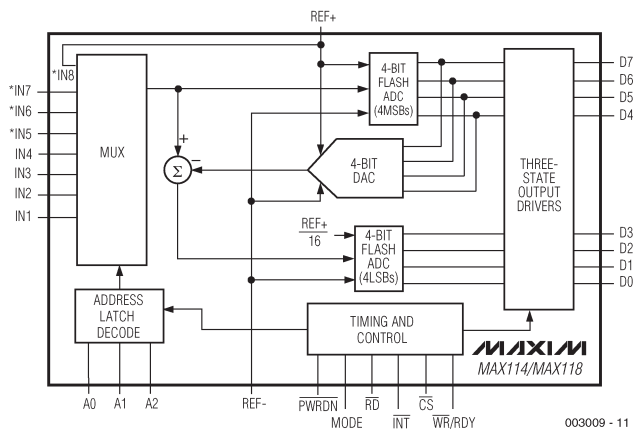Elektor Electronics October & November 2000

General Description
The MAX114/MAX118 are microprocessor-compatible, 8-bit, 4-channel and 8-channel analog-to-digital converters (ADCs). They operate from a single +5V supply and use a half-flash technique to achieve a 660ns conversion time (1Msps). A power-down (PWRDN) pin reduces current consumption typically to 1µA. The devices return from power-down mode to normal operating mode in less than 200ns, allowing large supply-current reductions in burst-mode applications (in burst mode, the ADC wakes up from a low-power state at specified intervals to sample the analog input signals). Both converters include a track/hold, enabling the ADC to digitize fast analog signals. Microprocessor (µP) interfaces are simplified because the ADC can appear as a memory location or I/O port without external interface logic. The data outputs use latched, three-state buffer circuitry for direct connection to an 8-bit parallel µP data bus or system input port. The MAX114/MAX118 input/reference configuration enables ratiometric operation.
The 4-channel MAX114 is available in a 24-pin DIP or SSOP. The 8-channel MAX118 is available in a 28-pin DIP or SSOP.

Applications
High-Speed DSP
Remote Data Acquisition
Portable Equipment
Communications Systems

Features
- Single +5V Supply Operation
- 4 (MAX114) or 8 (MAX118) Analog Input Channels
- Low Power:
    - 40mW (operating mode)
    - 5µW (power-down mode)
- Total Unadjusted Error £1LSB
- Fast Conversion Time: 660ns per Channel
- No External Clock Required
- Internal Track/Hold
- 1MHz Full-Power Bandwidth
- Internally Connected 8th Channel Monitors Reference Voltage (MAX118)

```
        ┌────∪────┐
IN4  1 │         │ 24  VDD
IN3  2 │         │ 23  PWRDN
IN2  3 │         │ 22  A0
IN1  4 │         │ 21  A1
MODE 5 │ MAXIM   │ 20  D7
D0   6 │ MAX114  │ 19  D6
D1   7 │         │ 18  D5
D2   8 │         │ 17  D4
D3   9 │         │ 16  CS
RD  10 │         │ 15  WR/RDY
INT 11 │         │ 14  REF+
GND 12 │         │ 13  REF−
        └─────────┘
          DIP/SSOP
                         003009 - 15
```
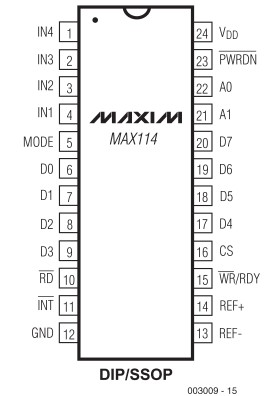
MAX114 Pin Configuration

Ordering Information

PART	TEMP. RANGE	PIN PACKAGE
MAX114CNG	0°C to +70°C	24 Narrow Plastic DIP
MAX114CAG	0°C to +70°C	24 SSOP
MAX114C/D	0°C to +70°C	Dice
MAX114ENG	−40°C to +85°C	24 Narrow Plastic DIP
MAX114EAG	−40°C to +85°C	24 SSOP
MAX114MRG	−55°C to +125°C	24 Narrow CERDIP

Pin Description (MAX114 only)

Pin	Name	Function
1	IN4	Analog Input Channel 4
2	IN3	Analog Input Channel 3
3	IN2	Analog Input Channel 2
4	IN1	Analog Input Channel 1
5	MODE	Mode Selection Input. Internally pulled low with a 50 μA current source. MODE = 0 activates read mode; MODE = 1 activates write-read mode.
6	D0	Three-State Data Output (LSB).
7, 8, 9	D1, D2, D3	Three-State Data Outputs.
10	$\overline{RD}$	Read Input. $\overline{RD}$ must be low to access data.
11	$\overline{INT}$	Interrupt Output. $\overline{INT}$ goes low to indicate end of conversion.
12	GND	Ground
13	REF−	Lower Limit of Reference Span. REF− sets the zero-code voltage. Range is $GND \leq V_{REF-} < V_{REF+}$.
14	REF+	Upper Limit of Reference Span. REF+ sets the full-scale input voltage. Range is $V_{REF-} < V_{REF+} \leq V_{DD}$. Internally hard-wired to IN8.
15	$\overline{WR}/RDY$	Write-Control Input/Ready-Status Output.
16	$\overline{CS}$	Chip-Select Input. $\overline{CS}$ must be low for the device to recognize $\overline{WR}$ or $\overline{RD}$ inputs.
17, 18, 19	D4, D5, D6	Three-State Data Outputs.
20	D7	Three-State Data Output (MSB).
21	A1	Multiplexer Channel Address Input.
22	A0	Multiplexer Channel Address Input (LSB).
23	$\overline{PWRDN}$	Power-Down Input. $\overline{PWRDN}$ reduces supply current when low.
24	V_{DD}	Positive Supply, +5V.

MAX114/MAX118

Functional Diagram

003009 - 11

MAX114/118

**Integrated Circuits
Special Function**

ELEKTOR ELECTRONICS

DATASHEET   II/2000

11/2000

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
LOGIC INPUTS						
Input High Voltage	V_{INH}	$\overline{CS}$, $\overline{WR}$, $\overline{RD}$, $\overline{PWRDN}$, A0, A1, A2	2.4			V
		MODE	3.5			V
Input Low Voltage	V_{INL}	$\overline{CS}$, $\overline{WR}$, $\overline{RD}$, $\overline{PWRDN}$, A0, A1, A2			0.8	V
		MODE			1.5	V
Input High Current	I_{INH}	$\overline{CS}$, $\overline{RD}$, $\overline{PWRDN}$, A0, A1, A2			±1	μA
		$\overline{WR}$			±3	μA
		MODE		50	200	μA
Input Low Current	I_{INL}	$\overline{CS}$, $\overline{WR}$, $\overline{RD}$, $\overline{PWRDN}$, A0, A1, A2			±1	μA
Input Capacitance (Note 2)	C_{IN}	$\overline{CS}$, $\overline{WR}$, $\overline{RD}$, $\overline{PWRDN}$, A0, A1, A2		5	8	pF
LOGIC OUTPUTS						
Output Low Voltage	V_{OL}	I_{SINK} = 1.6mA, INT, D0–D7			0.4	V
		RDY, I_{SINK} = 2.6mA			0.4	V
Output High Voltage	V_{OH}	I_{SOURCE} = 360μA, INT, D0–D7	4			V
Three-State Current	I_{LKG}	D0–D7, RDY, digital outputs = 0V to V_{DD}			±3	μA
Three-State Capacitance (Note 2)	C_{OUT}	D0–D7, RDY		5	8	pF
POWER REQUIREMENTS						
Supply Voltage	V_{DD}		4.75		5.25	V
V_{DD} Supply Current	I_{DD}	$\overline{CS}$ = $\overline{RD}$ = 0V, $\overline{PWRDN}$ = V_{DD} MAX11_C		8	15	mA
		MAX11_E/M		8	20	mA
Power-Down V_{DD} Current		$\overline{CS}$ = $\overline{RD}$ = V_{DD}, $\overline{PWRDN}$ = 0V (Note 3)		1	10	μA
Power-Supply Rejection	PSR	V_{DD} = 4.75V to 5.25V, V_{REF} = 4.75V		±1/16	±1/4	LSB

Note 2: Guaranteed by design.
Note 3: Power-down current increases if logic inputs are not driven to GND or VDD.