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Towards Low-Power Everyday Electronic Systems

Low Power Microelectronics, why and how?

By R. van Leuken and R. Nouta, DIMES, Delft University of Technology, The Netherlands

Although great improvements have been achieved over the years in reducing electrical equipment power consumption, there are indications that we can go a lot further in reducing power levels before we reach any physical limits. Apart from a short history of power reduction, this article describes several interesting and successful projects from the European Initiative in which significantly improved systems with much reduced power levels have been demonstrated.

What is Power and why is it important in everyday life?

Power is defined in a dictionary as the 'ability to do an operation'. In engineering it is the agent that enables processes and systems to do useful work. Power is the rate of doing work.

In an electronic or microelectronic context electrical power enables those systems to do work; it is measured in a unit called a watt (after the Scottish engineer James Watt (1736-1819)) which is the amount of energy consumed in one second. One watt is a small unit so we often use the unit kilowatt (a thousand watts) — a typical electric fire uses one kilowatt of power for example. We are charged for the electricity we use at home/factory/office by the number of kilowatts we use multiplied by the time in hours, so we are charged for kilowatt-hours. This is energy since it is a product of power and time!

In the UK, the electricity boards charge consumers around 6 pence per kilowatt-hour (or 'units' as they are often referred to on our electricity bills). This then enables us to run the lights/heating and use the multitude of electrical appliances that we all have such as TV, fridge, vacuum cleaner, etc., — the list is endless!

We also have some very important electronic gadgets which we need to use outside the home; in the car, in the street or wherever (so-called portable or mobile systems). I'm thinking here, of course, of mobile telephones, laptop/notebook computers, electronic organisers, as well as more traditional devices such as portable radios/CD players. In the case of these devices plugging into the mains supply may not be appropriate, at least when not close to an electric socket! So, of course, power for these is obtained from batteries, which may be rechargeable from the mains such as Nickel Cadmium (NiCd) batteries or used once and then thrown away e.g. alkaline batteries such as Duracell. Batteries, however, are a very expensive source of power: a typical small battery might have a capacity of say 10 watt-hour (not kilowatt-hour) and cost £2 typically. To obtain one kilowatt-hour would need 100 such batteries at a total cost of £200! When compared with the 6 pence cost of the same amount of electricity from the mains, we can see that electricity from batteries is very expensive. The size and weight of those batteries could also cause a problem!

In conclusion the portability of our modern electronic devices raises issues related to the provision of the power needed to drive those devices which we will now look at in more detail.

What is Low Power and why do we need it?

Low Power is a relative and not an absolute measure. It basically means a system that uses less power (by some factor) than required previously in a similar system.

The simple calculation in the previous section showed that the cost of power from batteries is very high compared to power from the mains supply. Clearly therefore, in battery-driven systems, there is a high motivation to develop Low-Power systems on cost grounds alone since the larger the power requirement of the system the larger the battery and therefore its cost.

In addition, if a battery of 1-kilowatt-hour capacity were needed for a particular application we are considering, we would need a battery of a size approaching a car battery but this would clearly be too large and heavy for all hand-held portable equipment.

A more typical battery in terms of size and weight for, say a mobile phone, is the AAA size. Because of its small size, it typically has a capacity of 0.5 watt-hour. This means that if this battery powered-up an electronic system requiring 0.5 watt then after one hour the battery would need changing or recharging. However if the system being driven only required 0.05 watt then the battery would last 10 hours. If the system power consumption was even less at 0.005 watts then we would get 100 hours out of the battery and so on.

So clearly Low Power is also very important in order to extend the operating life of portable equipment between battery changes/recharges as well as weight, size and cost.

The development of the mobile phone over the last 10 years illustrates the need for Low Power very well. Early models were large and bulky (mainly because of the large batteries required), and required battery renewal/recharging almost on a daily basis due mainly to the power-hungry analogue circuitry used in them. They were also costly.

The move to lower power digital models allowed the size of the phones to be reduced due to the smaller, lighter batteries used. Although additional functions were introduced such as message handling, etc, the operating life between battery changes was extended, and the cost of the units dramatically reduced because of the lower manufacturing cost.

The latest models, which have advanced features such as the ability to access the Internet, were designed using Low-Power techniques they are very small and light, have operating life between battery changes up to hundreds of hours or more, and are cheap and affordable to all.

Low Power may also result in a company being able to bring a new application or product to the marketplace, which would have been impossible previously

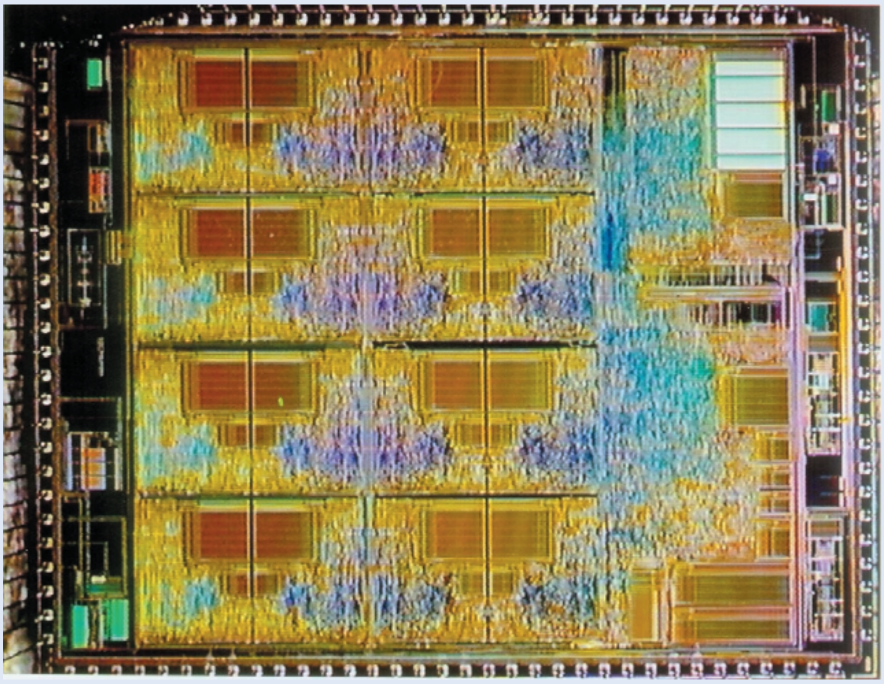
Finally, Low Power systems have increased reliability since the silicon chips (which are the heart of all electronic systems) run at lower temperatures and are therefore more reliable and we are less likely to get system malfunctions.

Turning now to static systems, such as consumer and various types of electrical equipment, which are powered from the mains supply rather than being battery driven.

It is clear that this type of equipment can also

COLOPODS

Cochlear hearing aids use an implant section in the cochlear part of the ear and an external processor and battery. In the current system the external section is rather bulky and has to be carried on the person. The aim is to produce a new device, which can be worn inconspicuously behind the ear. This requires a 50% power reduction overall. The work has concentrated mainly on selecting the optimum Low Power manufacturing process for the chips concerned, increasing system integration, and using novel Low Power techniques in the processor. Early results are encouraging. A photograph of a prototype ear-level unit named COLOPODS is shown in the photograph.



COLOPODS, a design for cochlear hearing implants.

LUCS

LUCS embraces the design of a Low Power chip set for a portable Ultrasound application. There is a need for a portable, lightweight, hand-held, ultrasound scanner for medical and veterinary diagnostics. Potential usage in the medical area would be in Urology (for bladder volume, bladder stones, and kidney stones), Obstetrics (foetal age), Abdominal (in emergency, operating theatres, and in military fieldwork). In the veterinary area the unit would be useful for use with pigs, cows, and horses (for pregnancy/fat thickness determinations). The work has concentrated so far on the use of novel Low Power circuits/systems and should result in the production of a demonstrator system by Pie Medical late next year. It is envisaged that the total system power requirement will be reduced by a factor of 3, from the 75 watts of current systems to around 25 watts. The photograph shws an impression of the proposed system.

LUCS is a low power chip designed for use in a portable ultrasound instrument.

benefit greatly from reduced power consumption.

Additional to the advantages already listed for portable systems, static systems have other Low Power considerations of which the more important are the following.

Cooling and System packaging considerations

Most of the electrical power needed by an electronic system is used inside the system and is converted to heat, which has to be removed by cooling otherwise the sensitive electronic components would overheat and possibly fail. If the system consumes a large amount of power, therefore creating a large amount of heat, special steps have to be taken in the system and component packaging, such as fins and cooling fans, to ensure that the heat is removed effectively. These additional steps add to the system cost and power usage.

We all know how hot a roomful of PCs can get and hence we may also require air-conditioning and other cooling methods to keep the temperature acceptable, again increasing cost.

Low-Power systems need less cooling. This in turn means that the power supply unit required to convert the mains supply into the voltages required to drive the electronic circuit can also be smaller and therefore cheaper.

Power/frequency considerations

Electronic systems are required to work at higher and higher frequencies (loosely termed speed) in order to give faster operation and higher performance. For instance, today’s PC’s run at frequencies over 500 MHz whereas only 5 years ago 33 MHz was the norm. The higher the frequency of operation the higher the power will be unless steps are introduced in the design to reduce the power to acceptable levels.

Effect on the environment

High power consumption and large cooling systems are considered to be bad for the environment in various ways. The US Government has gone as far as stating what the maximum proportion of the National budget that can be spent on power and cooling costs.

Overall then we can see that for reasons of cost, size and weight, long battery operating-life, high-frequency operation, high-reliability, and environmental reasons, Low Power is essential in the design of today’s electronic systems.

How is Low Power achieved?

We will only be able to cover the developments in Low Power very briefly and at a general level in this paper. For a much more detailed description of Low Power we refer the reader to one of the excellent textbooks on the subject. Two such texts are [1,2].

It is generally agreed that Low Power started with the invention of the transistor (the essential building block of electronic systems) in 1947 [3]. The transistor eliminated the need for many watts of power that had been required to power-up vacuum tubes (valves) that had been the basis of electronics up to then. Transistors generally ran at much lower power levels, typically in the tens of milliwatts range (1 milliwatt is one thousandth of a watt). This was further enhanced by the invention of the first Integrated Circuit (silicon chip) in 1958. This enabled the full potential of the transistor to be realised by enabling the whole electronic circuit to be created on a single chip and at lower power levels.

Another significant step was the development of the digital watch in the ‘70s. This required electronic circuits consisting of several thousands of transistors powered from tiny ‘coin cells’, the watches had to be physically no larger than traditional watches, and had to operate successfully without a battery change for up to one year. This required the development of Low Power circuits operating at voltages as low as 1.5 V with a power consumption in the microwatt range (1 microwatt is one millionth of a watt). These circuits also found other applications in instrumentation, medical and radio communication.

Since the ‘70s and particularly with the great demand for portable (or mobile) equipment in the last 15 years, the drive for Low Power has become much more acute. Much work has gone on, world-wide, developing processes, design methodologies and circuit techniques, which have enabled the power consumption of electronic circuits to be reduced by several orders of magnitude.

In order to see, in a little more detail, where and how the improvements have taken place, it is necessary for us to look briefly at the design process for electronic systems.

This process contains many steps but is often split into five main parts for clarity and convenience as follows.

Overall system level e.g., mobile phone.

This is the highest level in the design and improvements have been made by planning to place as much as possible of the system (ideally all) on-chip. This is usually referred to as system-on-chip.

Algorithm level e.g., the manipulation of two numbers.

At this level power can be reduced dramatically by minimising the number of discrete steps required to carry out computer operations such as addition/subtraction etc.

Architecture level e.g. memory blocks such as RAM/ROM.

Measures such as turning off whole blocks of the system when they are not carrying out any useful functions to save power. Analysis shows that, in a computer, many blocks are only used infrequently so significant power saving can be made by turning them off when they are inactive.

This has some parallels with the measure introduced by the carmaker VW in one range of its cars a few years ago. This particular model was marketed as being very good on fuel economy. So circuitry was added to the car to detect when the car was stopped, say at traffic lights, and turn the engine off. When the lights changed the engine quickly started and the car moved off.

Also it is sometimes worth adding additional circuitry to the design to enable the system to optimise its own power usage at any time (power management).

Logic/circuit level e.g. a circuit made up of several transistors.

In most digital circuits e.g. computers, the system is controlled by an electronic 'clock' circuit which synchronises system performance periodically (synchronous logic). Unfortunately, the clock itself uses a lot of power — often more than the rest of the system!

One option is to design the system without a clock (asynchronous logic) and save power that way. The design procedure however is more complex and may take extra circuitry.

Another option is to use clever circuit techniques to ensure that the circuit switching (which consumes power) is optimised and only takes place when really necessary.

Device/process level e.g. individual transistor.

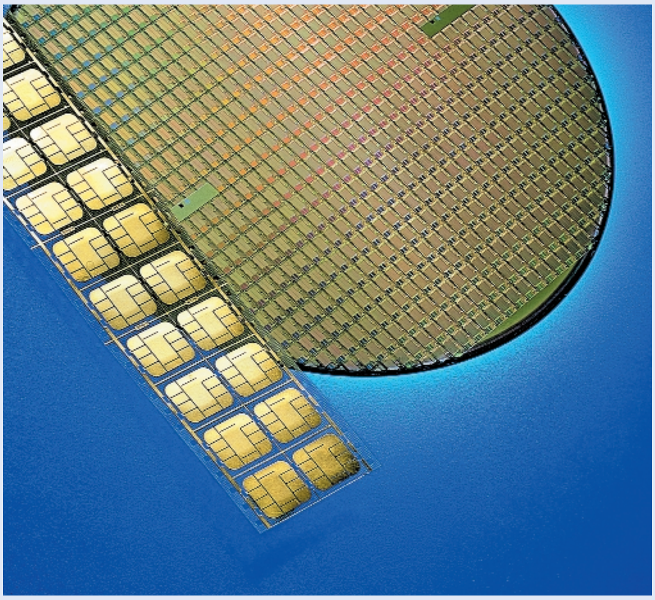
Power is the product of the applied transistor voltage and the resulting transistor current. Hence reducing transistor voltages from, say 5 V, to around 1 V (as was done in digital watches in the '70s), reduces power by a factor of 25!

Another major factor here is reducing the physical size of the transistors (scaling). This, not only enables more transistors to be squeezed into a given area of silicon (packing density) but also enables the transistors to consume less power and run at higher frequencies – a win-win situation. Therefore there has been much work in developing microelectronic technology so that smaller and smaller transistors can be made — currently we can make transistors with a minimum size of less than 0.25 micron, compared with 10 micron in 1970 (1 micron is one millionth of a metre). This makes it possible to design complete high performance, low-power, systems-on-chip containing several million transistors in a piece of silicon about 1cm square.

For instance, computers now made in 0.15-micron technology typically use one-third the power of those made in 0.5-micron technol-

DESCALE

This project is concerned with the design of a Low Power contactless SMART card. SMART cards are used extensively for all kinds of applications e.g. public transport tickets, telephone payment, security etc. currently the sales of these cards are increasing by around 30% per annum. Contactless SMART cards (that work up to 15 cm from the card-reader) have the advantages of convenience, speed-of-use, insensitivity to dirt and grease, and are less susceptible to vandalism.



DESCALE is the name of a project aimed at the design of low-power Smartcards.

The move to a Low Power version should produce a saving of between 3 and 5 times in power and will save cost, increase applicability and give better security in the cards.

The work so far has concentrated on the development of an asynchronous system (no clock so the system is only active when needed) whereas the current system is synchronous. This has resulted in new chips being developed which meet the power saving specification (4 times less power required) but with a slight penalty in terms of chip area. This is quite normal with asynchronous systems due to the increased complexity of the design. The photographed working prototype is currently being tested.

COSAFE

The COSAFE pump is a portable volumetric pump designed to provide long-term infusions associated with cancer chemotherapy, post-operative and chronic pain control, antibiotic infusions and other IV medications. The purpose of the COSAFE project is to develop an easy-to-use infusion pump designed for precision, safety and low power operation, extending operative life between battery changes and minimizing cost. This should also enable the new system to have additional features such as improved user-interface and improved performance.

COSAFE low-power volumetric pump for medical use.

The approach taken is that the current pump, traded under the name RYTHMIC, which is wholly software controlled, will be replaced by a power-minimized partly hardware, partly software co-design system which should give the required power reduction as well as an inherently safe design. The electronic control of the system will be based on a special processor, which incorporates highly safe operation with low power characteristics.

The major power savings of the new pump are achieved by moving the critical, time consuming and thus power consuming, functions of the system from software to hardware and by employing a more sophisticated algorithm for controlling the motor of the pump. The requirement of high safe operation imposes the use of safety mechanisms for controlling every possible failure condition, which may effect the proper operation of the system. These mechanisms for the basic circuit functionality are implemented in hardware (self-checking circuits) aiming at power minimization while the safe execution of the system procedures is ensured by mechanisms implemented in software to increase system functionality. It is estimated that with the followed design approach a reduction in power consumption of around 5 times from the current system will be achieved. The photograph shows the existing pump.

ogy and operate at three times higher frequency!

How much further can we go in reducing Power?

Many papers have been published [3,4] on what are the eventual limits in terms of Low Power. The paper by Meindl [3] is typical. He identified several different limits, each set by a different aspects of microelectronics. We will now briefly consider some of the main ones he listed.

Fundamental limit

All microelectronic systems are essentially applications of Physics. Therefore all microelectronic systems obey the laws of Physics and ultimately set the limits of those systems. Meindl concluded that we are currently using around a million times more power in electronic systems than the theoretical minimum so we have plenty more to go at!

Material limit

This limit is set by the properties of the silicon itself (or those of its more recent rival Gallium Arsenide). Meindl calculated that we are similarly a long way from any limits on power set by the silicon itself. The limit set by Gallium Arsenide is even further away.

Device limit

Most electronic systems are based on the operation of the Field Effect Transistor (FET). By how much more can we reduce its size (and hence the power it uses) before it ceases to behave as a transistor?

Meindl concluded that we could reduce its size by a factor of 4 at least from the current size before we run into trouble on this score. The technology to do this will not be with us until 2010 at the earliest!

Overall therefore his conclusion is that Low Power has plenty room for more reduction.

The European Low Power Initiative for Electronic System Design (ESDLPD)

In view of the great interest in Low Power, the European Commission set up a major programme in this area in 1997 to run until 2002 with a budget of 14 million Euro. The programme's aims are to:

– Foster excellence in Low Power design skills,

– Exploit synergy between participants, and

– Transfer know-how and experiences.

Furthermore, the programme's focus is to:

– Develop advanced methodologies,

– Adopt best practice for system and application design,

– Research (20% of the resources), and

– Show best practice on demonstrator systems (80% of the resources).

The programme involves 30 of the top companies in the field in Europe together with over 20 well-known Institutes and Universities.

The programme was designated as a ‘cluster’ which means that the 19 projects (Design Experiments) within the scheme make up a co-ordinated programme of work at all levels of design and is aimed at producing significant improvements in all areas of Low Power microelectronics.

Also, since a major aim of the programme, was to disseminate Low Power design know-how and experiences gained from the programme widely, the Commission insisted that each Design Experiment contained a section aimed specifically at Information Capturing and Dissemination activities (IC & D). Further the Commission appointed the Delft Institute of Microelectronics and Submicron Technology (DIMES) in the Netherlands as the action co-ordinator. The task of the co-ordinator is to co-ordinate, facilitate and organize quality improvements, knowledge sharing and knowledge transfer, from the programme.

In this context many methods are being used to ensure that the information gained from the programme is made available to other interested parties in Europe and elsewhere.

Networking is carried out through regular meetings of the two Interest Groups, one in the Digital area and one in RF/Analogue.

Results are gathered, based on the reports written by the Design Experiments and published in books of several types, journals and magazines, as well as, in the future, on a Low Power Design web server.

Additionally course material, design kits and tools are being produced; and special sessions held at major European Conferences comprising workshops and tutorials.

For further information on the IC & D activity please contact DIMES on (+31) (0)15278 6696 or access the ESDLPD website on
http://www.esdlpd.dimes.tudelft.nl

Output to date

The programme has been in operation since 1997 and several of the Design Experiments (which are all of 2-3 years duration) have finished or will finish shortly.

They are producing demonstrator outputs, which have impressive reductions in power over current systems and other advantages. A cross-section of the more interesting ones is shown in the insets in this article.

Conclusions

This article has attempted to describe the topic of power to the reader and its importance in everyday life. Further it has described why Low Power is important and how we can obtain systems operating at much reduced levels of power. Additionally it has detailed improvements made over the years but indicates that we can go a lot further in reducing power levels before we reach any physical limits.

The article then describes a successful, major European Commission initiative in this area and particularly how it disseminates the knowledge gained from that programme widely.

Finally the article describes several interesting and successful projects from the European Initiative in which significantly improved systems with much reduced power levels have been demonstrated.

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Acknowledgements

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Finally we would like to thank Professor Ted Pritchard for planning and writing the initial draft of the paper and Mr John Richer for reviewing it and making invaluable suggestions for improvements.

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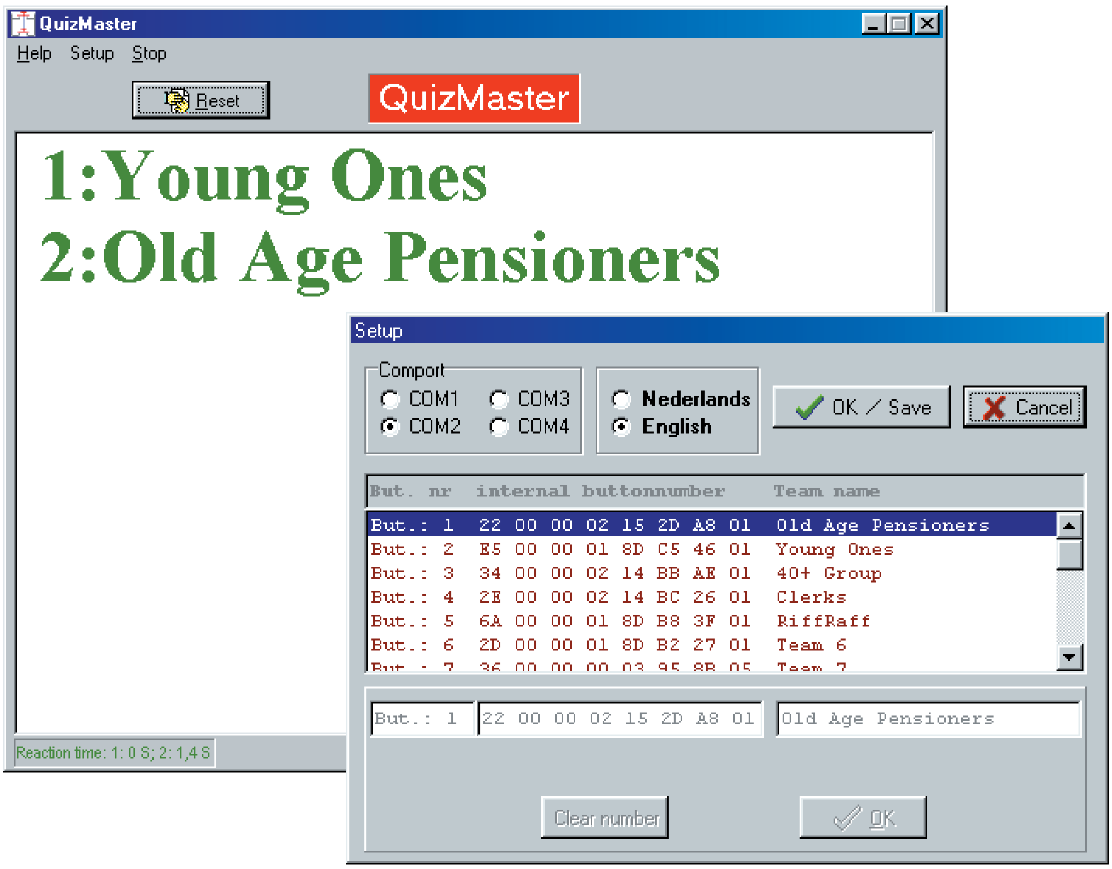
QuizMaster

the 1-wire model

Design by T. Rudolphi

With some simple hardware, ditto Windows program and a PC, it is possible to determine which of up to 20 switches is pressed first. Even the exact order can be displayed on a PC monitor. Ideal for quizzes and other games!



The most remarkable feature of this QuizMaster is its simplicity. In its entirety, it consists of no more than a trivial interface, a number of pushbuttons and a Windows program. The interface comprises, all in all, seven components and is connected to the COM-port of a PC. The pushbuttons for the quiz contestants (a maximum of 20) are fitted with a '1-wire multidrop'-device and are all connected in parallel to the interface. The program, written in 'C++ Builder' from Borland, controls the entire system and displays on the PC screen the order in which the pushbuttons were pressed.

1-Wire chips

The essential part for the operation of the circuit described here, is the '1-wire-chip', which is fitted into each pushbutton. This type of device has already featured in *Elektor Electronics* on earlier occasions, such as the articles '1-Wire Spy', published in June 2000 and 'e-Key' in the November 2000 issue. However, for completeness' sake, a brief description is included here.

For some time now, Dallas Semiconductor have been offering a range of components, which can be controlled, read and programmed by a master (a microcontroller for example) via a 1-wire bus. These '1-wire-devices' are specifically intended for tasks such as temperature measurement, battery management and data storage. With this 1-wire protocol, an integrated multiplexer unravels the incoming signals and passes the correct ones on to the chip. Because the output of a 1-wire device is open-drain, multiple devices are connected to a single bus in Wired-And configuration. It is also possible to mix these devices with 'normal' hardware.

Although the capabilities of the available 1-wire devices far exceed the requirements of the present application, the relatively reasonably priced DS2401 is nevertheless very appropriate for our use. This device can best be described as an identifier IC that has no other special function but functions solely as an 'electronic registration number'. The chip contains a 64-bit 'lasered' ROM containing a unique 48-bit serial number, an 8-bit CRC and an 8-bit family code. Reading the device allows immediate recognition and identification — and that is exactly what we need here.

Every 1-wire-chip possesses the identification feature and is, without exception, suitable for our application. For example, the DS1820 temperature sensor is readily available but is twice as expensive compared to the DS2401, and it is a pity of course, that its primary functionality would not be utilised.

Hardware

The schematic for the required hardware is shown in **Figure 1**. Shown on the left is the PC-interface and on the right a pushbutton with a 1-wire device, of which up to 20 may be connected in parallel on the 1-wire-bus (terminals DATA and GND). Whenever the pushbutton (S1) is pressed, the 1-wire-device is connected to the bus and can be recognised by the PC.

From the electronic perspective, simplicity is trumps. The interface consists of no more than a couple of (zener) diodes, two resistors and a capacitor while the control unit contains no components apart from the pushbutton and the IC.

The interface is powered from the PC via the RS232 connector. Resistor R2 and electrolytic capacitor C1 limit and filter the sup-

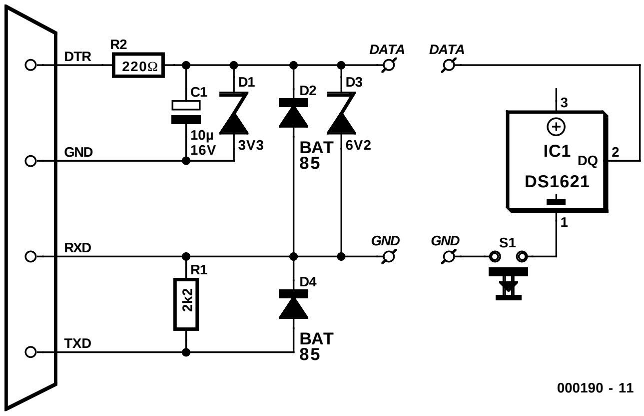


Figure 1. The hardware consists of an interface for the RS232-port and a pushbutton with a 1-wire-device.

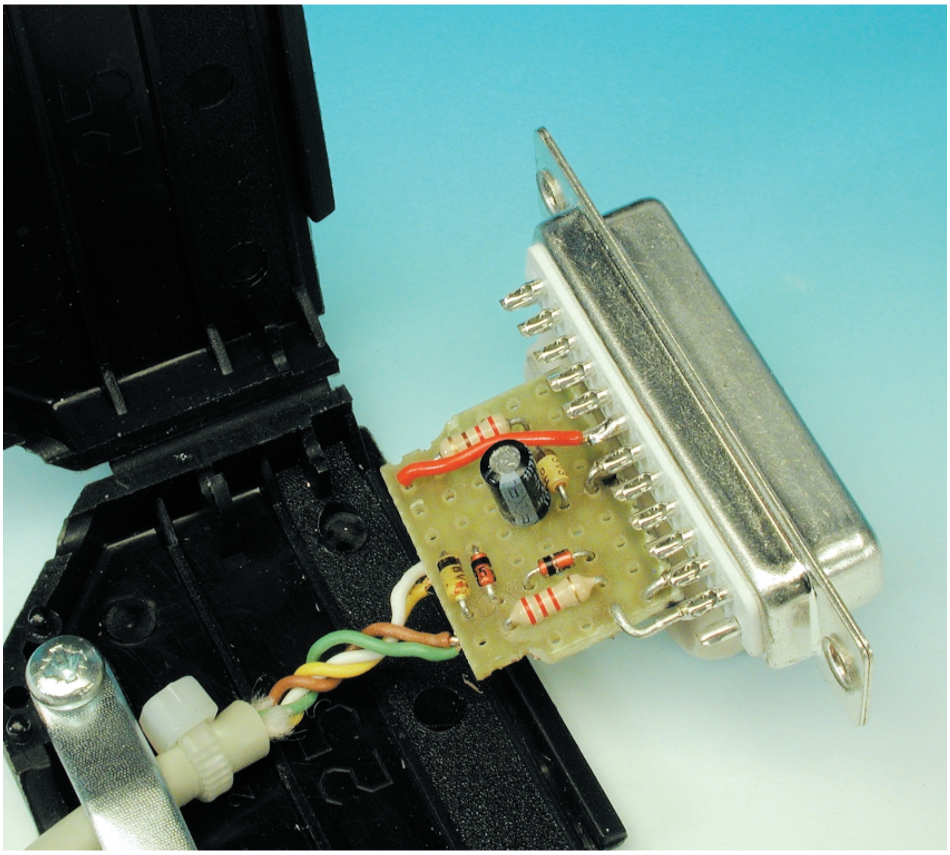


Figure 2. The entire interface can easily be built into an RS232 connector.

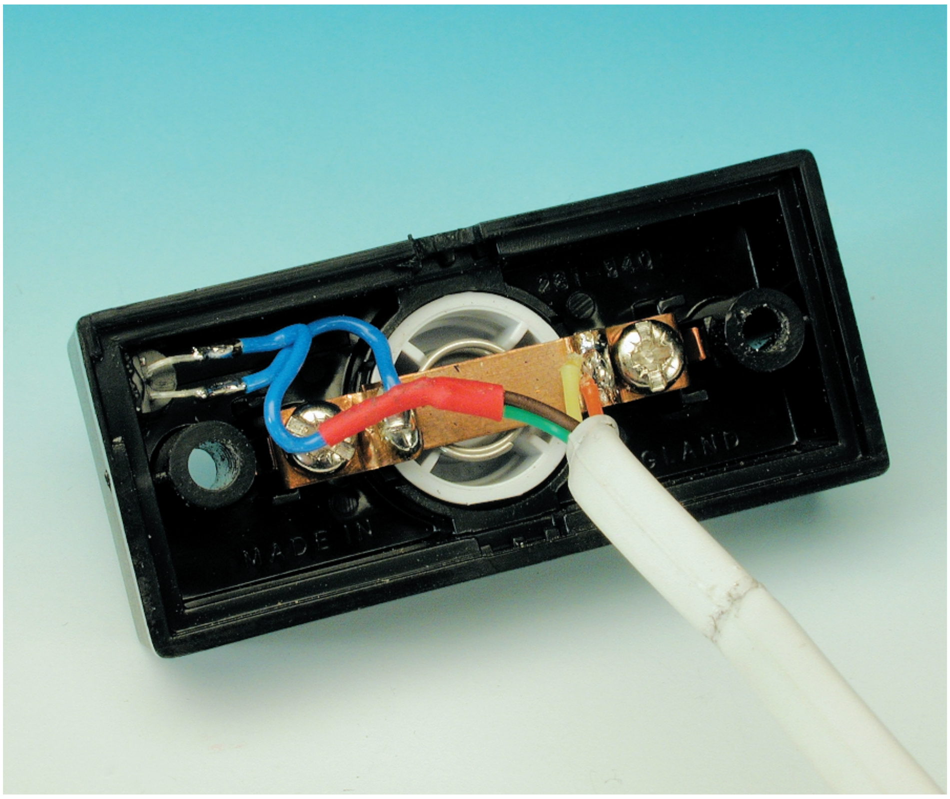


Figure 3. Inside this pushbutton is plenty of room for the DS2401.

ply voltage. Also, because the current requirement of the 1-wire devices doesn't amount to more than a few milliamps, pull-up resistor R1 limits the current to about 6 mA.

The length of cable between the interface and the pushbutton(s) should not exceed about 30 meters.

Simple Soldering Job

The interface is of such a simple design that it is not worth the effort to put it in a separate enclosure. It is much easier to connect the few components directly 'point-to-point' or on a small piece of prototyping board inside a sub-D connector. These connectors offer ample space as is illustrated by the photo of the prototype, shown in **Figure 2**. When a 25-way RS-232 connector is used, DTR, GND, RXD and TXD are pins 20, 7, 3 and 2 respectively. With a 9-way connector these are pins 4, 5, 2 and 3 respectively.

Because it is nice for the (nervous) contestant to have a pushbutton that is comfortable to the hand, we picked a generously sized doorbell button, which was secured to a small block of wood for the occasion. The DS2401 can be fastened on the inside with a drop of glue. Again, **Figure 3** shows how the prototype was constructed. The GND connection can be looped directly to one side of the pushbutton. The DS2401 is connected in series with the DATA line.

Thus prepared, all the candidates' pushbuttons have to be connected in parallel to the 1-wire-bus. The easiest way to do this is to use RJ-11 style telephone connectors (6-way with 4 contacts), which may be obtained from any DIY store. These connectors can be fitted to a flat telephone cable with the aid of a crimping tool. Using adapters with three female connectors it is possible to interconnect all the switches. The connections are as follows:

pin 1 = nc,
pin 2 = GND,
pin 3 = DATA,
pin 4 = DATA,
pin 5 = GND, and
pin 6 = nc.

This may appear a little more complicated than necessary, but the double connection prevents the crossover in the three-way adapter from throwing a spanner in the works.

Software

The software has been developed with 'C++ Builder' from Borland and runs under Windows 95/98. The program, including the source code, can be purchased through *Elektor Electronics* Readers Services (Order code **000190-11**) or may be downloaded for free from our web site.

A brief description of the program is as follows:

- One thread continually sends a 1-wire reset (a 480 µs low signal, followed by a 'listen-high period' of 480 µs).
- When a pushbutton is pressed, the built-in IC will respond to this signal.
- Then, the internal 64-bit identification number is retrieved, to see which switch was activated. An init file links this number with a contestant and this is what is displayed on the screen.

Setup

Before the QuizMaster can be put to use, a number of things need to be initialised. First, the RS232 (COM) port has to be selected. This can be done from the welcome screen.

If the interface is connected properly and the port is configured correctly, it is possible to select from the main screen the 'setup' menu item. A table then displays all 20 pushbuttons. For each of these pushbuttons it is necessary to know the internal 64-bit number and the name of the team (name of the contestant).

- To enter on the team name, double click the desired switch in the list. The underlying edit screen is activated and the name can then be entered in the last field.

- The 64-bit number has to be learned. When the desired quiz button is pressed, the corresponding number will appear in the appropriate field. After which you only need to click OK.

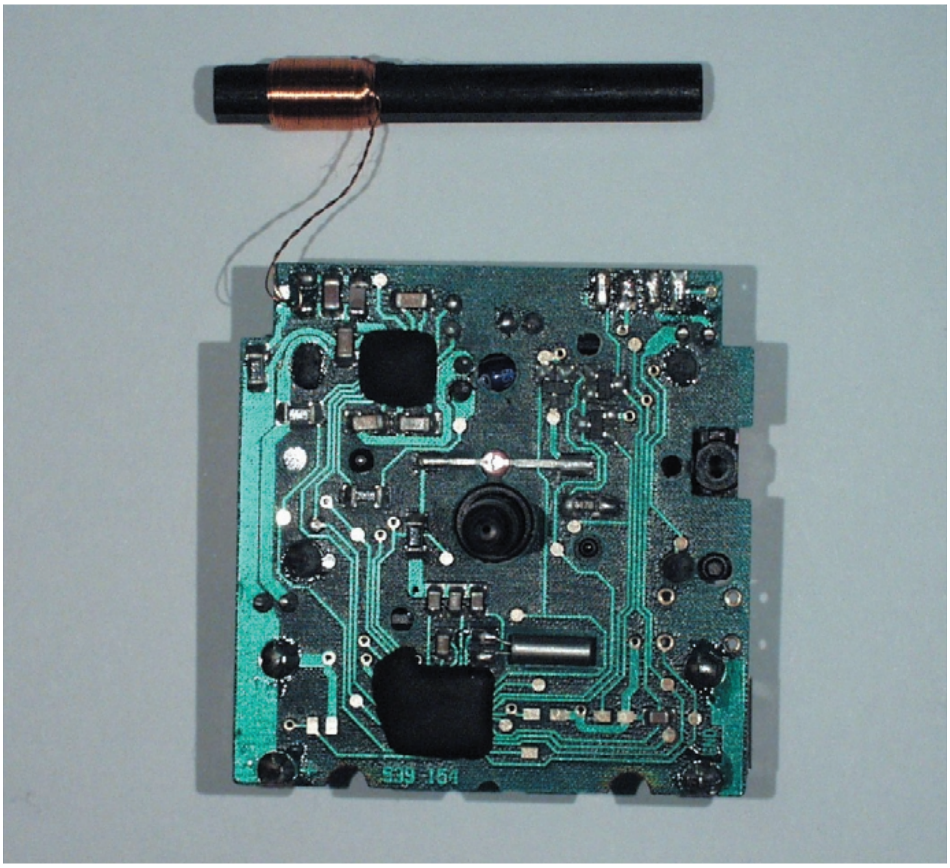
Repeat the above procedure for each of the switches. When everything is complete, click 'OK and Save'. All the information is now stored in a config.txt file (ASCII format), from which the program obtains the information when starting up. The QuizMaster is now ready for use!

(000190-1)

Radio Controlled Clocks

a peek under the bonnet

Recent advancements in circuit integration have drastically reduced the production costs of radio-controlled clocks. These days they are not much more expensive than their conventional quartz counterparts. This article gives us an insight into the design of an analogue radio controlled clock.



Convenience and reliability are probably the biggest attractions of a radio controlled clock. Standard quartz clocks are accurate enough for most purposes but with a radio controlled clock there is no longer the need to periodically synchronise it, compensate its movement or add or subtract an hour. All it needs is a fresh battery every so often and it will carry on showing the precise time and date through leap years, leap seconds, BST and GMT.

A look inside a modern radio controlled clock with a liquid crystal display (LCD) will typically reveal just two ICs and a few passive components. The first IC is connected to an antenna and receives the time signals while the second IC is responsible for decoding this time signal and displaying it. The quality of the radio is largely dependent on the microcontroller software. It governs the ease of use of the clock, the reliability of the displayed time and the battery life. With clever programming it is also possible to recover coded time signals despite radio interference.

Time signal reception

Radio stations transmitting time signals invariably use amplitude modulation in the long wave (LW) band. This operating frequency ensures optimum coverage thanks to ground wave propagation in the VLF band. The two basic techniques used for detecting this type of signal are superhetrodyne or direct conversion. At these low frequencies a direct conversion receiver is generally preferred because it requires very few external components to tune the receiver (typically two to four capacitors and a crystal). It also intrinsically consumes less power than a superhet. Further developments will undoubtedly lead to improved specifications for such receiver chips giving an even lower operating voltage and current along with improved interference rejection.

The same receiver configuration can be used to receive all the major time signal transmitters. Currently in the UK we have MSF Rugby, in the US they have the WWVF transmitter at Fort Collins (both operate on

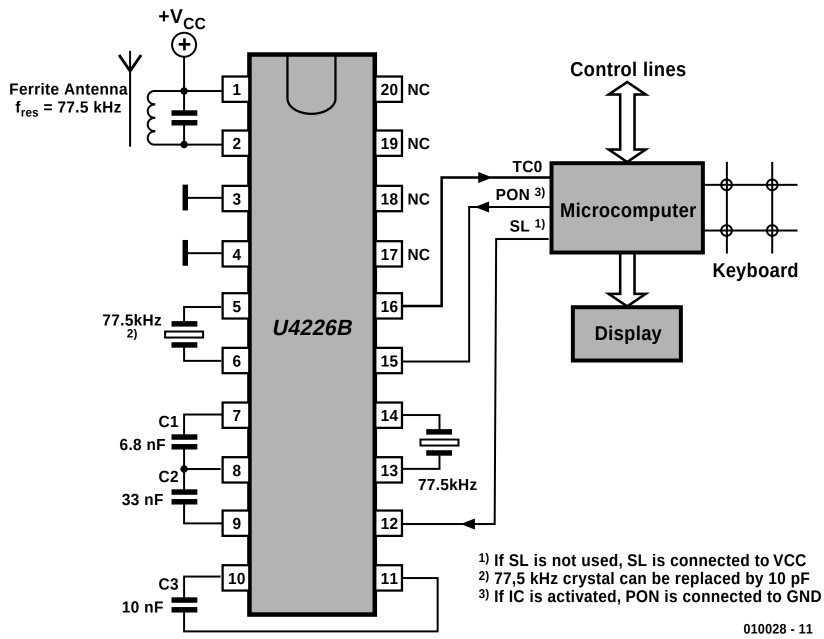


Figure 1. Application diagram of the U4226B from Temic (Atmel).

60 kHz). In Germany the DCF 77 transmitter at Mainflingen operates on 77.5 kHz and the Japanese transmitter near Tokyo operates on 40 kHz. Almost all radio clocks use one of two receiver chips, either the Temic U4226B shown in **Figure 1** or the UE6002 shown in **Figure 2.** This chip is produced by HKW Elektronik and is distributed in the UK by Galleon Systems Ltd. Both these chips use the direct conversion principle where a high-gain amplifier and filter are tuned to the frequency of the receive signal. One or two external crystals are needed to fix the receiver selectivity. The output consists of a digital data stream containing the time code information from the transmitter.

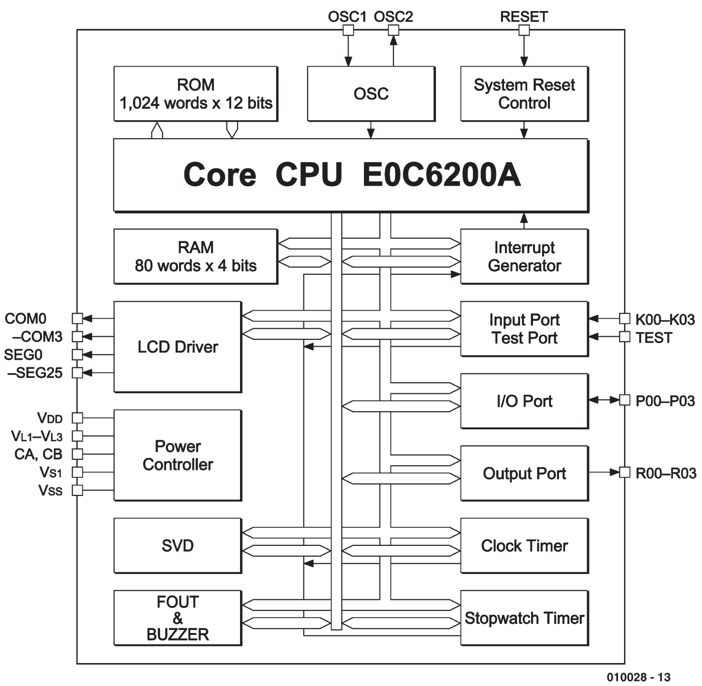


Figure 2. Block diagram of the UE6002 from HKW-Elektronik.

The Microcontroller

The majority of radio controlled clocks are battery powered. When choosing a microcontroller for this application it is important for the circuit designer to select one that can operate at a low voltage (preferably with just one cell) and will use as little power as possible to prolong battery life. Seiko Epson produce a 4-bit microcontroller family designed specifically for this application (**Figure 3**). The E0C6S37 is one variant of this family and has the following main characteristics:

- 1K ROM.
- 80 Nibble RAM.
- 4 inputs / 4 outputs.
- 26 Segment/4 Common LCD driver.
- 1 Timer, 1 stop watch timer.
- 2 kHz alarm tone output.
- 1.2V Threshold for voltage supervision circuit.
- Supply voltage 0.9-2.0 V.
- Current consumption typically 2.5 µA at 32.768 kHz.

This controller is intended for large scale production applications and is not intended for hobbyists. The development tools are relatively expensive and there are no OTP variants of the chips available for hobby applications. The programmed controllers are supplied in large quantities so it only becomes economically viable to use this controller for mass-produced products. Once the software for the application has been developed and thoroughly tested by the customer it is sent to the IC manufacturer where the chip mask is programmed. This process can take up to four weeks and is relatively costly. Any mistakes in the software design at this stage cannot be corrected and involve a repeat of the mask making procedure with additional expenditure in both time and money. To reduce production costs, the finished mask programmed controller chip is glued directly to the target PCB where a bonding machine makes connections between the input/output pads of the chip and the PCB. At this stage the chip is still completely naked and requires a blob of opaque epoxy based glue to cover its embarrassment. This coating gives protection from the environment and provides physical support for the chip and its fine bonding wires. A final bake will fully cure this epoxy layer.

The essential tasks that the microcontroller needs to take care of include:

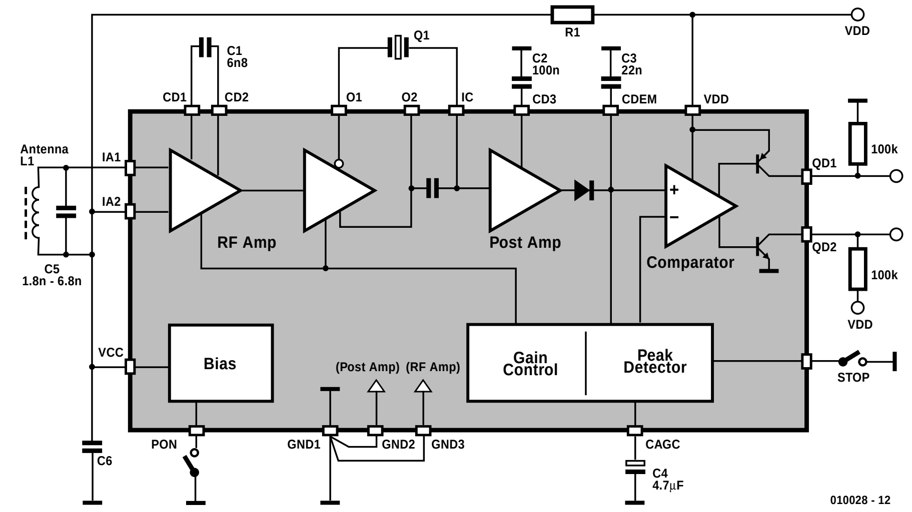


Figure 3. Internal block diagram of the E0C6S37 microcontroller from Seiko Epson.

– Display control.
– Push button scanning.
– Monitoring the battery voltage.
– Checking alarm time.
– Decoding the radio signal.
– Controlling the clock hands.
– Checking the reference position of the clock hands.
– Controlling the alarm sound.
– Running test routines during manufacture and testing.

A TYPICAL RADIO CONTROLLED CLOCK

Figure 4 shows the circuit diagram for a typical radio controlled clock using an analogue display, i.e., an hour and minute hand rather than an LCD. When the battery is inserted into the clock, the microcontroller will not know exactly where the hands are pointing, so it needs to calibrate the mechanical hand position. There is usually a reference point marked on internal gears attached to the hands. In our circuit, D1 and T3 form a light gate to detect a hole in the gears of the clock. This hole generates a signal when the hands are pointing at precisely 12 o'clock. This reference position is checked daily to ensure that no mechanical slippage has occurred.

IC3 is an E5130 stepper motor driver chip, it drives the two stepper motors in the clock attached to the second hand and the minute hand. This IC is again designed for such low voltage and current applications. The transducer Bz1 is driven by transistors T1 and T2 to provide a 2 kHz alarm tone. When the alarm time is reached, transistor T2 is first switched on to begin the alarm tone. If you are still in slumber mode and have not hit the alarm off button within 10 seconds, transistor T1 will switch on to form a bridge across resistor R1 that allows more current to flow through Bz1, thereby increasing the alarm volume (crescendo function). Transistors T1 and T2 are driven directly from the controller chip outputs and internal short circuit protection on the outputs of this chip ensure that excessive transistor base current is prevented. All control buttons on the clock are connected to the input port of the controller chip and these are fitted with internal pull-up resistors.

The stepper motor output control signals SEG0 to SEG3 can be mask programmed to drive an LCD display and there are also an additional 26 outputs available for use.

The interface between the controller and the time code receiver chip consists of three connections.

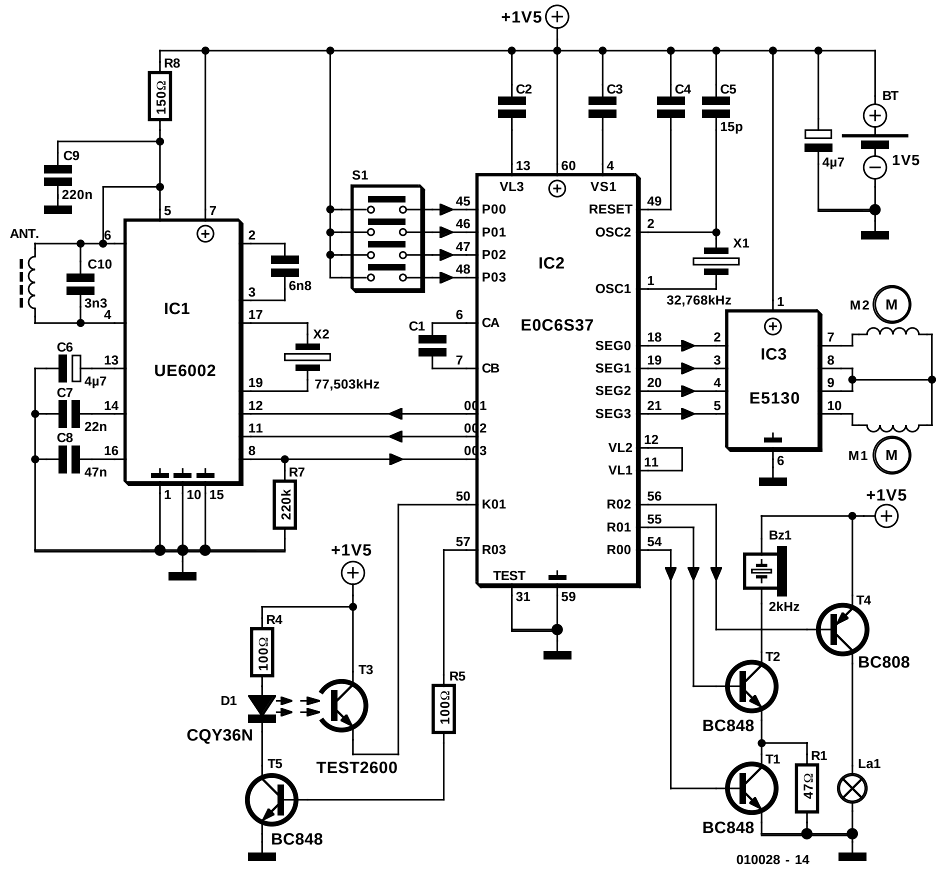


Figure 4. Circuit diagram of a DCF radio clock.

The received time code signal is sent to the microcontroller from pin 8 of the receiver chip. Pin 11 of the receiver chip is a 'power down' pin and allows the microcontroller to switch off the receiver chip to conserve power. The third line on pin 12 is used to mask out any interference generated locally by the microcontroller outputs. Analogue clocks employ stepper motors to move the minute and second hands and each step pulse generates a relatively high pulse of RFI lasting approximately 500 ms (60 ms stepper pulse plus resonance decay time). It is important that these stepper pulses are not output during critical times in each second of the received time signal so the movement of the hands must be exactly synchronised with the time signal. A signal on this line will tell the receiver chip that a stepper pulse is being sent and it will effectively hold the time signal output at its current level until the interference has passed, thereby masking out the interference from its output signal.

A coil wound on a ferrite rod together with capacitor C10 form the antenna for this 77.5 kHz system.

During use, once a battery is connected to the circuit, the microcontroller will move the clock hands until it finds the reference position. The time code receiver will then be switched on and the controller waits until it has received two complete valid messages. This may take more than two minutes. If any part of the message becomes corrupted by local interference such as a thunderstorm or multi-path signal distortion (reflections), the controller will wait until it receives two valid messages before it turns off the time code receiver, calculates the hand position, and moves the hands. The time code receiver is periodically turned on by the microcontroller during normal operation and the displayed time is compared to the received time code. When these two times do not correspond (e.g., when the changeover between GMT and BST occurs) the controller will wait for confirmation by receiving further time code messages before it updates the displayed time.

(010028-1)

Web Links

www.vishay.com/products/optoelectronics/
www.atmel-wm.com
www.epson-electronics.de/download/down4bit.htm#E0C6S37
www.hkw-elektronik.de
www.temic-semi.com/hn/broadcas/broadcas.htm

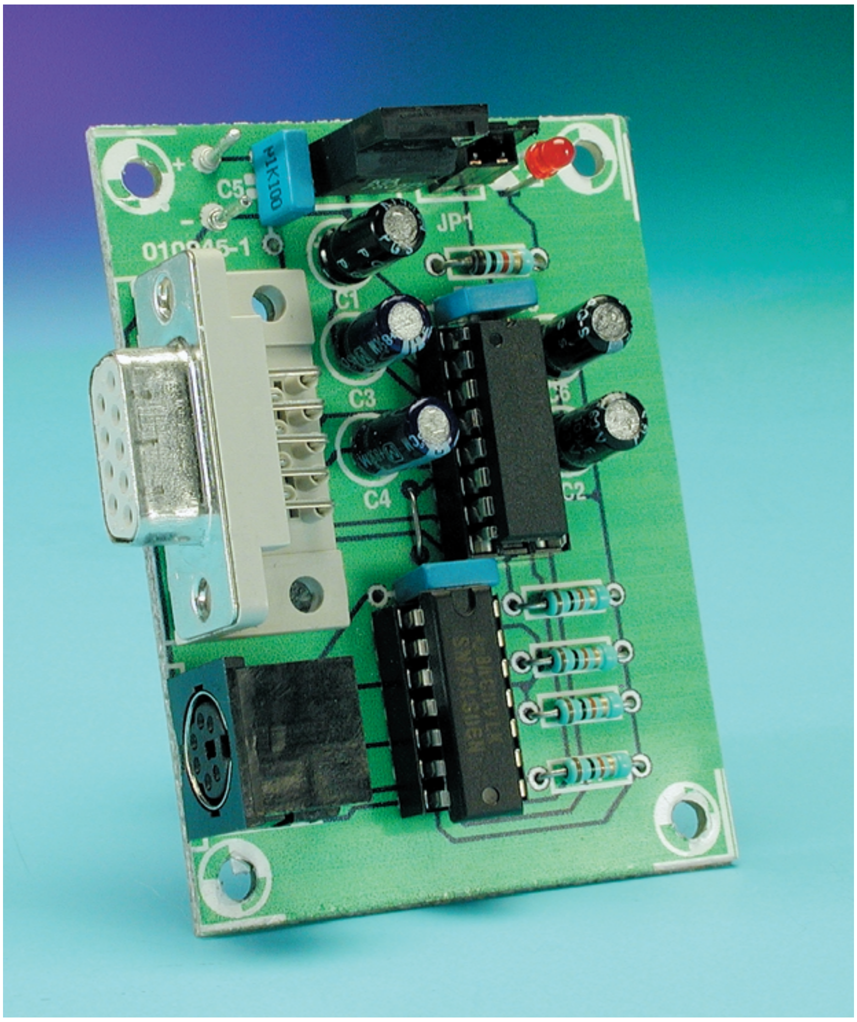
I^2C Interface for RS232 Port

new lease of life for the COM Port

Design by I. Gerlach, DH1AAD

IngoGerlach@welfen-netz.com

Back in October 2000 we described a versatile I^2C bus interface that plugged into the PC printer port. Nowadays the PC serial port is rarely used for keyboard or mouse connection so it's sensible to make better use of it. This design provides an I^2C bus connection to the PC's serial port.



From a hardware point of view this serial port version of an I^2C interface card could hardly be simpler. Looking at the circuit diagram (**Figure 1**) it can be seen that the MAX232 chip (IC1) is the main component of the circuit. This IC translates the signal voltage levels on the I^2C bus to RS232 voltage levels that can used by the serial COM port of a PC. Even Notebooks that are notoriously fussy about serial port signal levels will work happily with this interface.

The 9-way RS232 connector K1 that connects to the serial port of the PC has its DCD wire (pin 1) connected to the DSR wire (pin 6). The port driver software will check this connection during initialisation to determine if the interface card is present.

The 74LS06 inverters (IC2) perform the same job as in the parallel version of this interface — they convert the two wire bidirectional data from the I^2C bus into unidirectional signals that can be used by the PC.

Power for the interface card can be supplied by the I^2C equipment via pins 3 and 4 of the I^2C socket. LED D1 will indicate if this supply is available and lights up once the equipment is plugged in and switched on. If the LED does not light then you will need to power the interface card from some other source. A mains unit supplying approximately 9 V will be suitable and should be connected to the + and – pins on the PCB. In this case jumper JP1 should also be fitted and IC3 will regulate the on-board voltage at 5 V. Capacitors C6 to C8 provide supply voltage decoupling. The PCB layout and component placement is shown in **Figure 2** and, as you would expect from such a simple circuit, contains no surprises.

DLL for Windows, Perl for Linux

A number of software interface programs are available to control the serial interface and also the earlier parallel version.

`I2C_SER.DLL` Win95/98
`I2C_PAR.DLL` Win95/98

These are based on the `outp` and `inp` C functions, which have direct access to reading and writing of the hardware. They will only work under Windows 95/98. Windows NT/ME/2000 prevents direct hardware access by these functions.

`i2c_ser.pm` Linux Perl Module
`i2c_lpt.pm` Linux Perl Module

There is one header file for both Perl modules in C under Linux. With Linux `ioperm` can be used to set the I/O port access permission. The use of `ioperm` requires root privileges.

A more detailed description of these functions and modules along with some examples can be found in the file `I2C_FUNCS.HTML`. Installation of the software should go ahead without problem provided that you pay attention to the following guidelines.

Windows (95/98)
Open a new folder and name it `I2C`. Copy the file `i2c-01.zip` to this folder and unzip it. You will be able to find the DLLs in the `\LIB`

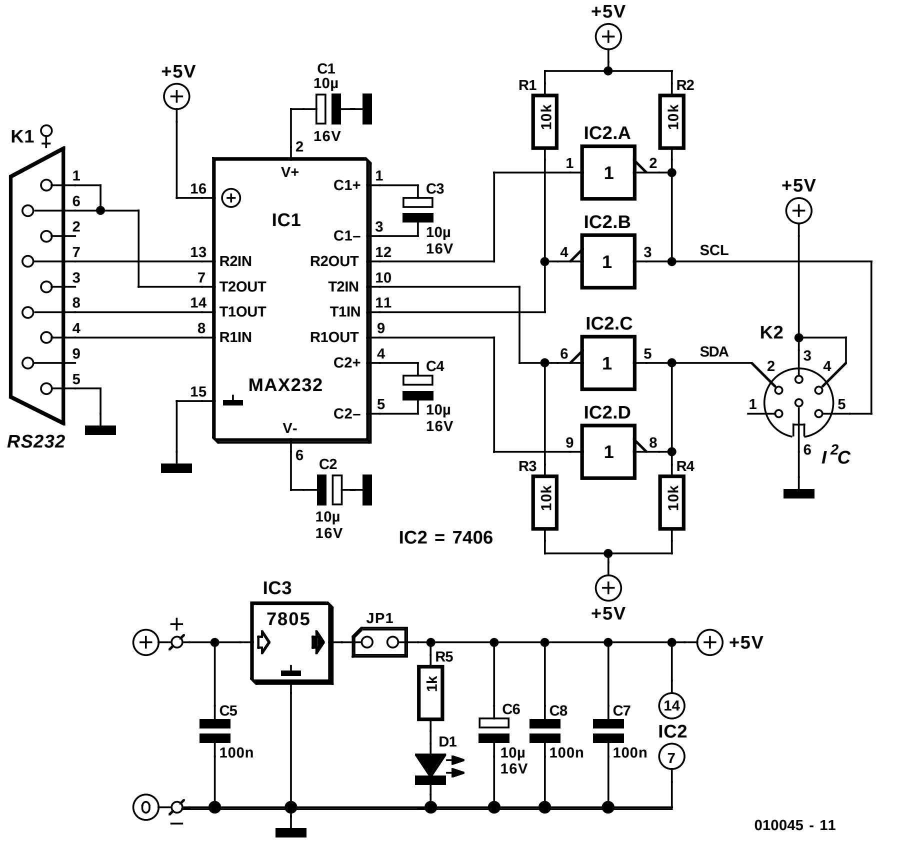


Figure 1. Circuit diagram of the serial I²C Interface.

COMPONENTS LIST

Resistors:
R1-R4 = 10kΩ
R5 = 1kΩ

Capacitors:
C1-C4,C6 = 10µF 16V radial
C5,C7,C8 = 100nF

Semiconductors:
D1 = LED, red, high efficiency
IC1 = MAX232
IC2 = 74LS06
IC3 = 7805

Miscellaneous:
K1 = 9-way Sub-D-socket (female), PCB mount, angled pins
K2 = 6-way Mini-DIN socket, pins at 240 degrees, PCB mount
PC1,PC2 = solder pins
JP1 = 2-way pinheader with jumper

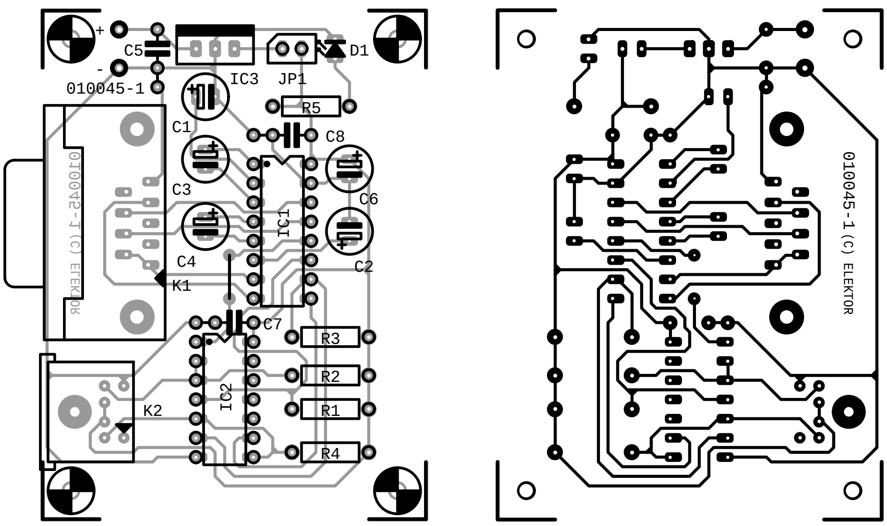


Figure 2. PCB layout and component placement.

Lib Functions

int set_port_delay (int delay)
Set the waiting time (delay) for port access. Reasonable values are in the range 2 to 10. The returned value is delay. This function must be used before initialisation is called.

int init_iic (int Portnr)
Initialises the Port (serial or parallel) for input /output and checks if there is an I^2C-Interface connected. A return value of 0 indicates that an interface has not been found. Port number 0 is automatically checked. The decimal address of the available interface is returned otherwise 0.

int deinit_iic (void)
Close the port. The value returned is always 0.

int iic_start (void)
send the start bit. The value returned is always 0.

int iic_stop (void)
Send the stop bit. The value returned is always 0.

int iic_send_byte (int sbyte)
Byte sbyte is sent over the I^2C bus. The return value of 1 indicates that an acknowledgement was received from the slave, otherwise the value 0 is returned.

int iic_read_byte (int ack)
A byte is read from the I^2C bus. The return value is the byte read. If ack =1 an ACK will be sent.

int lcd_init (void)
Initialises the display: 2 lines, 4-bit mode (default). The I^2C Adapter must be initialised first. Ten constants are defined in the C lib.

int lcd_instr (int cmd)
Sends the cmd command to the display.

int lcd_wchar (int cchar)
Sends the character cchar to the display. See lcd_init .

int lcd_rchar (int *cchar,int adr)
Reads a character cchar from the Display at Address adr.

int lcd_write_str (int *lstr)
Writes a String *lstr to the LCD.

char *lcd_read_str (int len,int adr)
Reads a string of characters into lstr from the address adr with a character count of len from the display.

int lcd_backlight(int cmd)
Switches the LCD backlight on (1) or off (0)(where this feature is available).

int lcd_get_adress(void)
Read the current position on the display. The return value equals the actual Cursor Address.

int iic_tx_pcf8574(int data,int adr)
Sends a byte to the PCF8574 at the Address adr. The default base address 112 is assumed here. If the PCF is at the address 114 then the adr value should be equal to 2.

int iic_rx_pcf8574(int data,int adr)
Receives a byte from the PCF8574, at the Address adr. The base default address 112 is assumed here. If the PCF is at the address 114 then the adr value should be equal to 2.

directory. It is important that the DLLs are accessible during program run time so copy them into the System folder of the windows directory.

Microsoft Visual C 4.2 was used to produce the DLLs. You can find the workspaces in `\LIB\i2c_ser` and `\LIB\i2c_par` and the source files in `\i2c_ser`, `\i2c_par`, `\src`, `\lcd` and `\pcf8574`.

Linux
Create a new folder in `/opt/i2c`. Copy the file `i2c-0.1.tar.gz` to this folder and unpack it using the command:

```
gzip -d i2c-0.1.tar.gz
tar -xvf i2c-0.1.tar
```

Now use `INSTALL` to compile the source files and build the Perl modules. The Perl modules `man`-Pages are `man i2c_ser` and `man i2c_par` for the serial and parallel port versions respectively. If you are using a different path than `/opt/i2c`, then it will be necessary to change the `HDIR= /opt/i2c/` entry in the Makefile under `/src`. Note that a functioning Perl must be installed on the PC.

(010045-1)

Literature:

– *The I²C Bus*, Elektor Electronics (Publishing), ISBN 0 905705 47 5.

– *Parallel Port Complete*, Jan Axelson, Lakeview Research, ISBN 0-9650819-1-5.

– Various Linux FAQs

Examples:

Once again Windows users seem to get preferential treatment — on our website you will find an example program (written in both Visual Basic and Delphi) that demonstrates the control of an I^2C EEPROM type PCF8582. Look for item 010045-11, Free Downloads, July/August 2001.

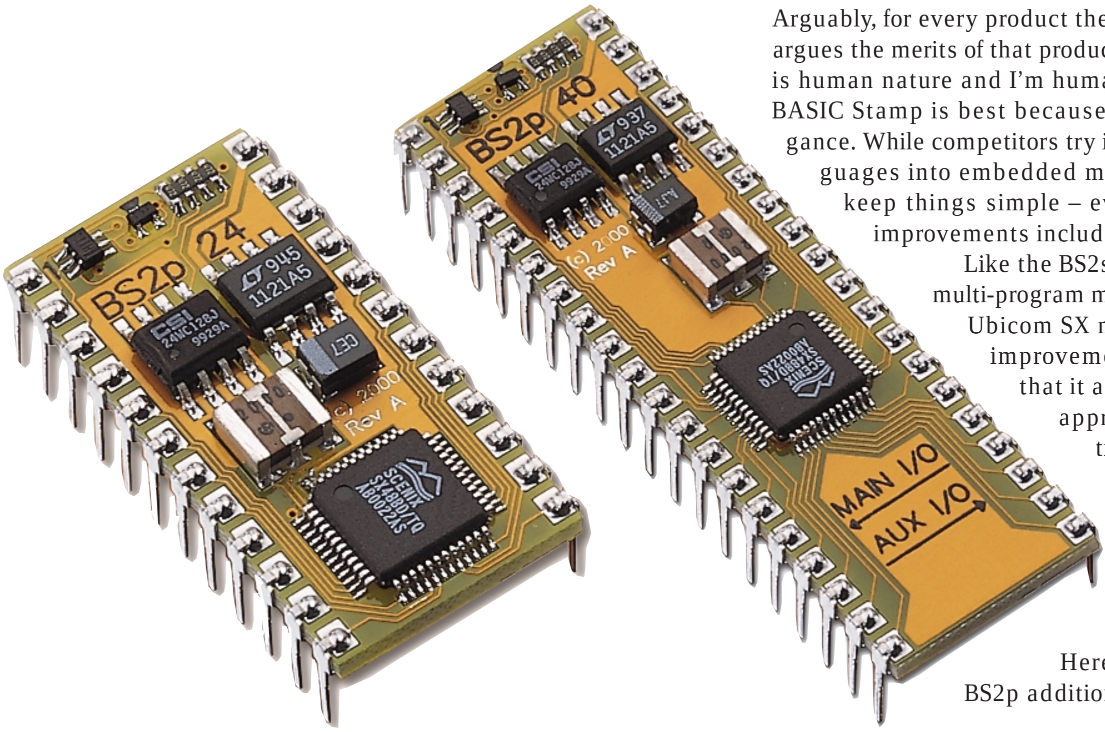
More Power and Performance from the Parallax BASIC Stamp

meet the BS2p!

By Jon Williams

jonwms@aol.com

With the success of the BASIC Stamp and its domination of the small, BASIC-language microcontroller market, one might expect that Parallax would sit back and simply enjoy the fruits of its past labours. Well, this is clearly not the case. If the introduction of the latest BASIC Stamp, the BS2p, is any indication, Parallax is not sitting still for anything.



Arguably, for every product there will be a customer that argues the merits of that product and why it is 'best'. This is human nature and I'm human too. For my money, the BASIC Stamp is best because of its simplicity and elegance. While competitors try in vain to jam desktop languages into embedded micros, Parallax chooses to keep things simple – even with the spectacular improvements included in the BS2p.

Like the BS2sx and BS2e, the BS2p is a multi-program module that is based on the Ubicom SX microcontroller. Firmware improvements in the BS2p means that it actually runs 20% faster (at approximately 12,000 instructions per second) than the BS2sx while consuming about 33% less current. This is a big help to robot builders and other battery-powered applications.

Here's an overview of the BS2p additions and improvements:

Editorial Note

The total size of listings 3 through 7 is such that they can not be included in this article. All program listings discussed in this article may be obtained from the Free Downloads section of the Elektor Electronics website at www.elelektor-electronics.co.uk. The file number is 014132-11.

– Parallel LCD routines for the Hitachi HD44780
– Philips I²C routines
– Dallas 1-Wire™ routines
– Pin-polling between instructions
– Serial buffering to scratchpad RAM
– 24-pin (16 I/Os) and 40-pin (32 I/Os) versions
– Double the scratchpad RAM of the BS2sx (now 127 bytes)

If you've used the BS2 or BS2sx for any length of time, you'll recognize that this is a very strong list of features and goes a long way toward extending the Stamp's versatility. Let's take a look at these new features.

LCD Support

The BS2p has native support for the popular Hitachi HD4470 LCD controller. The routines that support LCD control are:

– LCDCMD E-pin, command
– LCDOUT E-pin, command, [output data]
– LCDIN E-pin, location, [input data]

These routines require that the LCD be configured in 4-bit mode and have specific requirements as to where the connections can be. The syntax of each statement (specifically the control pin for LCD.E) tells the BS2p how the LCD is connected.

The table shows that the LCD can be connected to the pins at OutL (0-7) or the pins at OutH (8-15) and specific requirements as to where E, R/W, RS and the data lines need to be connected. Keep in mind that you don't have to use the LCD's R/W line if you are not going to read from its RAM. In this case, you can simply ground the LCD.R/W pin and use the Stamp control pin for other duties. Note that the Parallax documentation suggests that the LCD.E line be pulled down to ground through a 4.7-kΩ resistor.

The first of the LCD commands is LCDCMD and is used to send command a control code to the LCD. This command will be used during initialization and for moving the cursor home, clearing the LCD, etc. Here's a few typical commands:

Clear the LCD	$01
Move cursor home	$02
Move cursor left	$10
Move cursor right	$14

There are others. Consult the program listings here and the Hitachi documentation for the HD44780.

Writing data to the LCD has been made very easy with **LCDOUT**. There are two nice things about this new command: you can send the LCD a command byte (i.e., clear the LCD) before the write and the output data is structured just like **SEROUT**. This means you can use the typical **SEROUT** modifiers like BIN, HEC, DEC, STR and REP.

Reading information back from the LCD is just as easy with **LCDIN**. Its syntax is identical to **LCDOUT**. With **LCDIN**, the *location* byte needs to point to the starting memory location to read. The following constants are useful in programs that use the LCD commands:

```
DDRam    CON   $80
CGRam    CON   $40
```

DDRam is the memory that holds the characters being displayed. CGRam is the 64-byte memory area where custom character patterns are stored. If your program doesn't use this memory for custom characters, it can be used as off-board RAM with LCDOUT and LCDIN. The STR modifier can be used to transfer a block of bytes to or from the LCD.

Listing 1 demonstrates the simplicity of LCD output with the BS2p.

LCD Connections:

LCD	Option1	Option 2
LCD.E	BS2p.0 or BS2pP.1	BS2p.8 or BS2p.9
LCD.R/W	BS2pP.2	BS2p.10
LCD.RS	BS2p.3	BS2p.11
LCD.DB4	BS2p.4	BS2p.12
LCD.DB5	BS2p.5	BS2p.13
LCD.DB6	BS2p.6	BS2p.14
LCD.DB7	BS2p.7	BS2p.15

Philips I²C Support

The Philips I²C bus is a popular 2-wire, bidirectional bus. There is a wide variety of I²C parts available and now those parts can be very easily used with the BASIC Stamp. The two bus lines are SDA (serial data) and SCL (serial clock). The SDA and SCL lines must be pulled up to Vdd (+5 V) through 4.7-kΩ resistors.

The BS2p supports I²C devices with:
I2COUT *pin, slave addr, addr{\low_addr}, [output data]*
I2CIN *pin, slave_addr, addr{\low_addr}, [input data]*

The I²C devices can only be connected to group pins 0 & 1 or 8 & 9.

I2C Bus	Option 1	Option 2
SDA	BSP.0	BSP.8
SCL	BSP.1	BSP.9

The pin parameter of each command specifies the SDA pin. The slave_addr is the I²C device to connect with. The addr is the location within the I²C device to write to or read from. The use of the backslash allows two-byte addressing for those devices that support it. The parameter after the slash is the low-order byte of the address.

To demonstrate I²C routines, the program shown in **Listing 2** generates a pseudo-random number, writes it to an I²C RAM, waits for 100 milliseconds and then reads the data back. An LCD is used to display the address, output and input data.

Dallas 1-Wire™ Support

The Dallas 1-Wire™ bus is a system which has a single bus master and one or more slaves. In this case, the BS2p acts as the bus master. Each device on the 1-Wire™ bus has a unique serial number (used for addressing) that is manufactured right into the device.

1-Wire™ devices are supported with two easy-to-use commands:
OWOUT *pin, reset,* [*output data*]
OWIN *pin, reset,* [*input data*]

Communication to 1-Wire™ devices can be on any available pin. This pin should be pulled up to Vdd (+5 V) through a 4.7-kΩ resistor. The *reset* parameter has several options. For example:

0 No reset, byte mode, low speed
1 Reset before data, byte mode, low speed
2 Reset after data, byte mode, low speed
3 Reset before and after data, byte mode, low speed
4 No reset, bit mode, low speed
5 Reset before data, bit mode, low speed
8 No reset, byte mode, high speed
9 Reset before data, byte mode, high speed

Listing 1. LCD output with the BS2p.

```
' —-[ Title ]——————————————————————————————-
'
' File...... LCDDEMO.BSP
' Purpose... BASIC Stamp 2p —> LCD
' Author.... Jon Williams
' E-mail.... jonwms@aol.com

' {$STAMP BS2p}

' —-[ Program Description ]——————————————————————-
'
' This program initializes the LCD in 4-bit mode and sends a simple message
'
' Connections:
'   - LCD.E    —> Pin0 (pulled down [to ground] through 4.7K)
'   - LCD.R/W  —> Pin2 (or grounded for write-only operation)
'   - LCD.RS   —> Pin3
'   - LCD.D4   —> Pin4
'   - LCD.D5   —> Pin5
'   - LCD.D6   —> Pin6
'   - LCD.D7   —> Pin7

' —-[ I/O Definitions ]————————————————————————-
'
LCDpin         CON    0                          ' data on pins 4 - 7

' —-[ Constants ]——————————————————————————-
'
' LCD control characters
'
NoCmd          CON    $00                        ' just print
ClrLCD         CON    $01                        ' clear the LCD
CrsrHm         CON    $02                        ' cursor home
CrsrLf         CON    $10                        ' cursor left
CrsrRt         CON    $14                        ' move cursor right
DispLf         CON    $18                        ' shift display left
DispRt         CON    $1C                        ' shift displayright
DDRam          CON    $80                        ' Display Data RAM control
Line1          CON    $80                        ' address of line 1
Line2          CON    $C0                        ' address of line 2

' —-[ Initialization ]—————————————————————————
'
LCD_Setup:
  LCDCMD LCDpin,%00110000 : PAUSE 5         ' 8-bit mode
  LCDCMD LCDpin,%00110000 : PAUSE 0
  LCDCMD LCDpin,%00110000 : PAUSE 0
  LCDCMD LCDpin,%00100000 : PAUSE 0         ' 4-bit mode
  LCDCMD LCDpin,%00101000 : PAUSE 0         ' 2-line mode
  LCDCMD LCDpin,%00001100 : PAUSE 0         ' no crsr, no blink
  LCDCMD LCDpin,%00000110                        ' inc crsr, no disp shift

' —-[ Main Code ]——————————————————————————-
'
Main:
  LCDOUT LCDpin,ClrLCD,[" Parallax BS2p"]    ' splash screen
  LCDOUT LCDpin,Line2,["  LCD Control"]
  END
```

Listing 2. Random number generator, I2C demonstration.

```
' —-[ Title ]————————————————————————————-
'
' File...... PCF8570.BSP
' Purpose... Demonstrates I2CIN and I2COUT
' Author.... Jon Williams
' E-mail.... jonwms@aol.com

' {$STAMP BS2p}

' —-[ Program Description ]——————————————————————-
'
' Writes to and reads from I2C RAM. Data is displayed on line 2 of a 2x16
' LCD.

' Program requires 2x16 LCD
'   - LCD.E    —> Pin0 (pulled down [to ground] through 4.7K)
'   - LCD.R/W  —> Pin2 (or grounded for write-only operation)
'   - LCD.RS   —> Pin3
'   - LCD.D4   —> Pin4
'   - LCD.D5   —> Pin5
'   - LCD.D6   —> Pin6
'   - LCD.D7   —> Pin7

' —-[ Constants ]——————————————————————————-
'
LCDpin         CON    0                           ' LCD is connected to OutL
I2Cpin         CON    8                           ' SDA on 8; SCL on 9

NoCmd          CON    0
ClrLCD         CON    $01                         ' clear the LCD
CrsrHm         CON    $02                         ' move cursor to home position
CrsrLf         CON    $10                         ' move cursor left
CrsrRt         CON    $14                         ' move cursor right
DispLf         CON    $18                         ' shift displayed chars left
DispRt         CON    $1C                         ' shift displayed chars right
DDRam          CON    $80                         ' Display Data RAM control
CGRam          CON    $40                         ' Custom character RAM control
Line1          CON    $80
Line2          CON    $C0

addr           VAR    Byte                        ' address to write to / read from
rVar           VAR    Word                        ' for random number
tOut           VAR    Byte                        ' test value to write to LCD
tIn            VAR    Byte                        ' test value to read from LCD
temp           VAR    Word                        ' temp value for numeric display
width          VAR    Nib                         ' width of rt justified display
pos            VAR    Byte                        ' column position for display
digits  VAR    Nib                                ' number of digits to display

' —-[ EEPROM Data ]——————————————————————————-
'
Super2         DATA   %01100                      ' super-script 2
               DATA   %00010
               DATA   %00100
               DATA   %01000
               DATA   %01110
               DATA   %00000
               DATA   %00000
               DATA   %00000

' —-[ Initialization ]—————————————————————————
'
LCD_Setup:
  PAUSE 500
  LCDCMD LCDpin,%00110000 : PAUSE 5        ' 8-bit mode
  LCDCMD LCDpin,%00110000 : PAUSE 0
  LCDCMD LCDpin,%00110000 : PAUSE 0
  LCDCMD LCDpin,%00100000                         ' 4-bit mode
  LCDCMD LCDpin,%00101000                         ' 2-line mode
  LCDCMD LCDpin,%00001100                         ' no crsr, no blink
```

```
  LCDCMD LCDpin,%00000110                           ' inc crsr, no disp shift

  ' download custom character map to LCD

  LCDCMD LCDpin,CGRam                       ' write to CGRAM

  FOR addr = Super2 TO (Super2 + 7)         ' build custom char
    READ addr,temp                                  ' get byte from EEPROM
    LCDOUT LCDpin,NoCmd,[temp]                      ' put into LCD CG RAM
  NEXT


' —-[ Main Code ]—————————————————————————-
'
Main:
  LCDOUT LCDpin,ClrLCD,["  BSP <—> I",0,"C"]
  LCDOUT LCDpin,Line2, [" Communications"]
  PAUSE 2000
  LCDCMD LCDpin,ClrLCD

  LCDOUT LCDpin,ClrLCD,["I",0,"2:     Out="]
  LCDOUT LCDpin,Line2 + 10,["In="]

  FOR addr = 0 TO 255                       ' test all addresses
    RANDOM rVar                                     ' create "random" value
    tOut = rVar.HighByte

    I2COUT I2Cpin,$A0,addr,[tOut]                   ' write to I2C RAM
    PAUSE 100
    I2CIN I2Cpin,$A0,addr,[tIn]                     ' read it back

    ' display results

    LCDOUT LCDpin,Line1 + 4,[DEC addr]
    temp = tOut : width = 3 : pos = Line1 + 13
    GOSUB RJ_Print
    temp = tIn : width = 3 : pos = Line2 + 13
    GOSUB RJ_Print
    PAUSE 350
  NEXT

  PAUSE 1000
  GOTO Main

  END

' —-[ Subroutines ]—————————————————————————-
'
RJ_Print:                                           ' right justify
  digits = width
  LOOKDOWN temp,<[0,10,100,1000,65535],digits
  LCDOUT LCDpin,pos,[REP " "\(width-digits),DEC temp]
  RETURN
```

When writing code, it may be easier to define the CONstants like this:

```
OW_FERst   CON  %0001  ' Front-End Reset
OW_BERst   CON  %0010  ' Back-End Reset
OW_BitMode CON  %0100
OW_HighSpd CON  %1000
```

These values can be added together to create the correct reset parameter.

When receiving data in bit mode, all variables in the *input data* argument will only receive on bit, regardless of the variable type. Like its predecessors, the BS2p supports the definition of bit-sized variables. It is wise to use this ability to save valuable variable space when dealing with bit-mode reception of data.

Since 1-Wire devices each contain their own unique serial number, the first thing the programmer needs to do is retrieve that number from the device. Use the simple program in **Listing 3** to retrieve a 1-Wire serial number:

Once device serial numbers are known, they can be bussed together. The program in **Listing 4** reads two DS1820 temperature sensors that are connected to the same pin:

Pin Polling (Firmware Interrupts)

As much as Stamp users would like it to be, the BS2p is not capable of handling true interrupts – that's hard to do for any interpreter and the compact size of the PBASIC interpreter makes it even tougher. What the BS2p can do, however, is check on pins between PBASIC statements and take a specified action. When setup and enabled, the BS2p perform the following actions on a polled interrupt:

– Nothing
– Set an output pin to specified state
– Run another program
– Wait (pause program) until interrupt condition occurs
– Any combination of 2, 3 and 4

Let me explain again so we're absolutely clear. When setup and enabled, the BS2p will check the state of polled-input pins between each PBASIC instruction. If the specified input condition is met, the "interrupt" state is made true and specified action(s) will be taken.

To define input pins that will be polled, well use POLLIN. Here's the syntax:

POLLIN pin,state

The pin parameter will always be 0 to 15 and state will be 0 (low) or 1 (high). When activated, the specified pin(s) will be polled between PBASIC instructions.

When the interrupt state is true, polled-output pins can be controlled. Once setup, the control over these pins is automatic and follows the interrupt condition. To define output pins, use POLLOUT.

POLLOUT pin,state

The parameters are the same as with POLLIN, except that the BS2p is controlling an output. The state will be set on the specified pin when the interrupt condition is true.

With polled-inputs and outputs defined, use POLLMODE to enable them.

POLLMODE mode

The mode parameter will be from 0 to 15 with the following definitions:

– Deactivate polling and clear polled-inputs and outputs definition
– Deactivate polling and save polled-inputs and outputs definition
– Activate polling with polled-outputs only
– Activate polling with polled-run action only
– Activate polling with polled-outputs and polled-run action
– Clear polled-inputs configuration
– Clear polled-outputs configuration
– Clear both polled-inputs and polled outputs

Modes 8 through 15 are the same as 0 through 7 except that the interrupt condition is latched.

The simple code snippet shown in **Listing 5** will demonstrate polled-inputs and outputs.

When this code is run a **DEBUG** screen is opened with the "Waiting…" message happily scrolling by. Now press and hold the button connected to pin 4. The LED connected to pin 0 will light. Now release the button and notice that the LED goes out.

With the ability to control outputs with polled-inputs, you can create a "background logic gate" that operates while the Stamp program is running. Add this line to the code above and notice that either pin (4 or 5) will light the LED – a background OR gate.

```
POLLIN 5,0       ' interrupt when
pin 5 is low
```

The nature of the BS2p allows the control polled-output pins with standard output pins. See, for example, **Listing 6**.

Without polling defined, the only thing that would happen is that the LED on pin 0 would blink (due to the **TOGGLE** command). With polling active, the LED on pin 1 will blink at the same rate as the LED on pin 0 (in this case in the opposite state).

Keep in mind that the interrupt state is a global condition and if none of the polled-input pins meet their requirements, the interrupt state will be cleared. There will be times when you want to monitor a number of pins and take a specific action based on the inputs. This can be accomplished by latching the interrupt condition and checking to see what pin(s) caused the interrupt state.

The next program, **Listing 7**, is a simple alarm program that latches the interrupt condition. Pins 4 and 5 are setup to create an interrupt when pulled low. When the interrupt condition is true, the Alarm LED on pin 0 is lit. In order to determine which pin(s) caused the interrupt condition, **POLLMODE 10** (control outputs and latch interrupt condition) is used.

During the loop, scratchpad location 128 is read to determine any active interrupt pins. Since the interrupts have been latched, the variable *iPins* will show which pins were active during the polling cycle. With this information we can create a simple display. Once an action is taken on the interrupt, we can reset everything by re-issuing the **POLLMODE** command.

In the examples thus far, the BS2p program spent time in a loop waiting for an interrupt to happen. With **POLLWAIT**, the BS2p can suspend program operation until the interrupt condition is true. When the interrupt condition is true, the program resumes at the next line.

POLLWAIT *period*

POLLWAIT is very similar to **NAP** in that it puts the BS2p into low-power mode. Based on the period, the BS2p will "wake" from the low-power and scan the define polled-input pins. If any of the conditions are met, the program continues, otherwise the BS2p goes back into low-power mode. The possible values for period are:

– 18 ms
– 36 ms
– 72 ms
– 144 ms
– 288 ms
– 576 ms
– 1152 ms (1.152 seconds)
– 2304 ms (2.304 seconds)
– Wait without low-power mode

Just as with **NAP**, any outputs with glitch when the BS2p comes out of low-power mode (period from 0 to 7) to do its check. Try this code:

```
HIGH 3         ' turn LED on pin 3 on
POLLIN 5,0     ' scan pin 5 for low input
POLLOUT 2,1    ' light LED on pin 2 during
                 interrupt
POLLMODE 2     ' activate polled-output
control

Loop:
  POLLWAIT 0 ' low-power mode for 18 ms
  TOGGLE 1   ' toggle LED on pin 1
  GOTO Loop
```

When the program starts, the LED attached to pin 3 will light. Look carefully. Notice the apparent pulsing of this LED? This happens when the BS2p comes out of low-power mode and all pins are momentarily made inputs. You can see the change by setting the period to a different value. What you'll observe is that as the period gets larger, the 'glitching' becomes less frequent, but so does the polling frequency. Holding the button will make the interrupt active through every check and the LED on pin 0 will toggle at a rate determined by the **POLLWAIT** period.

For applications where low-power mode is not required and **POLLWAIT** is desirable, set the period to 8. This causes the BS2p to wait for the interrupt condition, but doesn't put it into low-power mode.

Finally, we can use **POLLRUN** to cause the BS2p to jump to another program slot when the interrupt condition is true.

POLLRUN *program*

The default program slot for **POLLRUN** is 0. If **POLLMODE** 3 or 4 is issued and no **POLLRUN** program was defined, the BS2p will jump to program 0 on the interrupt condition. If polled-outputs are also defined and enabled (**POLLMODE** 4), the outputs will be set before the new program is run. **POLLRUN** 3 and 4 have a "one-shot" behavior to prevent the BS2p from appearing to be locked up by continuously jumping to the specified program.

Serial buffering to scratchpad RAM

There are occasions when an application requires the reception and parsing of a long data stream. In most of these applications, only a small portion of the string is needed. While the **WAIT** modifier is useful in these cases, it is not always reliable at very high data rates.

The BS2p allows the programmer to redirect any serial input (**SERIN**, **I2CIN**, **OWIN**, **LCDIN**) to the scratchpad RAM area. Once there, it is a simple matter to user **GET** to parse the input string for the required data. This is especially easy if the location of the data is known. With this technique, the BS2p can buffer up to 127 bytes of serial data. Then syntax looks like this:

SERIN *pin,baud,[SPSTR L]*

The new modifier, SPSTR (scratchpad string), is similar to the STR modifier except that it redirects the data to the scratchpad RAM, starting at location 0. The L(ength) parameter tells the Stamp how many bytes to buffer.

More pins

Stamp customers have been asking for them and now the have them: more pins. The BS2p comes in a 40-pin version that gives the Stamp user an extra set of 16 I/O pins. Using the additional pins is somewhat similar to using program slots — the Stamp has to be specifically directed to use the additional pins. All Stamp instructions that require pin numbers stay the same, that is, they expect a pin number from 0 to 15. On the BS2p-40, the program specifies which set if I/O pins to use.

There are two ways to select the second set of I/O pins:

```
AUXIO     ' select auxiliary
            I/O pins
IOTERM 1  ' select auxiliary
            I/O pins
```

To switch back to the main I/O pins, we can use either of the following:

MAINIO' select main I/O pins

```
IOTERM 0   ' select main I/O pins
```

In case you're wondering, polled-pins can be defined on both sets of I/O groups and all of them are active, regardless of which set of I/O pins are in use at the time. You can even determine which of the 32 pins caused the interrupt condition by looking into the scratchpad RAM (see below).

Note that **MAINIO**, **AUXIO** and **IOTERM** are not available on the BS2p-24 since it only has one set of 16 I/O pins.

Effective use of EEPROM space

A popular use of the BS2sx and BS2e controllers is the data logging. Programmers have used extra program slots as non-volatile storage with the Stamp's **WRITE** and **READ** commands. The difficulty, however, has been the necessity to pass data from one program slot to another through the scratchpad for storage. This problem has been eliminated with the BS2p.

The BS2p has a new command called **STORE**. This syntax is simple:

STORE *location*

Location is the program slot (0 to 7) to be used as the target for **READ** and **WRITE.** The default location number is the same as the current program and gets changed to the new program slot whenever the **RUN** command is issued. The neat thing about **STORE** is that now the programmer can take advantage of unused program slots and, with a bit of code, treat them like one large, flat EEPROM block.

Read-Only RAM Locations

As stated, the BS2p has twice as much scratchpad RAM (127 bytes) as the BS2sx. There are five bytes at the end of the scratchpad that are read-only and provide useful information

Current program (low nibble) and **STORE** location (high nibble)
Interrupt pin detection,
  main pins 0 – 7
Interrupt pin detection,
  main pins 8 – 15
Interrupt pin detection,
  auxiliary pins 0 – 7
Interrupt pin detection,
  auxiliary pins 8 – 15

Locations 128-131 can be used by your program to determine what pin(s) caused an interrupt condition. An active interrupt pin will be indicated by a 1, regardless of its input state (active-low or active-high). The bits in these locations are active only when the interrupt is active, so you may need to latch the interrupt condition to determine the cause after-the-fact.

Not just another new stamp

The new BS2p is not just another new BASIC Stamp, it's a significant improvement in Parallax's line of small micros – probably the best since the introduction of the BS2. With greater processing power at lower current consumption than its predecessor, one can only hope that this is just a sign of more good things to come from Parallax.

(014132-1)

Introduction to TCP/IP and Embedded Internet (2)

Part 2: programming tips for TCP/IP stacks in webservers

By P. Stuhlmüller

The key to the implementation of a mini-webserver is the programming of the TCP/IP stack. Although this is strictly defined, there is nonetheless a certain amount of variety in actual versions of the TCP/IP stack. This article provides recommendations and advice relating to the programming of TCP/IP stacks.

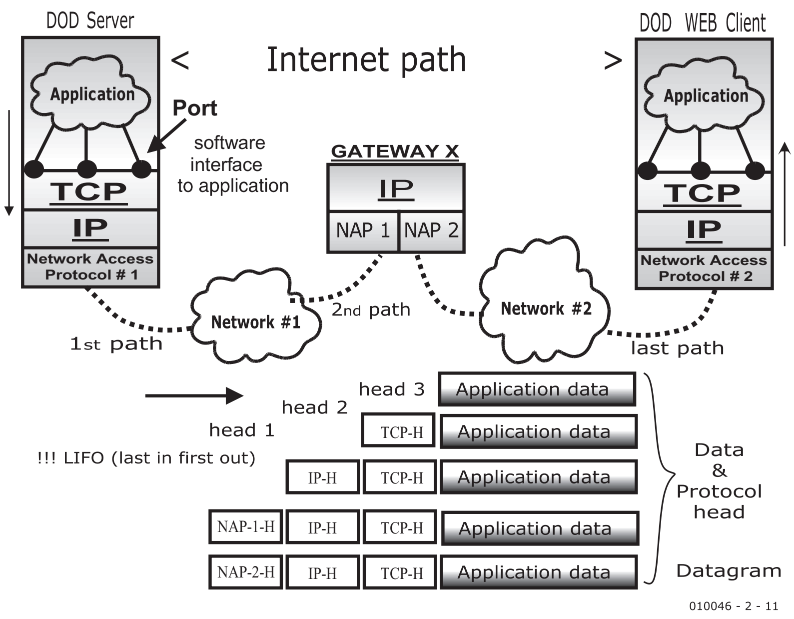


Figure 1. Structure diagram of the information flow of a datagram from the client to the server, via two separate LANs and a gateway acting as a bridge station.

Which software modules must be present in a webserver? The client is a general user of the Internet or intranet, and it logs on to the network using standardised software (t-online, AOL etc.). After the usual log-on procedure, we find ourselves on the homepage of the provider, which is displayed by the browser. The first connection link has thus been built up that far, and it remains active. From here, we could select our embedded webserver as the next step. After it has been selected, the webserver sends its standard page via the network to the client station. The selection process includes a test of the client ID as a minimal security barrier.

Figure 3 in the first instalment of this series shows the general scheme. The choice of the correct protocol in each situation is of vital importance. **Figure 1** shows, in simplified form,

the key features of the data stream. After the information packet leaves the server, it arrives at least one IP router. The NAP (Network Access Protocol) is the form taken by connection at the physical layer. This can be an analogue link or a digital link, using ISDN or the relatively new ADSL. The second factor that affects the structure of the software is the hardware nature of the server (individual site or network station). This affects the way in which the data for an information site are configured.
To make a data page available on the Web, the first thing that has to be done is to translate the text version into HTML (Hypertext Mark-up Language) format. MS Word 2000 can do this readily. What is important is how the Web pages should appear to the (technically oriented) webserver. If precisely aligned texts are to be combined with graphics and tables, it may be necessary to use the new XHMTL standard with the CSS (Cascading Style Sheets) extension. This makes it possible to control text parameters in detail, adjust the separations between elements, assign colours and draw frames and rules — and naturally, with a number of selectable 'click points'.
We cannot use Windows or Linux as the operating system for our webserver, since there is no hard disk drive in the hardware (as shown in Figure 5 in the first instalment).
However, we could plan to use Microsoft Windows CE 3.0 or Wind River VxWorks, integrated into flash memory that serves as program memory. For each of these operating systems, there are suitable tools available for converting data pages into web pages. The web pages are generated in advance in a PC and then loaded into the flash memory in the form of (X)HTML tables. The operating system (OS) then treats these scripts as data blocks, to which it adds currently measured data values (measurement values) as necessary. These are worked into the tables or graphics in such a manner that at the end, the browser in the client can transform the complete data packet into a web page. The web page thus contains both fixed regions and variables in the web layout. This takes place purely on the application level in the OS or DOD model. Various subsidiary data pages can be generated via the start page. HTML scripts can be used to create simple links (direct links and forward connections). However, we will not go into this subject in this article.

Shall we shake hands?

The selection process can take place at the webserver via HTTP, or in a more direct form via FTP (File Transfer Protocol). An IP address is always required. Our primary attention must go the selection of the proper protocol for the webserver. We have to define the type of acknowledgement procedure that has to be carried out among the client, router and server. There are connection-based protocols as well as protocols that require only a physical link. The client 'speaks' first, which means that it selects the server. The first set-up is not acknowledged. If the selection of the (private embedded, not general-Internet) server is successful, a virtual connection can be set up via the acknowledgement message from the 'target', although this is not possible with some types of protocols. A virtual connection is a point-to-point connection that is maintained by software, with a more or less large 'handshaking' component. It should by no means be confused with a fixed connection, such as that between the two terminals of an RS232C link. As noted, the permanence of the point-to-point connection depends on the application.
The TCP/IP protocols should actually be seen as a derivative of RS232C (that is, asynchronous). The two terminals must first be synchronised. This takes place using the SYN flag (SYN = 1). The mutual exchange indicates that it is actually possible to set up a connection. The normal three-way acknowledgement mechanism (handshaking) relates to setting up a connection for a datagram. Once the first handshake has completed with the ACK flag, the actual datagram is sent, and then the connection may be established again, depending on the situation. The datagram itself is initially not further acknowledged, and the connection is terminated with the FIN flag (see **Figure 2**).

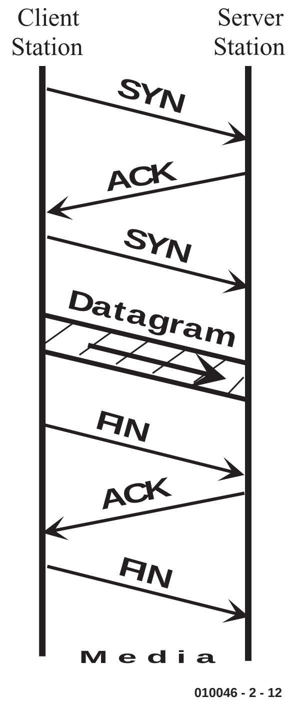


Figure 2. Three-way handshaking between two stations, which is generally used in Internet protocols for establishing and terminating connections.

Large quantities of data are split up into smaller pieces for transmission. The recipient can then request the sequence number from the sender, and thus the next part of the complete packet (frame). However, this again is very dependent on the particular protocol used.
Now we come to the terms SLIP, PPP, PPTP, TCP, UDP, ports and sockets, all of which are specialised expressions that designate connection protocols for the appropriate Web applications and the software for the activation of these protocols. Port numbers are used for identification. The items that are most commonly used in programming are summarised in **Table 1**. SLIP plays a major role here, since with it selection is integrated and is sent with the order into the Internet in the final datagram. The UDP protocol is preferably used in cases where the number of return messages should remain small. Return messages necessarily arise as a result of plausibility testing, but the number of such messages is affected by the type of protocol used. It must be accepted that errors can occur. After a suitable pause when waiting for the response, the request may be re-sent, or the client may be requested to do so. Even TCP does not guarantee a completely error-free transmission of the packet data block under all conditions, although it has a relatively high standard of performance. How-

ever, it does have very secure handshaking in each of the detail-level phases. The amount of handshaking must be kept within limits in order to prevent the amount of processing time from rising to impossible levels. Anything that can be transmitted with a 99.9% probability of being error free does not have to be acknowledged, since too much handshaking will plug up the network.

The large number of different protocols forms a very important component of programming. We simply make use of existing, proven facilities. Using these protocols saves time and makes for compatibility. As can be seen from the TCP/IP header, they are called via **sockets**.

Datagrams and service primitives

The first thing you need t o know for programming TCP/IP stacks is that a request is sent to a particular participant (in this case, our webserver) via the network. This involves the transmission of a number of data blocks in the form of datagrams, including various protocol headers for the higher-level protocols, in the direction of the first communication partner (that is, the first accessible Internet host or router). This service is provided by the appropriate point-to-point connection protocol. The terminal software that is used (there are several possibilities) transfers the complete datagram.

Clearly, all that the protocol stack software in the client has to do is to precisely reconstruct this datagram and look after the transfer. The communications between the two partners is one-way at this moment, which means that the IP datagram is transferred without handshaking and thus must be considered to be somewhat unreliable. From experience, however, the probability of an error is negligibly small. That is all for the time being.

The Internet protocol is specified in great detail in the IP datagram. It defines functional requirements that are designated as **service primitives** and **parameters**. These service primitives are services that are either located in the various layers or are made available in the various layers. There are two defined services that are relevant to the IP: the **transmit service** and the **receive service**.

The **transmit service** employs the following parameters: source address (Source), target address (Destination), protocol, type of service, identification, not-fragment indicator, lifetime value, data length, options and finally, the data content.

The **receive service** receives the datagram and employs the following parameters in the process: source address (Source), target address (Destination), protocol, type of service, data length, options and data content.

The terminal software remains active after the datagram has been sent from the client. It waits for a return message, which should contain a response from (our) webserver. The data section of the datagram contains the information for the webserver that tells it which page it should provide to the client, or in other words, which page it should send in its response.

On the side of the embedded server, the terminal software is practically permanently active, but it is installed such that it requires almost no processing time in the idle state. If a request from the Internet network reaches the webserver, the TCP/IP stack executes the receive service and responds with its own server datagram as part of its transmit service. Depending on the application, the socket may remain active afterwards or it may be de-activated.

The meanings of the port numbers, together with the sockets, form the actual interface to the application procedures (also called the Application Program Interface, or API) for the webserver, which in response to a request from the client station must initiate a data page to be sent back. This is of fundamental importance for the TCP/IP stack programmer.

Operating systems: VxWorks and Windows CE 3.0

From what you have already read, you have probably received the impression that TCP/IP is not all that simple. However, this is all a matter of perspective. If there are not any sockets available for our home-made monitor program for the microcontroller hardware, the important consideration is to first choose the elements that are actually necessary (protocols). These must then be selected from (for example) open-source code (such as Unix or Linux libraries) and integrated into our existing microcontroller software (monitor program). The search may be laborious, but at least it is rewarding.

On the other hand, if we use an operating system that can be installed in flash ROM for our webserver project, such as Wind River VxWorks, implementation is almost child's play, since TCP/IP is already integrated. All that we have to do is to call the sockets ourselves and make sure that we observe the requirements and use the appropriate port numbers in the procedure.

Without question, the ideal solution for remote control applications is Windows CE 2.12 or 3.0. Windows CE is an operating system that has been specially designed for control tasks, and with which Microsoft wants to get a foot in the door of the enormous world of industrial applications. It supports external control (remote access) by implementing LAN drivers (Level 2, Data Link Layer) as well as wide-area connections (Internet and/or wireless).

The TCP/IP stack, with Winsocket management, selection procedures and the PPP, SLIP, CSLIP, PAP, CHAP and TAPI protocols, is obligatory. There are various examples of how to activate sockets under Windows CE. Everything is truly made easy for the user!

Windows CE has a separate platform generator (platform builder in the form of definition and binding software with many dialogues) that takes over the preparatory work for many specific cases of Internet accesses. It links all the essential core elements of the operating system such that the result can be precisely adapted to the needs of the application.

Windows CE shows a way to implement TCP/IP stacks that certainly should not be ignored for professional applications. If by contrast the TCP/IP stack is put together from Unix and/or Linux libraries, the amount of effort may be significantly larger.

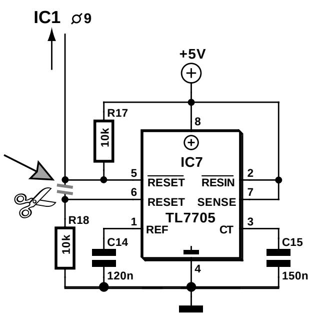
(010046-2)

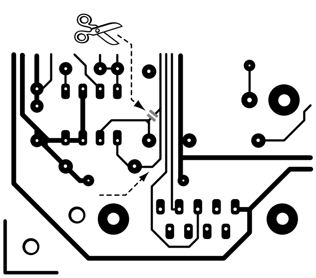
The third article of this series, which will appear in the July/August 2001 issue, features a practical implementation of a TCP/IP stack.

Protocols and Services	Meaning
SLIP	*Serial Line Internet Protocol*: supports direct selection via a selection procedure to the Internet or TCP/IP network; does not support dynamic IP addressing functions or security facilities; works as a network interface to the DOD Reference Model [four-level interface: level 4 = application, level 3 = transport, level 2 = Internet, level 1 = network interface (physical transmission) à Ethernet IEEE 803.3, Token Ring, FDDI, PPP, Frame Relay and X.25].
DOD Internet Levels Protocol Layer	The *Department of Defense* layer model incorporates TCP and UDP in the transport layer. The application level (level 4) supports the FTP, HTTP, Telnet, NFS, SMTP, NNTP, SNMP and DNS protocols. The Internet level (level 2) supports IP, ARP, DCHP and ICMP, as well as RIP and OSPF.
IPX/SPX	IPX/SPX is an Internet/Novell standard that is equivalent to TCP/IP and is a protocol for the general Unix standard.
PPP	*Point-to-Point Protocol*: supports direct selection via the TCP/IP header; offers self-identification (authenticity), dynamic IP addressing (in contrast to SLIP) and error correction.
PPTP	*Point-to-Point Tunnelling Protocol*: enables the transmission of packets from a private (separate) network; these are first encrypted and are then effectively transmitted through a ‘tunnel’ in a public network (the Internet).
FTP	*File Transfer Protocol*: transfers files between clients and servers that also allow a station to be externally controlled via the network or cable connection. FTP can be executed via TCP ports 20 and 21, even in command-line mode.
TFTP	*Trivial File Transfer Protocol*: the simplest form of data exchange; utilises UDP port 69. TFTP does not support file management, user names or passwords for protection, while FTP allows these options.
UDP	*User Datagram Protocol*: located in the transport layer of the DOD model, it acts as a unidirectional link, for example to directly connect a client station to the first (nearest) Internet host computer, but not in a virtual connection (!). It avoids return messages and thus has low overhead demands. It is considered to be less reliable than TCP. UDP reduces the amount of processing power required from the microcontroller. It is primarily usable for non-critical connections in the Web. It does not assume any fixed connections.
TelNET	Enables the client to function as a terminal station; especially usable with Unix hosts, but not particularly important for an embedded webserver.
HTTP	Hypertext Transfer Protocol: the transfer protocol of the World Wide Web; typically transfers documents generated in (X)HTML.
Port	A calling number, defined at the application level, for a particular service that is provided by TCP/IP. Applicable to the TCP and UDP protocols. The following are some sample ports: TCP port 21 = FTP, port 23 = Telnet, port 80 = HTTP (the Web); UDP port 53 = DNS, port 69 = TFTP, port 161 = SNMP.
socket	Software interface for a specific combination of an IP address and a port for a specific application in level 4 of the DOD model. The socket process or service is a call to the application layer. Sockets remain active on the transmit and receive side as long as the connection is maintained.
CIDR	*Classless Inter-Domain Routing*: used in supernet models (multiple networks with separate IP addresses) for binding into a network, so that the IP address table can be compressed and limited. Reduces the size of the routing tables used by most Internet routers.
NAT	*Network Address Translation*: converts a private network address into a global Internet address with a valid assignment. Very important for a webserver located in a LAN.
ARP	*Address Resolution Protocol*: located in level 2 (Internet) of the DOD model, it looks after translating IP addresses into physical hardware addresses; also supported by Windows CE. ARP writes to the addresses of network adapters, such as Ethernet controllers. Very important in all LAN connections.
IGMP	Internet Control Message Protocol: supports diagnostic messages, especially when a network, host or port is inaccessible. Used by the Ping command.
ICMP	*Internet Group Management Protocol*: organises groups of nodes and supports diagnostic and control messages in the network; used especially for multicasting applications.
RTO	*Retransmission Time Out*: in general, timers are activated in the TCP to trigger retransmission of a datagram if they time out, since this means that the first attempt was probably unsuccessful.
DHCP	*Dynamic Host Configuration Protocol*: provides dynamic assignment of a large number of IP addresses from applications for direct use in the Internet. It is installed as a DHCP server on Windows NT machines, where it extends the Administrator options. It is important if the webserver system has a Windows NT TCP/IP network server installed as an Internet station.
SMTP	*Simple Mail Transport Protocol*: used by electronic mail messages for transfers between networks.
SNMP	*Simple Network Management Protocol*: employed in LANs as the network manager; may be important for webservers that are integrated in LANs.
NNTP	*Netnews Transfer Protocol*: used to send and receive newsgroups (announcements), e.g. Usenet.
NFS	*Network File Server*: allows the file directories of external stations to be linked to a local file system; primarily suitable for Unix applications.
Virtual circuit	Used especially with connection-based protocols; increases the level of return messages and handshaking. A quasi-temporary software connection is established between the client and the server, somewhat like a ‘virtual leased line’.
Internetwork	The linking of several (local) networks to form a single network; not the same as the Internet.
ISDN	*Integrated Services Digital Network*: digital coding on the telephone line.
ADSL	*Asymmetric Digital Subscriber Line*: a telephone line with a high download rate (up to 500 kbit/s) but a low upload rate (up to 50 kbit/s).
LAN	*Local Area Network*: an Ethernet or Token-Ring network.
WAN	*Wide Area Network*: formed by coupling LANs and network hosts.

Major-Domo
May 2001 — 000184-1

Pins 5 and 6 of IC7 have been mixed up in the circuit diagram and on the PCB. Pin 6 should go to R18 only. Pin 5 is connected to pin 9 (RESET\) of IC1. The modification to the PCB is illustrated here.





AM Receiver
February 2001 — 000176-1

On the PCB, the ground pin of the antenna input should be connected to the ground plane on the PCB.

Darkroom Timer
April 2001 — 000182-1

In the components list, IC3 should be identified as S210S02 (Sharp), not S201S01. The S01 does not have a zero-crossing detector and will cause more electrical noise than the S02. However, both parts may be used in the circuit.

PPP Valve Power Amplifier
May 2001 — 000118

The caption with Figure 4 should read: Transistorised equivalent version of the PPP power stage of Figure 3. The circuit diagram in Figure 5 shows the circuit configuration for EL34 output valves. The type numbers with V3 and V4 should therefore be corrected to read 'EL34'.

Tbe diode next to C11 should be labelled D5, not D1. Capacitor C6 should be marked with an asterisk (only fitted if required).

In the parts lists, the value of C10 should be corrected to read 22µF in compliance with the circuit diagram.

The wire links for the connection of the input transformer mentioned in the text (1:1 or 1:2 transformation ratio) are not shown in the circuit diagram or on the PCB. On the component overlay, the rectangle representing the transformer is too large and partly covers the solder pins B-2, A-2, B-1 and A-1. Depending on the transformation ratio of Tr1, the solder pins should be connected as follows:

Ratio	Wire links
1:1	B2-A2 and B1-A1
1:2	A2-B1

When a cinch socket is used, the amplifier may be driven without an input transformer. The ground pin of the cinch socket is then connected to ground and the signal pin to C1 (signal input).

The parts list with the heading 'Power supply, stereo (one channel)' belongs with the 'stereo power supply' PCB. Unfortunately this PCB could not be included in the article, and its layout will be included as soon as possible in the Free Downloads for the PPP Valve Power Amplifier.

The LED in the box marked 'Power' in the wiring diagram (Figure 6) is symbolic only. In actual fact the power-on indicator circuit consists of a LED, a 470-Ω resistor and an 1N4007 diode, all connected in series.

The quiescent currents of the power output valves are 35 mA for the EL34 and 65 mA for the KT88. By connecting 1.5-kΩ resistors in parallel with R17 and R18, the standby switch reduces the quiescent current to about 20% of the nominal value. The switch is wired as follows.

The LED in the box 'STANDBY' has a series resistor of 1.5 kΩ and is polarized such that its anode is connected to junction R18-C14-P2 on the PCB. When the standby switch is closed, the LED and its 1.5-kΩ series resistor are connected in parallel with R18, and lights up. A 1.5 kΩ resistor should be inserted in the connection between R17 and the (second) contact of the standby switch. When this contact is closed, the 1.5 kΩ resistor is effectively connected in parallel with R17.

On the stereo prototype, the standby switch was omitted for cosmetic reasons only.

The wiring of the amplifier was carried out with the following wire strengths: 1.5 mm^2 for the heater voltage, 0.75 mm^2 for the mains voltage, 0.5 mm^2 for the high voltage and 0.25 mm^2 for the grid bias and the LEDs.

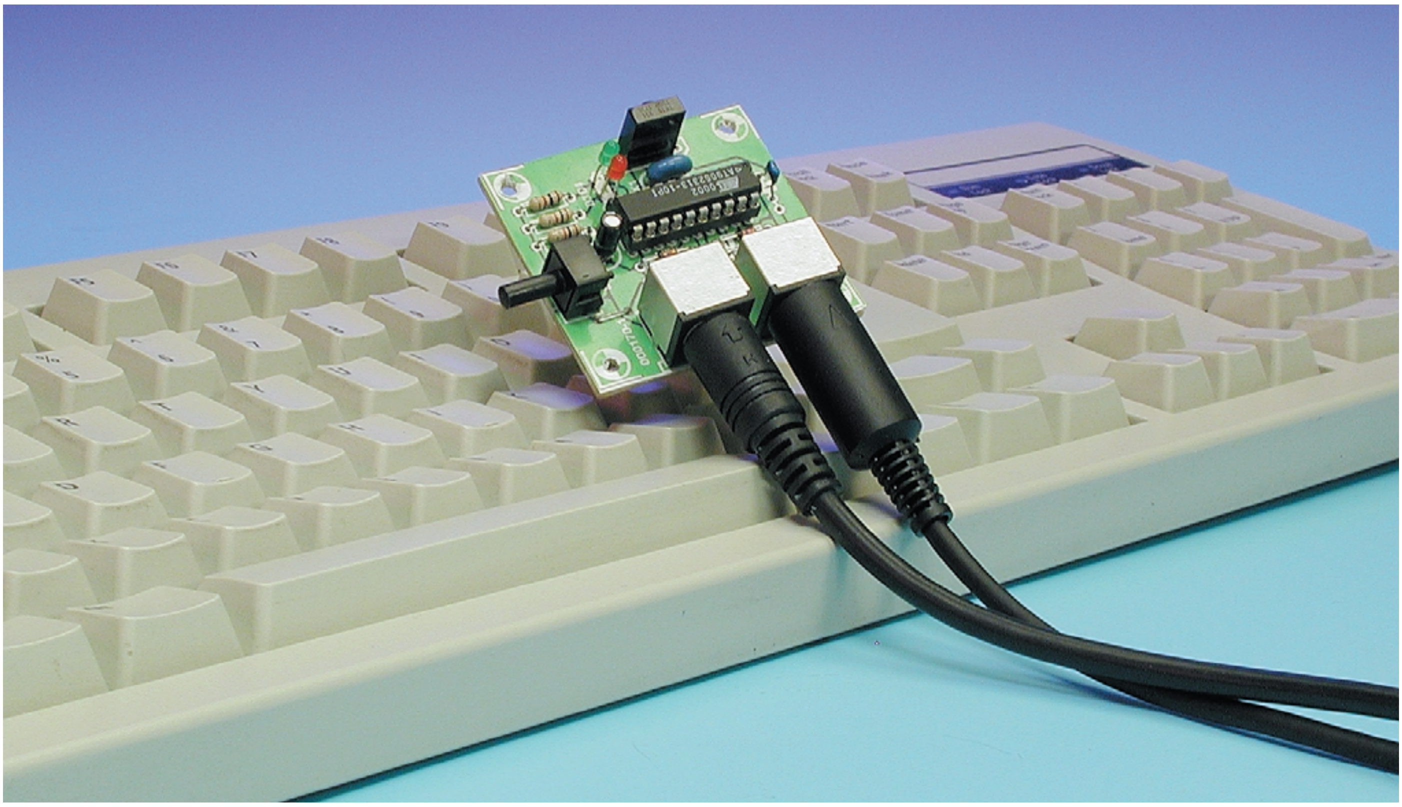
Infrared Remote Control for PCs

using the RC5 code

By J. Ferber

McFerber@gmx.net

Using this infrared receiver with your PC will let you control your favourite programs using a readily-available RC5 transmitter: useful if your PC has a suitable video card and you use it as a television, or if you want to use Winamp, for example, to play MP3 files through your hi-fi.



If you want to install a PC in your living room as a television or as part of your hi-fi setup, a remote control is practically indispensable. Who wants the trouble of going to the PC's keyboard to adjust the volume or change channels? Unfortunately, PCs do not offer built-in infrared receivers compatible with ordinary transmitters. And so we must make the necessary hard- and software ourselves.

There are several steps involved in getting a PC to react to the pulses of infrared sent out by the transmitter. Hardware is required to receive the pulses and process them into a form suitable for input to a microcontroller, where, according to how the user has programmed it, they can be translated into a different format. In principle any of the PC's interface ports can be used, for example the serial RS-232 interface or the parallel Centronics interface. Our receiver, however, is designed to work using the keyboard port. This has many advantages: it keeps the hardware to a minimum (for example, no level shifters are required); power can be drawn from the PC's keyboard connector, removing the need for an external power supply; and the software can be arranged to pass signals through from PC to keyboard and vice versa, so that the receiver can stay permanently in circuit, removing the need to keep changing plugs and sockets.

No software needs to be installed on the computer, making the circuit completely independent of operating system, working equally well under Windows, Linux or DOS. And because Apple computers use the same AT keyboard protocol as PCs, the circuit also works with MacOS.

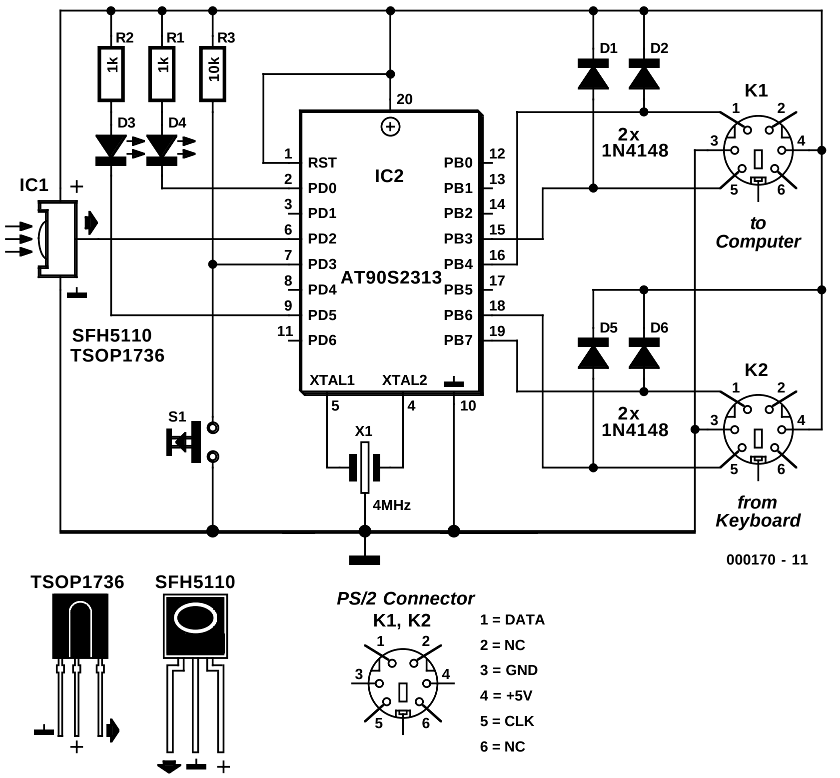


Figure 1. Circuit diagram of the remote control receiver.

Hardware and Software

As can be seen from **Figure 1**, the hardware is rather simple. There are only two ICs, a couple of passive components, and, for the 'user interface', a push-button and two LEDs. The keyboard is plugged into PS2 socket K2, and the PC is connected to PS2 socket K1 using a suitable male-to-male cable.

IC1 is the well-known combined infrared receiver/demodulator type TSOP1736 from Vishay, see url [1] or alternatively the SFH5110, the successor to the SFH506 from Siemens (Electrovalue). When selecting the component the modulation frequency of 36 kHz must be taken into account: this frequency is used in most infrared remote control systems. At the output of the receiver (pin 2) the transmitted signal is available demodulated and amplified, and with noise removed.

The microcontroller, an AT90S2313 from Atmel, receives this signal on port PD2. This device is part of Atmel's AVR family of 8-bit RISC microcontrollers and has already been seen in several *Elektor Electronics* projects. The instruction set, a data sheet and application notes can be found at [2].

For us, the most important characteristic of the AT90S2313 is that the microcontroller offers 128 bytes of EEPROM which can be used to record infrared codes and the corresponding keyboard commands during the programming phase, to be read out again during normal operation.

The complete program, which is around 1 kilobyte long, was written using the Atmel assembler which is freely available from their website at [3]. You can obtain the software in three ways: simplest (although most expensive) is to buy a ready-programmed microcontroller from the Publishers' Readers Services Readers' Services as order code **000170-41**. Alternatively, you can program the microcontroller yourself: the software (source and object code) is available on diskette (order code **000170-11**) or freely downloadable from the *Elektor Electronics* website [4]. There you will also find a PDF file containing the circuit board layout.

The present version of the software is designed only for use with RC5-compatible transmitters; however, the author is working on implementing other remote control protocols. A difficulty here is the number of control bits used (and hence the total number of infrared commands available). Since the address in the EEPROM keystroke table is derived from the infrared command code, the number of command codes may not exceed the number of bytes in the EEPROM (128 in this case). This is however the case for several infrared protocols. One solution would be to add an external I2C EEPROM device.

There is little to be said about building the tiny circuit board shown in **Figure 2**. As long as all the components are fitted correctly (don't forget that the infrared receiver's lens must point outwards!) the circuit should work straight away. It is important to connect the two PS2 connectors correctly or the software will not work (although the green LED will flash).

Beware: fitting the microcontroller or infrared receiver incorrectly may damage your motherboard: before fitting the ICs check the polarity of the supply voltage.

Programming

User programming is very straightforward. In the initial state, when the PC is switched on, the green LED flashes. Press button S1, and

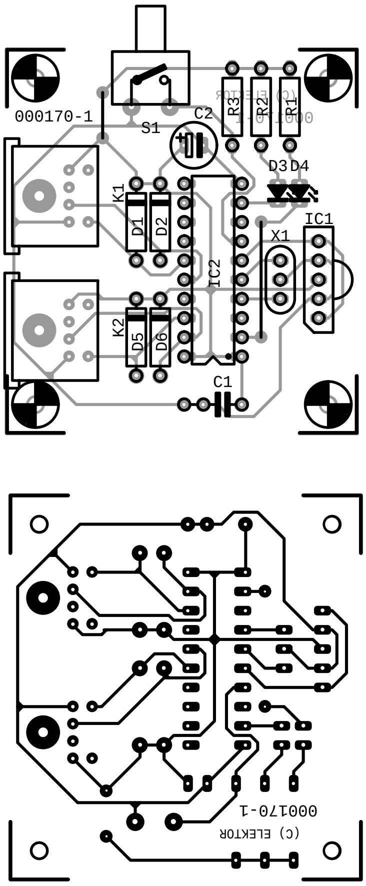
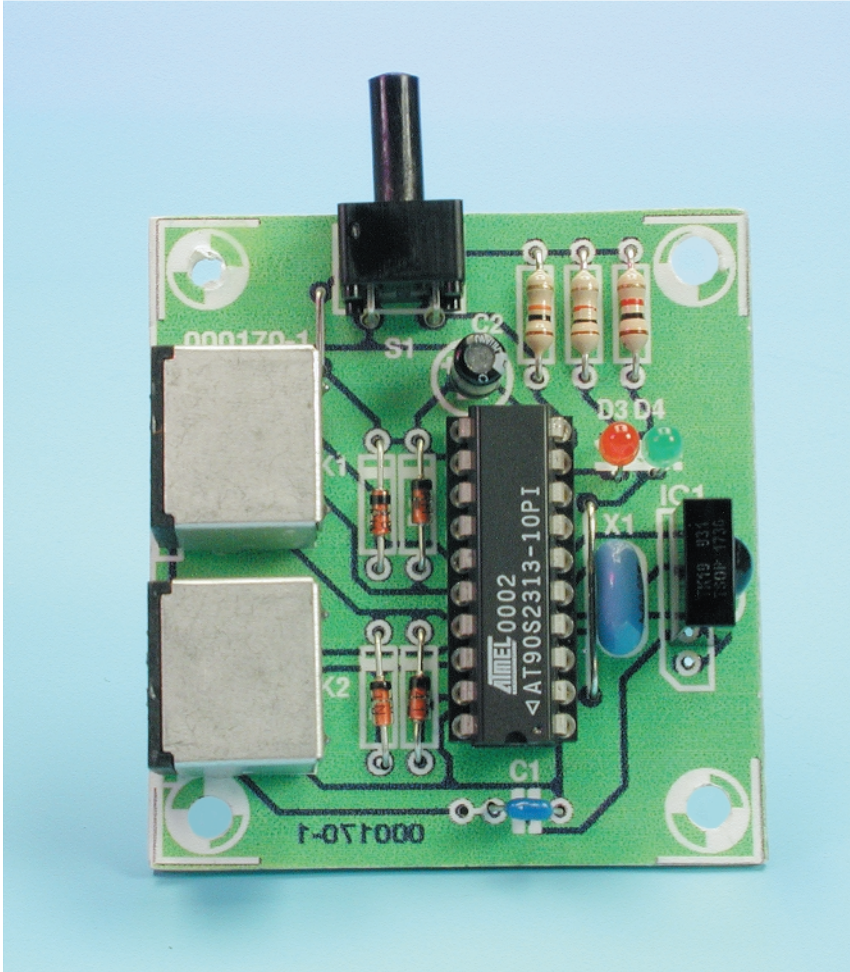


Figure 2. PCB artwork.



COMPONENTS LIST

Resistors:
R1,R2 = 1kΩ
R3 = 10kΩ

Capacitors:
C1 = 100nF
C2 = 10µF 16V radial

Semiconductors:
D1,D2,D5,D6 = 1N4148
D3 = LED, red, high efficiency
D4 = LED, green, high efficiency
IC1 = TSOP1736 (Conrad Electronics #171069) or SFH5110 (C-I Electronics #01.00.5110.36)
IC2 = AT90S2313, programmed, order code **000170-41**

Miscellaneous:
S1 = pushbutton, 1 make contact
K1,K2 = 6-way mini DIN-socket, PCB mount
X1 = Resonator, 4MHz, 3 connections
PCB, order code **000170-1**
Disk, project software, order code **000170-11**

the microcontroller software goes into programming mode, indicated to the user by the green LED being lit steadily. Now press a button on the infrared transmitter, for example PLAY. Reception of the command is confirmed by the red LED. Now press the corresponding key on the keyboard (in Winamp the X key is PLAY) and the red LED changes state again. The command is now programmed, and can be overwritten using the same procedure.

Key combinations such as control-T are entered as usual by holding down the control key while tapping T. Further commands can be entered in the same way until the EEPROM is full, with 64 commands.

Because of the rather limited amount of EEPROM space, only single and double key codes are allowed (control-S is allowed, control-Alt-S is not). This covers most of the normal shortcut combinations. One suggestion would be to call up unsupported shortcuts or longer strings of keys as a macro using a supported shortcut.

When programming is complete, programming mode is exited by pressing the push-button again: the green LED flashes. Now if you press a button on the transmitter, the microcontroller acknowledges with a brief flash on the red LED and sends the appropriate keyboard code to the PC.

(000170-1)

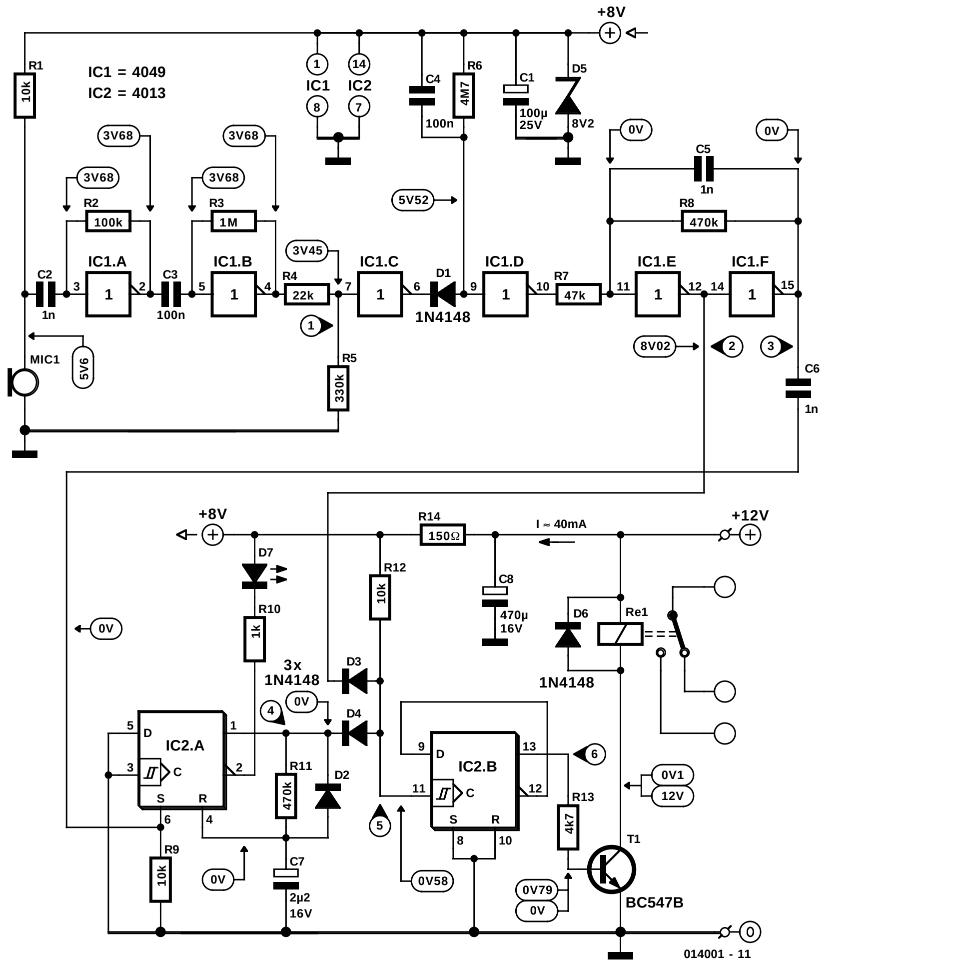
Website urls

[1] www.vishay.com/products/optoelectronics/tsop17x.html
[2] www.atmel.com/atmel/products/prod200.htm
[3] www.atmel.com/atmel/products/prod203.htm
[4] www.elektor-electronics.co.uk

Clap Activated Switch

001

B. Trepak



This circuit has been designed to respond only to two hand claps which occur in (relatively) quick succession, and to ignore one hand clap or even continuous clapping, as well as most other sounds which normally have a lower frequency contents than a hand clap. Even so, the system is not foolproof but is should be adequate for simple domestic applications such as switching lights on and off.

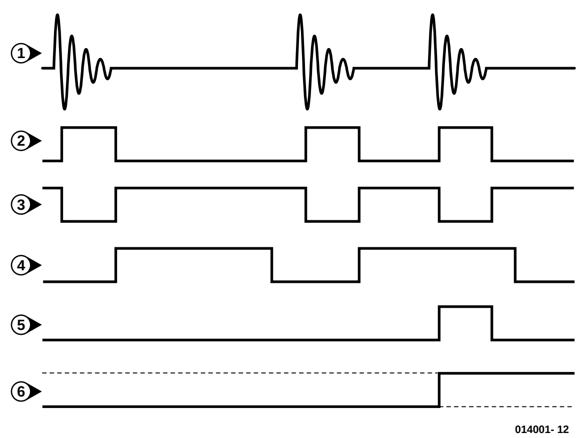
The circuit diagram and the accompanying timing diagram will be discussed briefly to explain the basic operation of the circuit.

The sound picked up by the electret microphone is first amplified to a level suitable for further processing. This is done with two inverters from a 4049 IC, which is normally listed as a 'hex inverter' package. By connecting high value feedback resistors between the input and output of each inverter, and coupling the inverters with a capacitor (C3), a primitive but otherwise perfectly adequate analogue amplifier is created. The value of capacitor C2 at the amplifier input is such that only higher frequency sounds are amplified. The amplifier output signal is 'squared' before being used to charge C4 via D1. The final two inverters from the 4049 package, IC1e and IC1f, are configured to act as a Schmitt trigger. The first inverter of this pair produces a negative pulse each time a sound of sufficient amplitude is picked up by the microphone. The duration of this pulse is determined by that of the sound and the values of C4-R6 which are chosen to ensure that the output will only go high when the sound ceases. The final inverter produces a corresponding positive pulse.

The rising edge of the Schmitt trigger output signal is differentiated by C6-R9 producing a positive going pulse when the sound ceases. This triggers monostable IC2a built around one half of a 4013 dual D flip-flop. If a second pulse appears on D3 after the first one has ceased, while the output of the monostable is still high, the clock input of toggle flip-flop IC2b will go high causing the Q output to go high and T1 to be turned on. Consequently relay Re1 is energized and the load is switched on and will remain on until a valid clap command is received (toggle function).

LED D1 is connected to the $\overline{Q}$ output of IC2a and will indicate the time slot available for the two successive claps.

The circuit is best powered from a mains adaptor set to achieve about 12 V DC output voltage when loaded with 40 mA plus the relay coil current.



The microphone is an electret (a.k.a. 'condenser') type with an internal amplifier which is normally supplied without any leads. The pad connected to the microphone encapsulation is usually the negative terminal.

When the relay is used to switch mains-powered loads, electrical safety precautions should be observed, including compliance with the relay contact ratings specified by the manufacturer and a minimum contact distance of 6 mm between all contacts and wires carrying the mains voltage. The coil resistance of the relay should not be lower than about 400 Ω to prevent overloading of T1 and the supply voltage dropping when the relay comes on. Only the make contact of the relay is used.

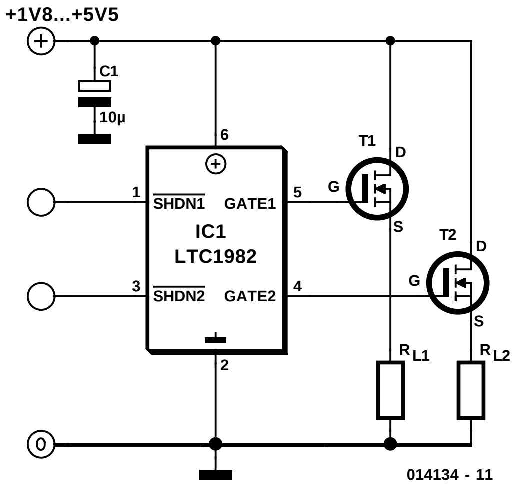
(000167-1)

Dual High Side Switch Controller 002

One of the most frequent uses of n-channel MOSFET's is as a voltage controlled switch. To ensure that the MOSFET delivers the full supply voltage to the load it is necessary for the gate voltage to be a few volts above the supply voltage level. This can be a problem if no other suitable higher voltage sources are available for use elsewhere in the circuit.

The LTC 1982 dual high-side switch controller from Linear Technology (www.linear-tech.com) solves this problem by incorporating a voltage tripler circuit in the gate driver stage. The gate voltage is limited to +7.5 V which is 2.0 V above the IC's maximum operating voltage. It can directly drive the gate of logic-level MOSFET with a V_{GS}(th) from 1.0 V to 2.0 V. A suitable n-channel logic level MOSFET would be the BSP 295. This device can switch up to 1.5 A and is available in an SOT 233 SMD package.

(014134-1)



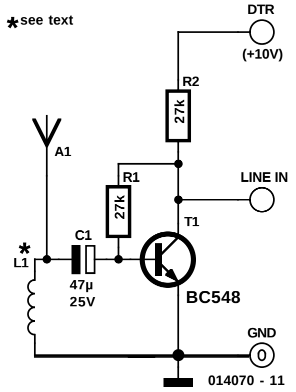
Very Wideband PC Radio

003

B. Kainka

PC radios are certainly nothing unusual. However, unless you are prepared to spend a lot of cash you can't buy a wideband PC radio that receives short-wave signals — if you want one that will not break the bank, you will have to build it yourself. There's no need for a battery or power supply, since power can be drawn directly from the PC serial interface. The audio signal is fed into the PC sound card. The circuit diagram in **Figure 1** shows this simple audion receiver. The transistor in the common-emitter circuit demodulates AM signals, thanks to its exponential characteristic curve. Since the base–emitter junction is already biased, RF potentials of a few millivolts are sufficient to achieve demodulation. For this reason, the audion circuit is significantly more sensitive than a simple diode detector.

1

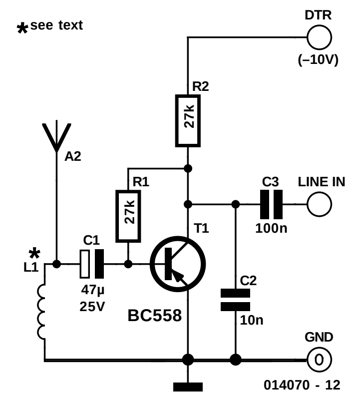


So where is the tuning capacitor? It's not needed, since the receiver has an extremely wide bandwidth and (simultaneously!) receives all strong signals ranging from the 49-m band to the 19-m band. The coil is wound in two layers with 15 turns on a pencil. This yields an inductance of around 2 µH. The resonant circuit capacitance of around 100 pF is composed of the base capacitance of the transistor and the aerial capacitance. This places the resonant frequency at around 11 MHz. The low input impedance of the transistor damps the resonant circuit to the point that its Q factor is 1, so the bandwidth is also around 11 MHz. The receiver thus picks up everything between 6 MHz and 17 MHz. This complete elimination of the usual selection leads to surprising results.

Less is more. For communications technicians, this means: less selectivity = more bandwidth = more information. Indeed, here you dive into a sea of waves and tones. The special propagation conditions for short-wave signals cause first one signal and then another signal to predominate. You hear messages in several languages at the same time, music ranging from classical to pop and folk songs from distant countries. Without the bother of the usual dial spinning, you can roam at your leisure through the entire short-wave region.

The supply voltage for the radio must be first switched on by using a program (HyperTerminal is adequate) to switch the DTR lead of the serial interface from –10 V to +10 V. If you want to avoid this trouble, you can use a PNP transistor. The alternative circuit diagram shown in **Figure 2** shows

2



some additional improvements. The coupling capacitor prevents the dc component from reaching the input of the sound card, and residual HF components are shorted out by the parallel capacitor. With these modifications, the radio is also quite suitable for direct connection to a stereo system, final amplifier or active speaker. In such cases, you can do without the PC and use a battery (1.5 to 12 V) instead.

A downpipe from the eavestrough can be used as an aerial if it is insulated at its lower end (where it connects to the sewer system) by a rubber ring or concrete. If you are not so fortunate as to have access to such an arrangement, you will have to rig a wire aerial (at least 5 m long).

(014070-1)

Li-Ion Protection Circuit

004

Linear Technology application

When a lithium-ion battery is discharged below the minimum recommended cell voltage its life expectancy is dramatically reduced. The circuit described here can avoid this by disconnecting the load from the battery when the cell voltage reaches a set level.

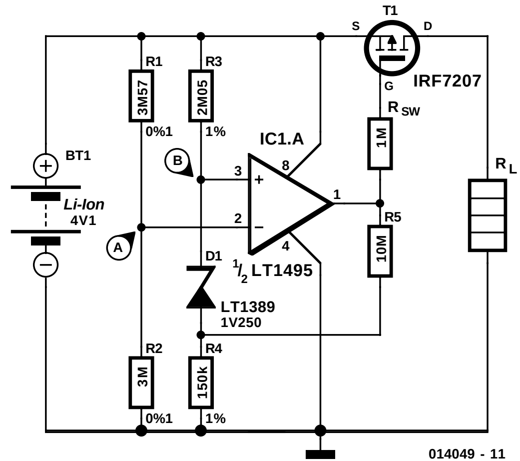
The voltage at junction A may be set to 3 V, for example, by selecting the correct ratio of R1 and R2. When the battery voltage drops below the minimum value, the voltage at junction A will be smaller than that at junction B. The latter voltage is equal to:

$$V_B = 1.25\ \text{V} + I\,R4 = 1.37\ \text{V}$$

where:

$$I = (V_{min.} - 1.25\ \text{V}) / (R3 + R4) = 800\ \text{nA}$$

($V_{min.}$ = minimum value)



At this point the output of opamp LT1495 will go high, causing SW1 (a P-channel logic level MOSFET) to block and break the connection between the battery and the load.

Because the battery voltage will rise when the load is disconnected, a certain amount of hysteresis is created by the addition of R5. This prevents the circuit from oscillating around the switching point. The value of R5 shown here provides 92 mV of hysteresis. So the battery voltage has to rise to 3.092 V before the load is reconnected to the battery. An increase or decrease of the hysteresis is possible by reducing or increasing the value of R5, respectively. The required hysteresis depends in the internal impedance of the battery and the magnitude of the load current.

The switching point defined by the values of R1-R2 is quite critical with a circuit such as this. If the switching point is too high, then the available capacity of the battery is not fully utilised. Conversely, if the switching point is too low, the battery will be discharged too far with all the harmful consequences that may entail. Using the values shown here and including the tolerances of the parts, the switching point is between 2.988 V and 3.012 V. In practice it may be easier to select slightly lower values for R1 or R2 and connect a multi-turn trimpot in series with it. This makes an accurate adjustment of the switching point possible and has the additional advantage that R1 and R2 may be ordinary 1%-tolerance types.

Finally, before using the protection circuit it is advisable to first connect it to a power supply instead of a battery and carefully verify the operation of all its features!

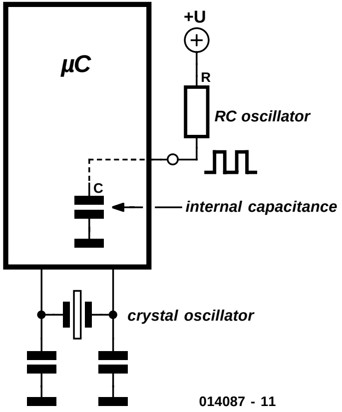
(014049-1)

Low-Cost Temperature Measurement with a Microcontroller

005

It frequently happens that you have an application in which you want to measure the temperature of a circuit or the outside world. This can be easily achieved using additional components in the form of ICs, or by using a RC network and a software routine. However, if all the I/O port pins are already in use, it's hard to know what to do. A circuit trick can provide a solution to this dilemma.

As a rule, modern microcontrollers have RC oscillators with (relatively large) temperature coefficients. Since instructions are processed at the speed of the RC clock, the execution time of a software loop varies with the chip temperature. If your program includes a loop that increments a counter, you will obtain a count that is different for each different chip temperature, and a specific temperature can be assigned to each counter value. Of course, it is necessary to have a highly stable time reference, which may be provided by the 50-Hz mains frequency (for example) or a second (crystal) oscillator network connected to the microcontroller. Such a second oscillator circuit is used with low-power microcontrollers to operate them at very low clock rates, such as 32 kHz, in order to save power. The RC oscillator is then only put into play as needed to meet the demands placed on the software.



(014087-1)

BITBUS Monitor

006

A. Grace

Intel's BITBUS is an extensive protocol for the low cost networking of distributed control systems. Primarily intended for use in factory automation, BITBUS networks use one master and up to 250 slaves. The full specification may be found in Document no. 280645-001 © Intel Corporation.

The BITBUS specification has a pre-defined connector designation based on the standard 9 way 'D' connector. The pin-out is summarized in the **Table**.

The **circuit diagram** shows the design of a simple differential BITBUS transmission detector. The original design was used to monitor the presence of BITBUS data between two pieces of control equipment.

The BITBUS specification allows for two types of transmission, synchronous and self-clocked.

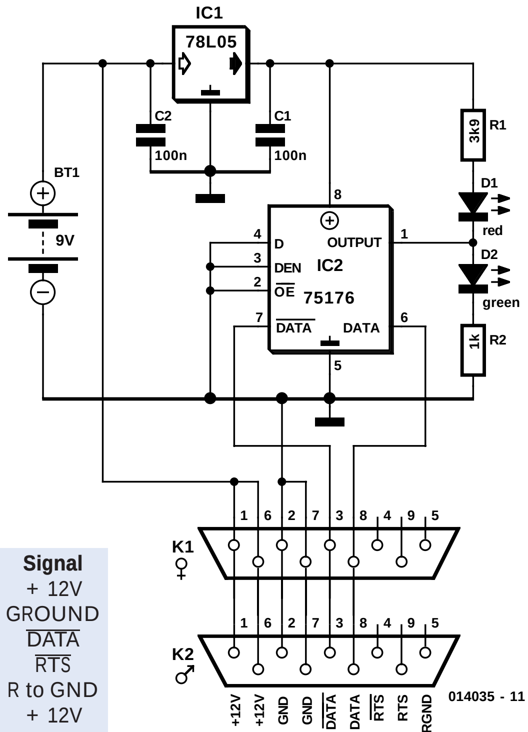
Synchronous transmission is used for high speed (0.5 to 2 Mbits/sec) data links over a short distance (30 metres). The data is transmitted using data and $\overline{\text{DATA}}$, and clocked by using RTS and $\overline{\text{RTS}}$.

Self-clocked mode permits data to be transmitted, all be it much slower, over greater distances — 375 Kbits/sec over 300 metres or 62.5 Kbits/sec over 1200 metres. Self-clocked mode combines serial data and the clock onto a single signal data and /data wire pair.

BITBUS data is detected using IC2, a 74176 RS485 transceiver. In this instance it is used in the receiver mode only. The DATA and $\overline{\text{DATA}}$ signal lines are wired to pins 8 and 3 of the connectors respectively. The receiver output, on pin 1, toggles when there is data present on the BITBUS network. This is represented by the two LEDs flashing on and off. The red LED represents a High, the green LED, a Low.

If the network utilises the full capability of the BITBUS system, the BITBUS Monitor can be powered from the +12 V supply line, which is a available on pin 1 and pin 6 of the BITBUS connector. The +12 V is stepped down via IC1, a +5 V low-current regulator. Use of the BITBUS Monitor could not be simpler. Plug the Monitor into the network and the LEDs will flash if there is data present. If there is no data on the network only one LED will light.

(014035-1)

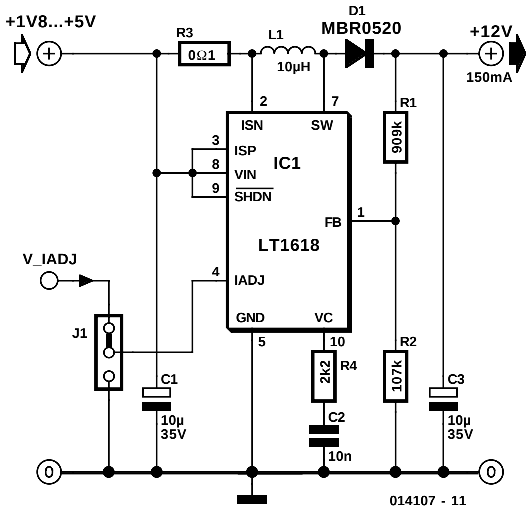


Pin no.	Signal
1	+ 12V
2	GROUND
3	$\overline{\text{DATA}}$
4	$\overline{\text{RTS}}$
5	R to GND
6	+ 12V
7	GROUND
8	DATA
9	RTS

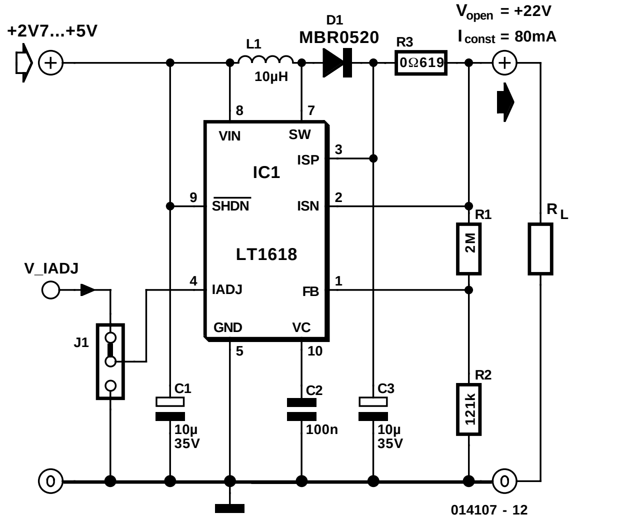
Step-up Switching Regulator with Integrated Current Limit

007

1



2



In the form of the LT1618, Linear Technology (www.linear-tech.com) has made available a step-up switching regulator with a current limit mechanism. This makes it easy to protect an otherwise not short-circuit-proof switching regulator: the input voltage is always connected to the output via an inductor and a diode. We can limit the current at the input (**Figure 1**), which limits the current drawn by the entire circuit; alternatively, with the circuit of **Figure 2**, the output current can be limited. This enables the design of constant current sources at voltages higher than the input voltage. In the circuit shown the nominal output voltage of the step-up switching regulator will be around 22 V.

The output voltage can be calculated using the formula

$$V_{out} = 1.263\ V\ (1 + R1/R2)$$

The output current can be set via R3 as follows:

$$I_{max} = V_{sense} / R3$$

where $V_{sense} = 50\ mV$

The I_{ADJ} input can be set to a voltage between 0 V and +1.58 V resulting in a linear reduction of the limit current. The sense voltage of 50 mV across R3 for maximum current is reduced as follows:

$$V_{sense} = 0.04\ (1.263\ V - 0.8\ V_{IADJ})$$

Hence, for a fixed value of R3, the V_{IADJ} input allows the current limit to be adjusted.

Note that in the first circuit the sense resistor R3 is fitted between the input electrolytic capacitor and the inductor. If R3 is fitted before the capacitor, the inductor current cannot be properly controlled.

The LT1618 operates on input voltages between +1.6 V and +18 V. Its output voltage must lie between V_{in} and +35 V. With a switching current of 1 A through pin SW to ground, an output current of around 100 mA can be expected. The switching frequency of the IC is about 1.4 MHz, and the device is available in a 10-pin compact MSOP package.

(014107-1)

Ammeter

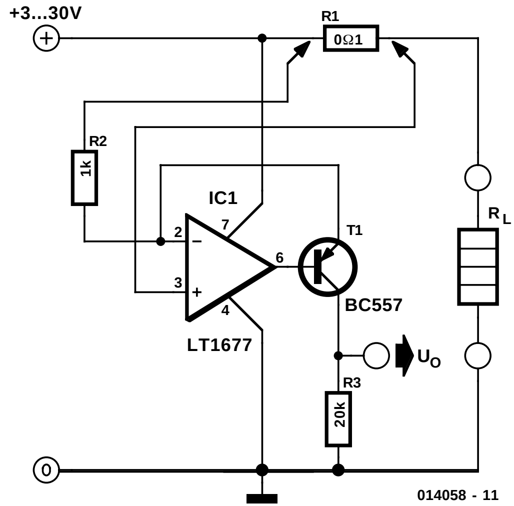
008

Linear Technology application — www.linear-tech.com

From the feedback from our readers we have learned that the measurement of currents in the positive lead of a power supply is often fraught with practical difficulties. The circuit shown here will in many cases be a welcome aid. The design is not really new, but it is very useful.

The required shunt or current measuring resistor R1 is connected in series with the load. The voltage drop across this resistor is proportional to the current through the load. As usual, the opamp will strive to minimise the potential difference between its inverting- and non-inverting inputs. As a consequence, a compensating current will flow from the emitter of T1 to the inverting input of IC1 with the value U_{R1}/R2. The same current flows through R3 as well, of course, resulting in a voltage of U_{R1}·R3/R2; at the values shown this is 2 V per ampère. This voltage can be displayed with a moving coil instrument or other appropriate indicator.

An important remark: as can be seen, the inverting input of the opamp is effectively connected to the power supply. This requires an opamp with an input common-mode range that includes at least the positive supply rail. Also, the output has to be able to swing (close) to the power supply voltage, otherwise T1 will not turn off sufficiently. This requires a very good 'rail-to-rail' opamp. The LT1677 that is used here is cut out for this purpose and has, among other things, the following characteristics:

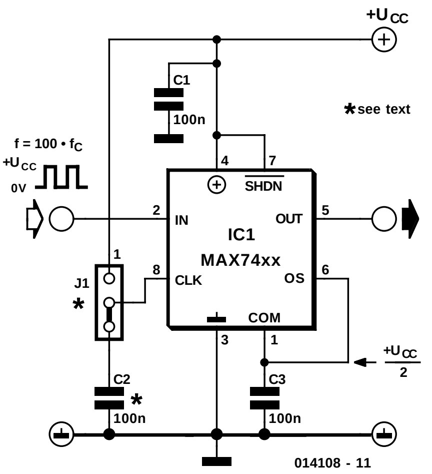


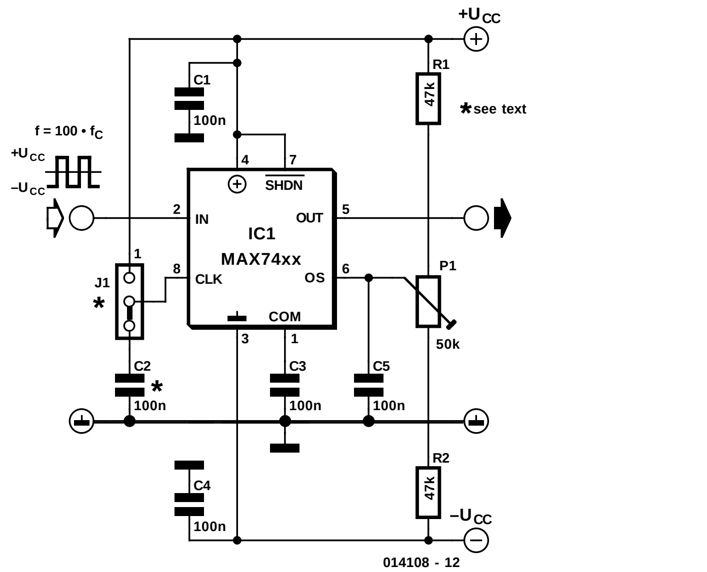
– rail-to-rail input and output;
– extremely low noise (3.2 nV/√Hz at 1 kHz);
– gain/bandwidth 7.2 MHz;
– offset 60 µV;
– power supply range 3 to 30 V.

These particular characteristics make the LT1677 eminently suitable for the processing of small signals.

(014058-1)

Switched-Capacitor Fifth-Order 1 Hz to 45 kHz Low-Pass Filter 009





Low-pass LC-filters in the audio frequency range require huge ferrite-cored inductors. Active filters are also tricky to construct because of the tight tolerance required of the resistors and capacitors. Switched capacitor (SC) technology, however, allows small audio frequency low-pass filters with adjustable corner frequency to be constructed simply. The switching clock frequency used is 100 times higher than the desired corner frequency, so that any residual switching-frequency component at the output can be removed easily using an RC or LC low-pass combination.

Maxim (www.maxim-ic.com) has recently released eight new SC filter ICs with a current consumption of only 3 mA. Four different filter characteristics are available, and there are both 3 V and 5 V versions of the devices. The corner frequency can be continuously adjusted from 1 Hz to 45 kHz by suitable choice of clock frequency. **Table 1** gives an overview of the components and their chief characteristics.

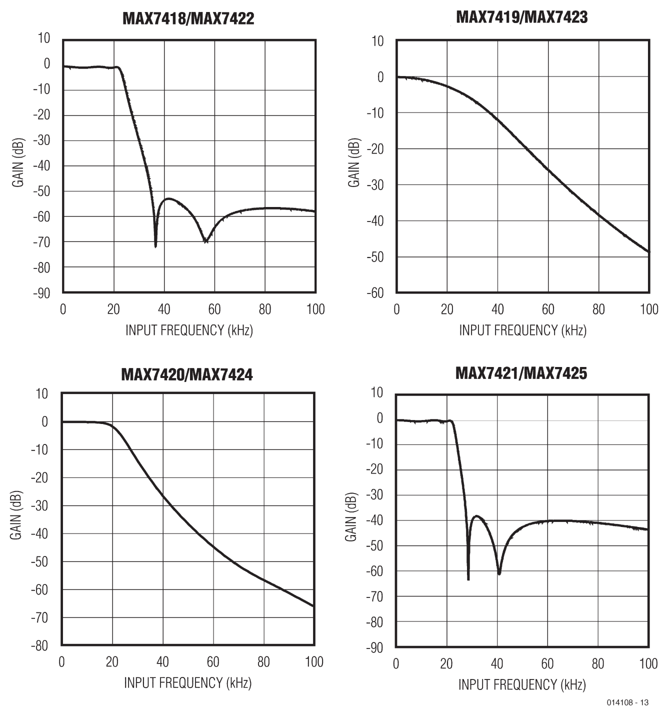
Figure 1 shows the frequency responses obtained with a clock frequency of 2.2 MHz, nominally giving a 22 kHz low-pass filter.

A second interesting possibility is stand-alone use without an external clock. A capacitor is connected to the CLK pin, which sets the frequency of a built-in oscillator circuit. This option is only suitable where the exact corner frequency is not important, since otherwise the capacitor must be adjusted to tune the corner frequency. The frequency of the internal oscillator also suffers from a slight drift with temperature.

The MAX74xx circuit can be powered either from a single 3 V or 5 V supply (according to the device) or from a symmetrical ±1.5 V (respectively ±2.5 V) supply. When using an external clock, note that a square wave with a duty cycle of 50 % ± 10 % is required, with a frequency 100 times the desired filter corner frequency and an amplitude appropriate for the supply voltage (see **Figure 2**).

The output DC offset can be calculated as follows:

Vout = (Vin – Vcom) + Vos



where Vcom is half the supply voltage (or 0 V when using a symmetrical supply). Vos is the offset compensation voltage, if any, fed into the OS pin. If the offset voltage need not be set, OS can be connected directly to COM. The formula thus tells us that if a single supply is used, a DC component equal to half the supply voltage is required. A reasonably low-impedance drive is required for the device, whereas the output should be connected to an impedance of at least 10 kΩ.

In stand-alone mode with a capacitor C connected to the CLK pin, the filter corner frequency depends on the capacitance as follows:

$$f_c = 0.01\, f_{osc} = 0.01\, k\Omega / C$$

Here C is in pF and f is in kHz. The appropriate value of k is given in **Table 2**.

(014108-1)

Table 1.

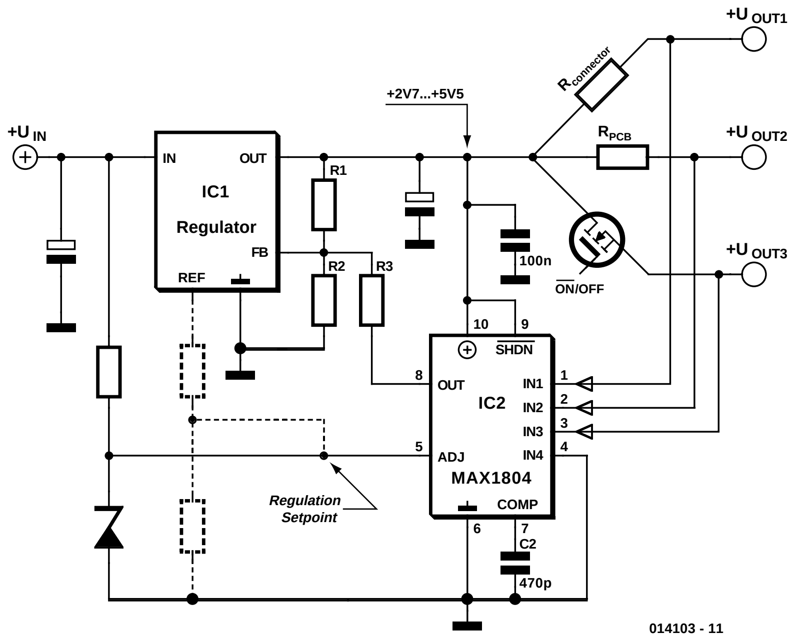
+3 V supply	+5 V supply	Filter frequency response	Characteristics
MAX 7422	MAX 7418	Elliptic filter, r = 1,6	53 dB stopband rejection
MAX 7423	MAX 7419	Bessel filter	linear phase
MAX 7424	MAX 7420	Butterworth filter	maximally flat passband
MAX 7425	MAX 7421	Elliptic filter, r = 1,25	37 dB stopband rejection

r = corner frequency / stopband lower frequency, i.e. steepness of cutoff in transition band

Table 2.

+3 V supply	+5 V supply	k
MAX 7422	MAX 7418	$k = 87 * 10^3$
MAX 7425	MAX 7421	$k = 87 * 10^3$
MAX 7423	MAX 7419	$k = 110 * 10^3$
MAX 7424	MAX 7420	$k = 110 * 10^3$

Voltage Regulator Assistant 010



Everyone will be familiar with the problem of voltage drop across wires, connectors or filtering components such as inductors, which force the voltage at the regulator output to be set higher than the circuit operating voltage. If the current drawn falls then the operating voltage rises above its nominal value; when the current rises, the voltage falls.

Assistance here comes in the form of the four-input MAX1804 *Feedback Integrator*, a novel product from Maxim (www.maxim-ic.com). The device can be connected to your favourite voltage regulator and will intervene in its feedback loop if any of its four inputs is fed with too low a voltage. The MAX1804 manages the fine control of the regulator output voltage by increasing it until the lowest voltage of those sensed is made correct. Unused inputs to the MAX1804 are automatically disabled if the voltage present is below 90 % of the nominal value. The MAX1804 will therefore not intervene in the feedback loop if the voltage drop is too great. The device is designed for supply voltages between +2.7 V and +5.5 V. It is supplied directly from the output of the controlled regulator.

The OUT connection of the MAX1804 is connected to the feedback pin of the regulator via R3, which has a rather higher value than R1 or R2. The OUT pin draws as much current as necessary to ground to force the regulator to raise its output voltage to bring the lowest of the MAX1804 inputs to four times the voltage on the ADJ pin. The voltage on ADJ can be provided by a reference voltage generated by the regulator, or, if this is not available, by an external voltage reference or Zener diode. The available control range can be set via R3: in the limit, R3 is effectively in parallel with R2.

The COMP pin is used for compensating the regulation loop. The manufacturer recommends a compensation capacitor of 470 pF.

The shutdown pin ($\overline{SHDN}$) forces all four inputs and the output into a high-impedance state, so that the MAX1804 can no longer affect the regulator.

(014103-1)

Random Flashing LED

011

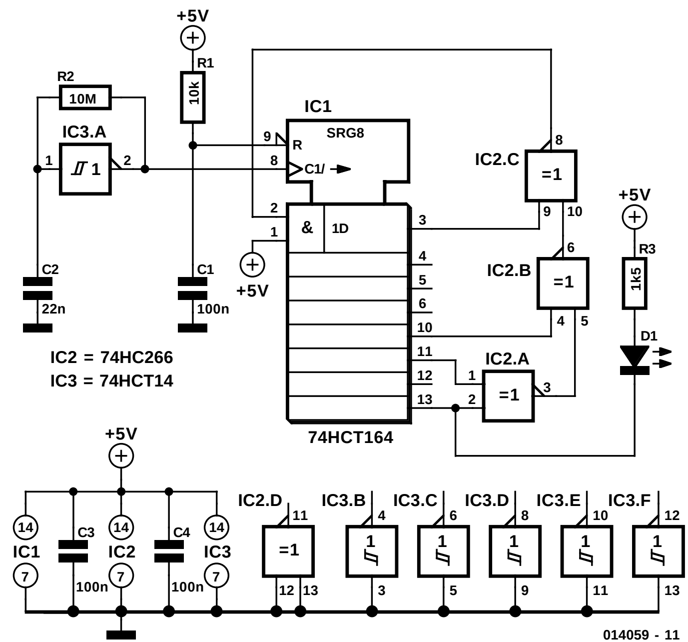
In recent years, the chapter ‘flashing lights’ in its many incarnations, has already received plenty of attention in *Elektor Electronics*. Therefore, a newly presented flasher circuit has to have at least one special characteristic in order to be considered for publication.

The version described here is therefore definitely not an ‘ordinary’ flasher. Unlike most other circuits, the on/off rhythm of this circuit is not regular, but random. The circuit will undoubtedly find applications in various games, while it may also be very appropriate as a ‘pseudo-alarm-indicator’ to deter potential burglars.

Obviously, a random flasher will require a little more circuitry than a standard version. As is shown in the schematic, Schmitt-trigger IC3a is used to build a conventional oscillator, which runs at a relatively low frequency. This signal is used to clock a shift register IC. By feeding back the various outputs of the shift register through three inverting XOR gates (IC2a/b/c), the level changes at the output QH of the shift register will exhibit a quasi-random characteristic. This voltage is applied to a high-efficiency LED (D1), which completes the flasher.

The circuit has been designed for a power supply voltage of 5 V. The current consumption is about 8 mA when the LED is on.

(014059-1)



Fan Control IC with Over-temperature Output

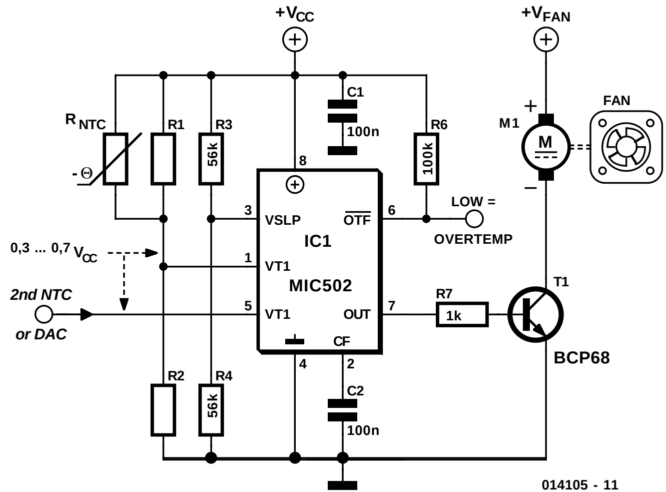
012

A simple proportional fan controller can be built using the MIC502 from Micrel (www.micrel.com). With this IC the speed of the fan runs slowly at low temperatures, reducing noise and wear. Any fan can be controlled using the pulse width modulated output signal via a driver transistor. Using PWM control has the advantage that the fan can be run much slower than using variable DC control. Up to two NTC thermistors can be connected. The second control voltage can alternatively be derived from a DAC output from a processor system, for example. The MIC502 operates from a supply between 4.5 V and 13.2 V (V_{CC}). Since drive is via a transistor, the actual fan voltage can be higher than the supply voltage: you can drive a 12 V fan from a 5 V controller.

Control is independent of supply voltage, since the device only uses the ratio of the voltages at inputs VT1 and VT2 (so-called ‘ratiometric’ operation). A voltage of 0.3 V_{CC} gives rise to an output duty cycle of 0 %, stopping the fan.

0.7 V_{cc} at input VT1 and/or VT2 produces an output duty cycle of 100 %, making the fan run at full speed. Whichever of the two inputs VT1 and VT2 has the higher voltage (corresponding to the higher temperature) takes priority.

The VSLP input can be used to set the voltage below which the fan is switched off (*sleep mode)*: both inputs VT1 and VT2 must be below this voltage. The fan starts again if either input VT1 or VT2 rises above VSLP + 0.12 V_{cc}. If sleep mode is not required, the VSLP input should be tied to ground. A capacitor is connected to the CF pin to set the basic frequency of the PWM signal: a value of 100 nF is recommended, giving a frequency of about 30 Hz. At power up or at exit from sleep mode an integrated start-up timer causes the fan motor to receive full voltage for a time 64/f (around 2 s at 30 Hz), ensuring a reliable start.

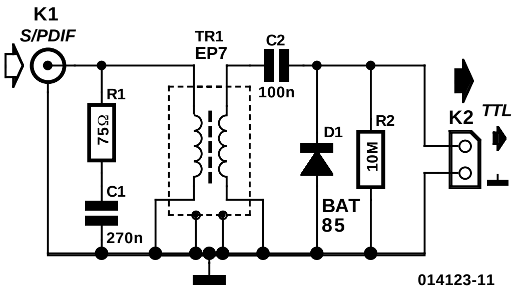


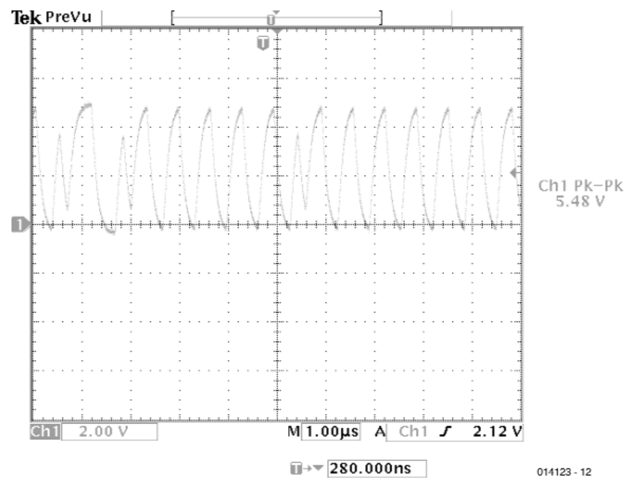
Finally an open-collector over-temperature output $\overline{OTF}$ ('over-temperature failure') is provided that can be pulled up to the desired logic level with an external resistor. $\overline{OTF}$ switches low when one of the two inputs VT1 or VT2 rises above 0.75 V_{cc}.

(014105-1)

S/PDIF-to-TTL-Converter

013





The idea for this circuit came from the question whether there was a simple method for connecting a digital audio output to the TTL input of, for example, a sound card. A typical S/PDIF signal has a level of 0.5 V_{pp} at 75 Ω. This level is of course much too low to drive an input that works at TTL levels. The simplest way to obtain the correct voltage is to use a small transformer to step up the voltage. The input impedance of the circuit should be 75 Ω in order to keep distortion of the signal as low as possible.

The transformer we've used has an EP7 core with an accompanying former, since it is very small; the outer dimension are only 10.7 mm by 8.5 mm. A core material of T38 was chosen (available from Farnell), which gives the transformer an A_L of 5200 nH. Since the windings (copper is diamagnetic) form a large part of the transformer, we find that in practise the A_L-value is a lot lower (30 to 40 % less).

The primary winding consists of 15 turns of 0.2 mm diameter enamelled copper wire. This is wound in one layer from a pin at the corner to a pin at the other corner. The secondary winding consists of 150 turns of 0.1 mm diameter enamelled copper wire and is wound similarly between two corner pins. Be very careful with the coil former whilst joining the halves of the core with the metal clip: it is very easily broken. The clip also shields the transformer. The coil former can be fixed in place during the winding using a 3.5 mm drill-bit and a piece of paper.

In order to keep the input impedance linear and constant within an as wide as possible bandwidth, the 75 Ω terminating resistor has a 270 nF capacitor connected in series. At the secondary is a clamping circuit (C2 and Schottky diode D1), which gives the correct DC offset to the AC signal. The screenshot of the oscilloscope shows the output signal. This was taken at a sampling frequency of 48 kHz. It is clear that this is the limit at which this circuit can be used, at 96 kHz the logic '1' level will become too small.

A second possible method would be to have a potential divider between 5 V and earth, set to be exactly in the middle of the two logic levels. An AC-coupled S/PDIF signal (1 V_{pp} open circuit) should be large enough to be accepted at the logic input. A third method could be a combination of the previous two. With a winding ratio of 1:5 the quality of the signal (especially the bandwidth) will be much better and could give a better performance when used with the potential divider.

The aim was to keep this circuit completely passive, avoiding the need for an external power supply. This has in fact been achieved, albeit with a limited performance. No doubt a different core material and a larger core should give better results. The converter still has plenty of scope for home experimentation!

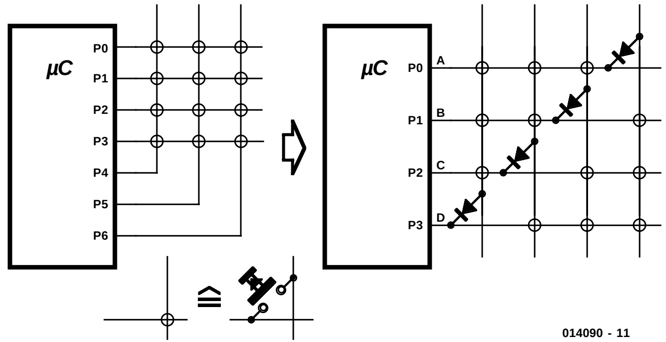
(014123)

Key Scanning with a Small Number of Connections

014

If a large number of keys have to be scanned, the individual keys are not normally connected directly to the microcontroller. Instead, a matrix arrangement is used. This allows the number of port pins to be reduced to seven for twelve keys, for example. The software scans the rows and columns and thus determines which key is pressed. However, sometimes only a small microcontroller with just a few port pins is available, so even this economical matrix method cannot be used.

Using a trick, the same problem can be solved using only four port pins. This requires the use of four extra diodes and the possibility of individually configuring the pins as either inputs or outputs via software. Four column lines (1-4) are arranged in a matrix with the four row lines (A-D) that are connected to the microcontroller, with each row line connected to a column line by a diode (1N4148). The software can recognise a pressed a key by applying a voltage to each row in turn while observing the states of the remaining port pins, which are configured as inputs. Thanks to the diodes, a voltage will be detected on only one of the inputs, depending on which key is pressed, and the software can assign the appropriate action to this event.



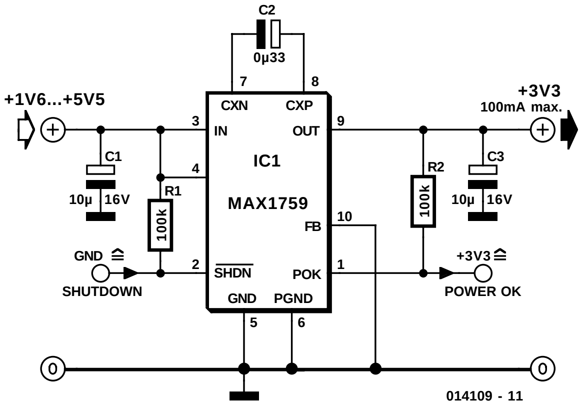
(014090-1)

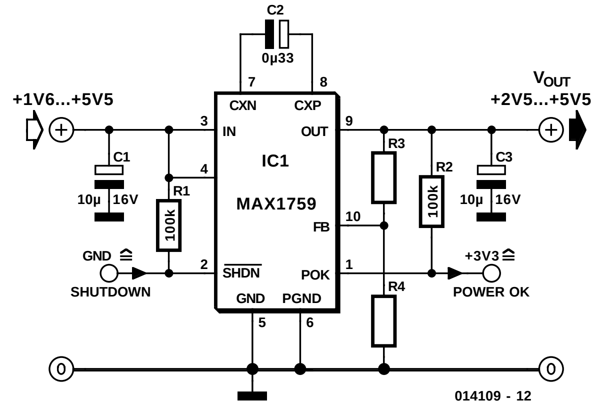
Step-Up/Step-Down Switching Regulator

015

If you wish to convert a range of possible input voltages into an output voltage that lies somewhere in the middle of that range, a regulator that can automatically switch between step-up and step-down modes is required. Such a device is the MAX1759 from Maxim (www.maxim-ic.com), which can take in an input voltage between +1.6 V and +5.5 V and generate an output between +2.5 V and +5.5 V. It is based around a switched capacitor (C2).

A further special feature of the MAX1759 is the automatic detection of the potential divider R3/R4. This allows it to





produce an externally settable output voltage between +2.5 V and +5.5 V, as given by the following formula:

$$V_{OUT} = 1.235\ \text{V}\ (1 + R3/R4)$$

The resistors should be chosen with values of the order of 100 kΩ.

If the feedback input FB is tied to ground, the MAX1759 switches over to an internal voltage reference giving a fixed output voltage of 3.3 V.

The open-drain 'power OK' output POK goes low when the regulator control loop is not stabilised, and is pulled high when the output voltage is stable and at the desired value.

(014109-1)

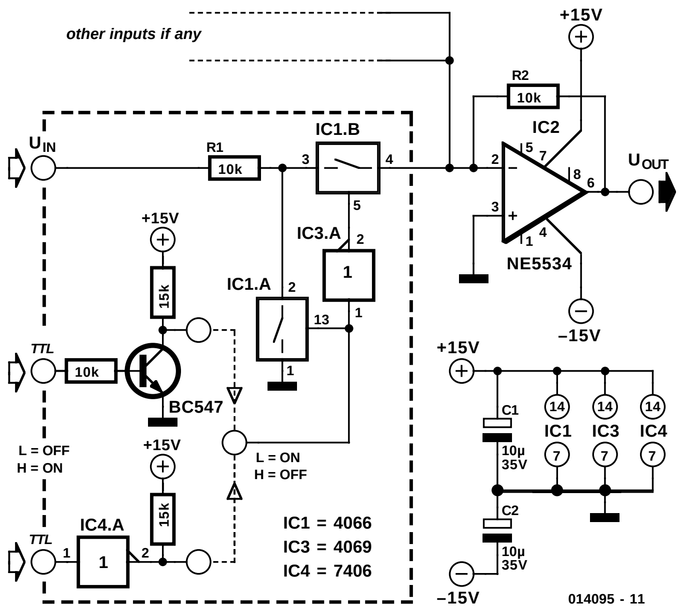
Switching Amplifier for Analogue Signals

016

H. Prince

If analogue signals have to be switched, a bilateral switch such as the 4066 is often utilised. Because this IC can be powered from single-ended supply only, all the associated components are usually connected to the same asymmetrical supply (typically 8 V). The disadvantage of this is that the opamp runs on only half the power supply voltage, with the corresponding reduction in output voltage. The result is, among other things, a reduced signal to noise ratio.

The circuit described here solves this problem. The design is based on the fact that the current in the bilateral switch (IC1) at zero volts can flow in both directions. We will have to take precautions to make sure that the input voltage at the switch is not allowed to become negative. This is taken care of by using one of the switches in IC1 to short the input to ground at the right time.



The operation is as follows: When the switch input is ‘high’, IC1a is closed and IC1b is open so that no signal arrives that the inverting input. IC1a shorts the signal to ground. When the switch input goes ‘low’, IC1a is opened and IC1b is closed and the audio signal is amplified by the opamp.

In order to make the switching levels TTL-compatible, a small buffer stage can be added to each input, consisting of a BC547, for example, or a 7406, as is shown in the schematic. If need be, multiple inputs can be connected to the virtual earth node resulting in a mixing circuit. The circuit inside the box has to be duplicated to achieve this.

The gain is easily calculated using the standard formula: $U_{out} = –(U_{in}·R2)/R1$. The input impedance of each individual input is about 10 kΩ. Take note: the circuit inverts!

It speaks for itself that any spare ports and switches can be used for additional inputs.

(014095-1)

Fairy Lights

017

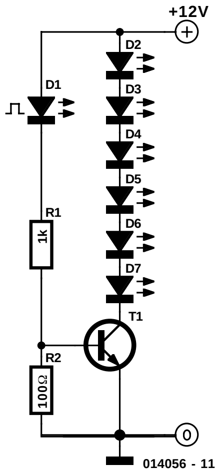
M. Schreiner

This simple and cheap circuit is not just for Christmas! There are just two resistors, a small-signal transistor such as a BC547, one 'flashing' LED and a string of 'normal' LEDs. The flashing LED works as an oscillator and switches the transistor on and off; and the transistor switches all the other LEDs. An (unregulated) 12 V mains supply can be used for power.

No current-limiting resistor is required in the LED chain, because the forward voltages of the LEDs in the chain add up to the supply voltage. If red LEDs are used, with a voltage drop of 1.65 V, then 12 V will supply seven; alternatively, use six yellow (2.1 V each) or five green (2.7 V). You can of course always mix the colours.

Variation:
Alongside the NPN transistor add a PNP transistor with its emitter connected to +12 V, with another string of LEDs connected down to ground. The two strings will flash alternately.

(014056-1)



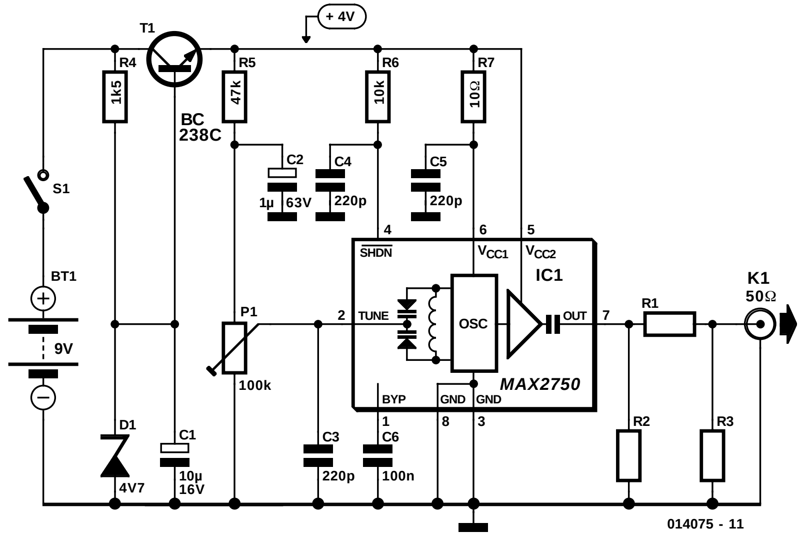
2.5-GHz Signal Source

018

More and more communications systems are operating in the 2.4-GHz ISM (Industrial, Scientific and Medical) band, including Bluetooth, various WLAN (Wireless Local Area Network) and Home-RF systems. A simple test oscillator for the frequency band between 2.4 GHz and 2.5 GHz can prove useful in testing receivers.

Such an oscillator is available from Maxim (www.maxim-ic.com) as a single IC. The MAX2750 covers the frequency range between 2,4 GHz and 2.5 GHz using in internal LC network that can be tuned using a varactor diode that is also built into the IC. An output buffer delivers a level of –3 dBm into 50 Ω. This component is housed in an 8-pin μMAX package.

The circuit is powered from a 9-V battery. The BC238C transistor stabilises the battery voltage at around 4 V. Although the MAX2750 can work with supply voltages



between +2.7 V and +5.5 V, the frequency stability of the free-running oscillator is better with a stabilised supply voltage. All connections to the IC are decoupled using 220pF capacitors, which must be located as close as possible to the IC pins. The tuning voltage at pin 2, TUNE, may lie between +0.4 V and +2.4 V, which provides a tuning range between 2.4 GHz and 2.5 GHz. If it is desired to switch off the oscillator, this can be done by connecting the Shutdown input ($\overline{SHDN}$) to earth potential. When the IC is shut down, its current consumption drops to around 1 µA. Here the shutdown input is connected to the Vcc potential by a pull-up resistor, so that the oscillator runs.

The –3 dB output level can be reduced using the indicated pi attenuator. A number of resistance values for this attenuator are shown in the table.

(014075-1)

Output level	Attenuation	R1	R2, R3
– 3 dBm	0 dB	0 Ω	–
– 5 dBm	2 dB	10 Ω	470 Ω
– 10 dBm	7 dB	47 Ω	130 Ω
– 15 dBm	12 dB	100 Ω	82.5 Ω
– 23 dBm	20 dB	243 Ω	61.9 Ω

Pulse Edge Visualiser

019

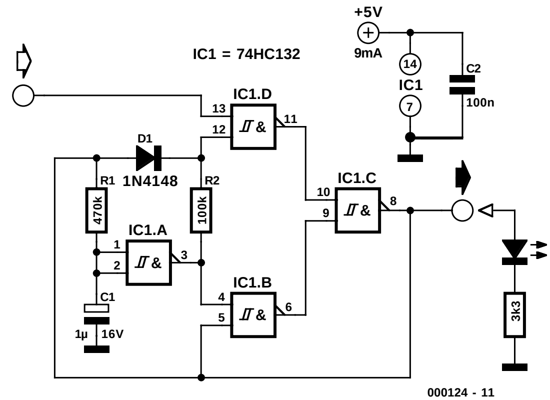
F. Rimatzki

A digital signal must have a certain duration before it can be monitored using an LED. Short pulses cause the LED to flash for an interval that is too short to be registered by our ‘slow’ eyes. The small supplementary circuit described here, which consists of only four two-input NAND gates in the form of a 74HC(T)132, two resistors, a diode and a capacitor, lengthens a short pulse enough that it can be clearly recognised using an LED.

The output level at pin 8 prepares the circuit for the subsequent pulse edge. If a logic ‘1’ is present at the output, C1 will be fully charged and the output of gate 1a will be Low. The output of IC1b and pin 9 of IC1c will thus be High. The High level on pin 8, which is applied to the input of IC1d via D1, ‘overrides’ the Low level on pin 3 that is applied via R2, so a High level is also present at pin 12 of IC1d. The whole arrangement is stable only as long as the input signal is also High.

If on the other hand a Low level is present at the output, the capacitor will be discharged and the output of IC1a will thus be High. This means that pin 9 and pin 12 are also High (D1 is now blocking). This state is also stable, but only as long as the input signal remains Low.

The situation changes as soon as the signal level at the input changes. When a positive or negative pulse edge appears at the input, the level at either pin 9 or pin 12 (respectively) goes Low momentarily while the level at the other pin remains unchanged. As a result, the output level changes in the same direction as the input signal. A new, immediately following level change has no effect, since it can reach the output only if pin 9 and pin 12 are simultaneously High. This is true only after the expiry of a prescribed interval determined by the values of R1 and C1 (in this case, several hundred milliseconds). During this ‘dead time’, a change in the input level has no effect at all on the output!



The circuit is so compact and simple that it can be used for applications such as debouncing pushbutton switches or digital signals. For such purposes, it can simply be inserted in the signal path.

It can also be easily fitted into the housing of a logic tester, and if a high-efficiency LED is used, it can make even short pulses visible.

By the way, the current consumption of the circuit (around 9 mA average) is least when the input level is Low, since in this case only the gate input current and diode leakage current flow through R2. In the opposite case, a much higher current flows via pin 8, D1 and R2 to pin 3. This behaviour can easily be reversed by simply swapping D1 and R2.

Even more power savings can be realised by replacing D1 and R2 with a true OR gate. With this modification, the circuit can be left permanently connected to a power source and no on/off switch is necessary.

The pulse edge visualiser should be powered from the circuit being tested, if only because of the values of the logic levels. Pay attention to the switching speed (HC or HCT) and the thresholds of the ICs used.

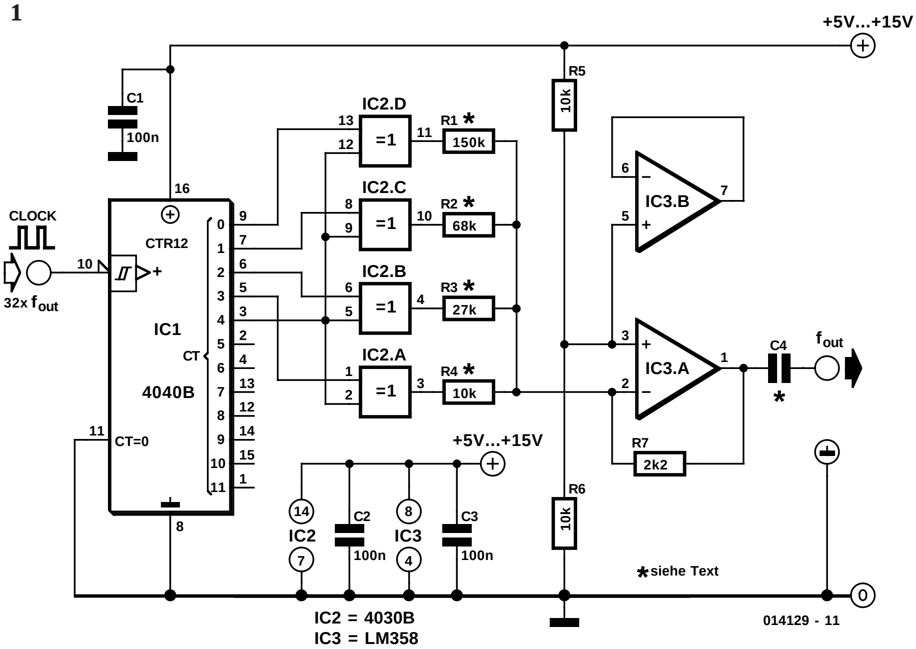
(000124-1)

Wideband Waveform Generator 020

This circuit is designed to provide a wideband digital sine wave signal source. Its main feature is that because it synthesises the signal in 32 steps, no low-pass filter is required to suppress the odd harmonics.

A well-known method for synthesising a sine wave under control of an input frequency is to apply a low-pass filter to a square wave of the same frequency. Along with the fundamental, this includes odd harmonics. After filtering out these parts of the signal we are left with a clean sine wave at the desired frequency. Unfortunately, the corner frequency of the low-pass filter limits the usable range of frequencies.

1



The solution presented here in **Figure 1** avoids low-pass filtering by using more voltage levels than just 'high' and 'low'. Here there are 16 voltage levels which follow one after the other in a series of 32 samples. Outputs Q0-Q3 of counter IC1 control the voltage steps. Q4 inverts the polarity of the output in the second half of the period. This does not completely remove the odd harmonics — the signal still has steps in it — but they are severely attenuated.

Resistors R1-R4 together provide operational amplifier IC3 with 16 voltage levels. R5 and R6 hold the non-inverting input of IC3 (pin 3) at half the supply voltage. The operational amplifier therefore operates as an inverting amplifier with R7 as the feedback resistor. To obtain as symmetrical a signal as possible, a potentiometer is recommended for fine adjustment of this path.

This fine adjustment was be made before measuring the distortion: a THD+N figure of less than 10 % (over a bandwidth of 22 kHz) and less than 13 % (over a bandwidth of 500 kHz) was obtained with an input frequency of 32 kHz and an output frequency, therefore, of 1 kHz. The measured output signal is shown in **Figure 2**.

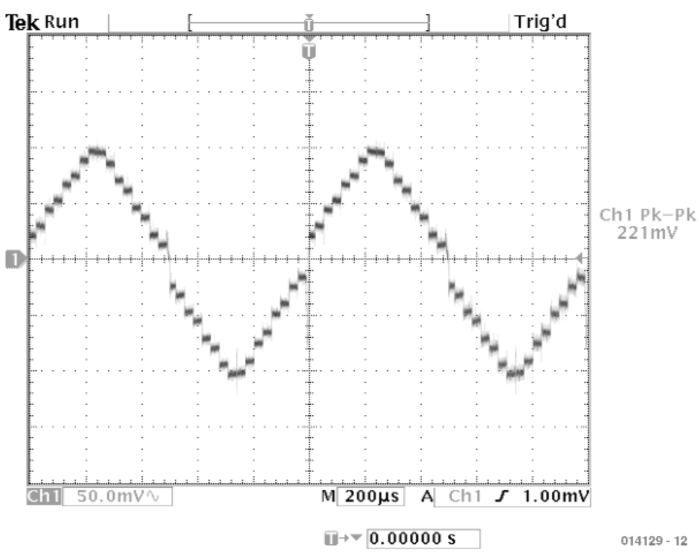
The shape of the output waveform (in this case a sine wave) is determined by the ratios between resistors R1 to R4. This allows plenty of scope for experiment! The clock frequency at the input to the counter should always be 32 times the desired output frequency.

The output of the operational amplifier has a DC offset of half the supply voltage. If this causes a problem in the circuit being driven, a coupling capacitor C4 must be fitted: the lower the operating frequency and the lower the load impedance, the greater the required value of capacitor.

The circuit operates from a supply of between +5 V and +15 V, and this determines the amplitude required of the input clock signal to drive counter IC1. The amplitude of the output signal can be set with resistor R7 and is independent of the output waveform. The current consumption of the waveform generator is about 3 mA.

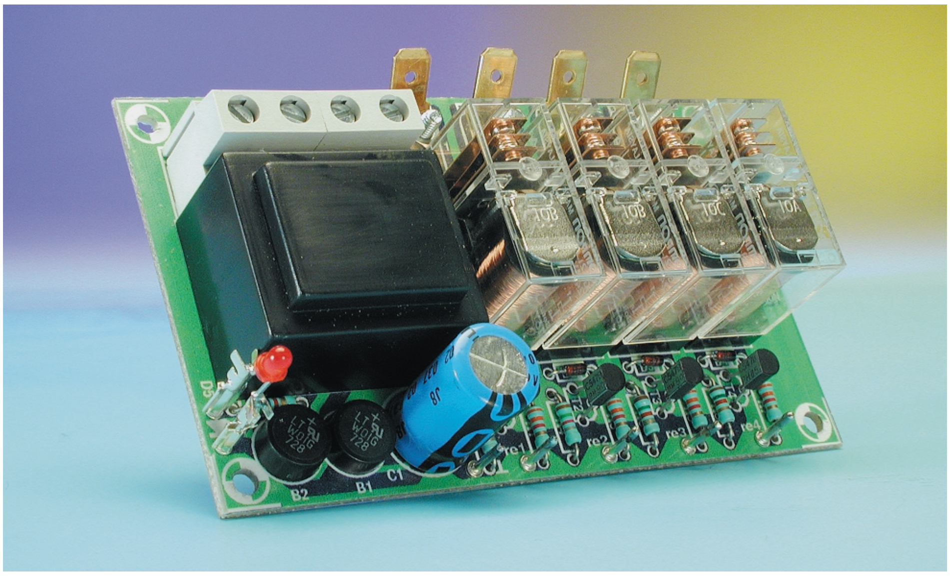
(014129-1)

2



Switchbox for Loudspeakers/Amplifiers

021



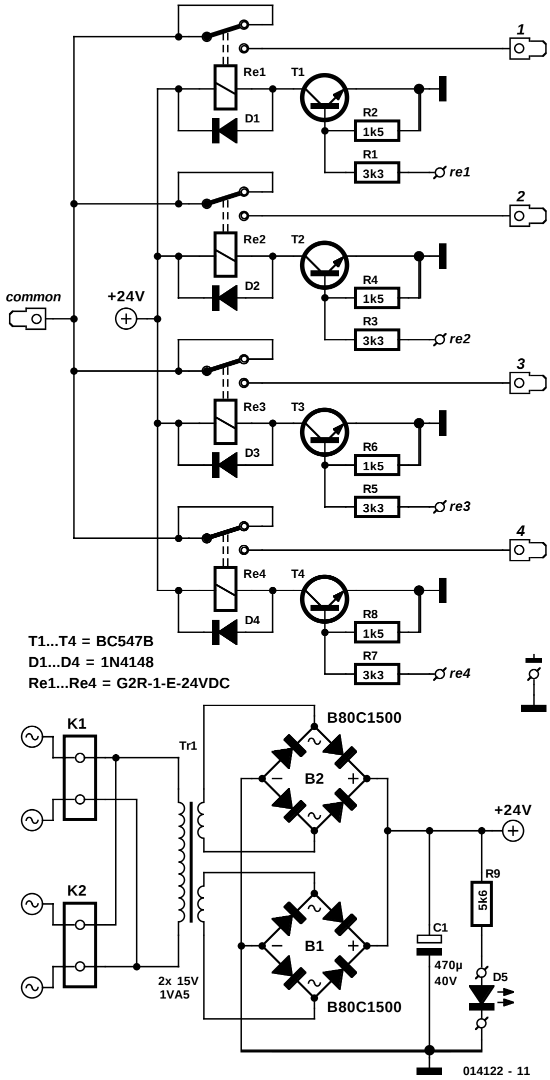
Anyone who has ever taken part in a listening test with various loudspeaker systems and amplifiers knows that the differences are often very subtle and difficult to judge. To make a good comparison it is absolutely necessary that changes from one combination to another can be made quickly. The adjacent circuit will be a welcome aid in these cases. It is specifically intended to switch between four amplifiers or loudspeakers. Also, when using the ‘Simple Remote Control’ described elsewhere in this issue it is not even necessary to leave your listening position.

The circuit consists of four relays, each with its own switching transistor and power supply. The connections for the loudspeakers/amplifiers are deliberately made with robust connectors, in order to deal with large currents and minimise the influence on the quality. The relays that have been selected are rated 16 A and each contact has two pins. The voltage dividers have been chosen such that the transistors will start to conduct at a voltage of around 2 V.

The power supply is provided by a 1.5 VA transformer, which is actually capable of delivering more power than is required by the relays used (not even 0.6 VA). We make welcome use of the fact that the open-circuit voltage of short-circuit proof transformers is significantly higher than the rated voltage. With one relay energised, the power supply voltage is around 23 to 24 V, and that is more than may be expected from a 15 V winding.

A striking detail is that two bridge rectifiers have been used for the power supply. The reason is that with short-circuit proof transformers of this kind, the two secondary windings are usually not equal to a degree that permits direct parallel connection. Providing each winding with its own rectifier does make this possible. This way, current cannot flow from one winding to another and unnecessary losses are avoided. An additional advantage is that a transformer with a single secondary winding may also be used, in this case the current will flow through one bridge rectifier through the load to the other rectifier.

The ripple voltage on the power supply amounts to less than 350 mV_{pp}. The mains connection on the printed circuit board has been duplicated. This allows for an easy loop-through mains voltage when multiple PCBs are used. LED D5 is the power supply indicator.



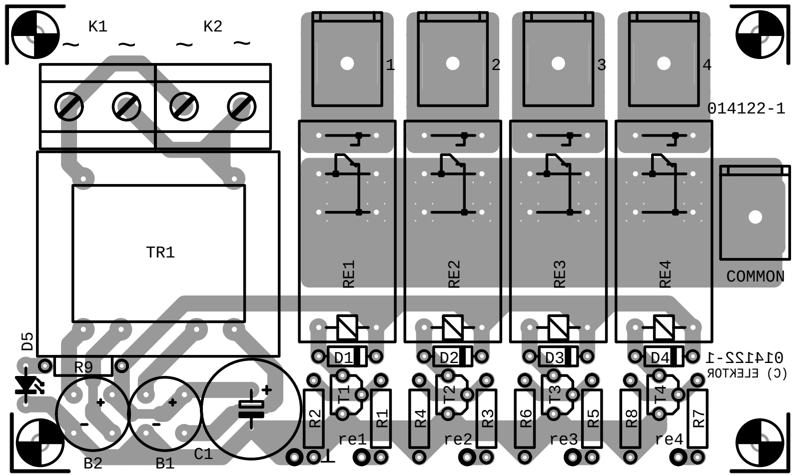
COMPONENTS LIST

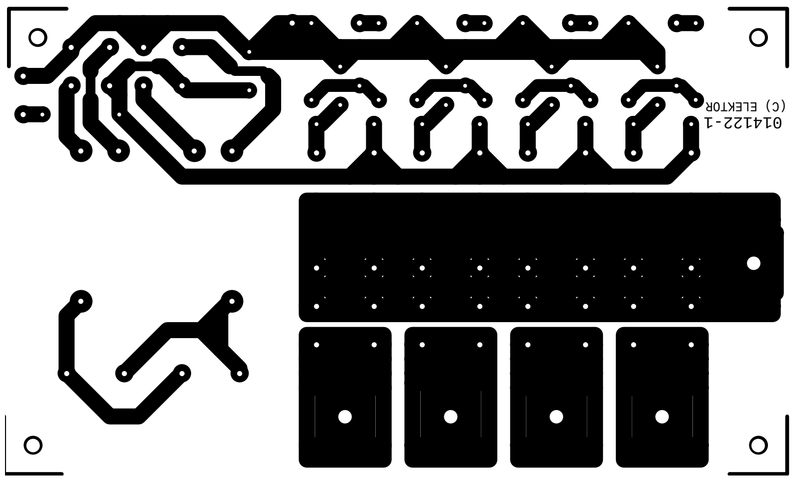
Resistors:
R1,R3,R5,R7 = 3kΩ3
R2,R4,R6,R8 = 1kΩ5
R9 = 5kΩ6

Capacitors:
C1 = 470µF 40V radial

Semiconductors:
B1,B2 = B80C1500, round case (80V piv, 1.5A peak)
D1-D4 = 1N4148
D5 = LED, high-efficiency
T1-T4 = BC547B

Miscellaneous:
Re1-Re4 = G2R-1-E-24VDC Omron (Conrad Electronics)
K1,K2 = 2-way PCB terminal block, lead pitch 7.5mm
Tr1 = 2 x 15 V/1VA5, e.g. Hahn type BV EI 302 2028
5 off spade terminal, screw mounting (3mm screw)





Considering that the circuit comprises a small number of parts, it is unlikely that the construction, with the aid of the PCB design shown here, should present any difficulties.

(014122-1)

Baudrate Divider Calculator for AVR Micros

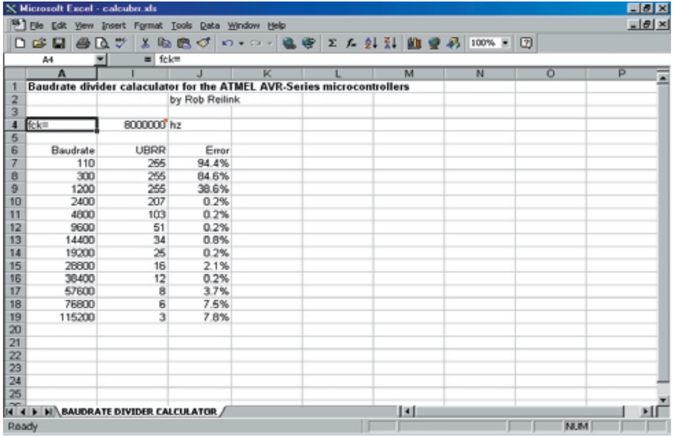
022

R. Reilink

An Excel spreadsheet is an extremely useful tool when you need to calculate a value to be loaded in the UBRR register of an Atmel AVR microcontroller. As most AVR programmers will know, these values depend on the crystal frequency used because they are derived from it. Without such a spreadsheet, such calculations are tedious.

A Microsoft Excel spreadsheet called **calcubrr.xls** was developed for this purpose. It may be downloaded as file number **000167-11** from the Free Downloads section on the *Elektor Electronics* website, www.elektor-electronics.co.uk. Look under July/August 2001 items.

(000167-11)



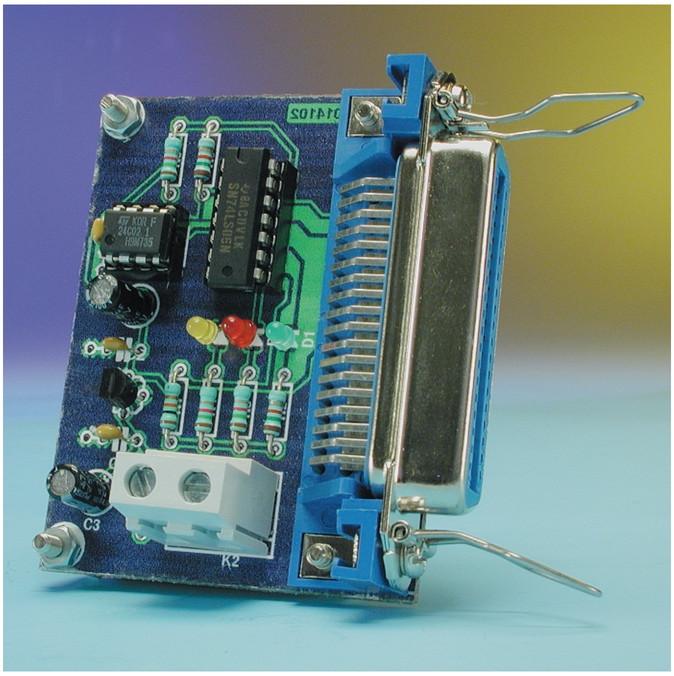
Baudrate divider calaculator for the ATMEL AVR-Series microcontrollers

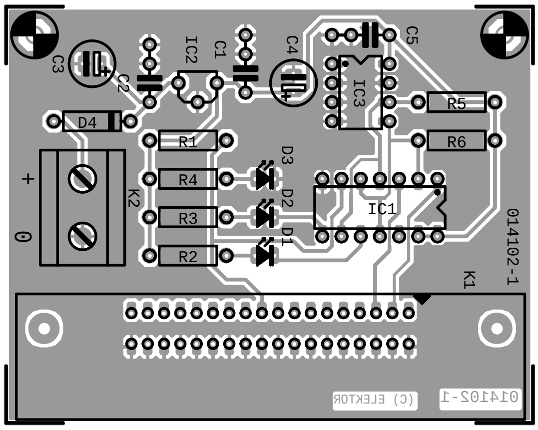
by Rob Reilink

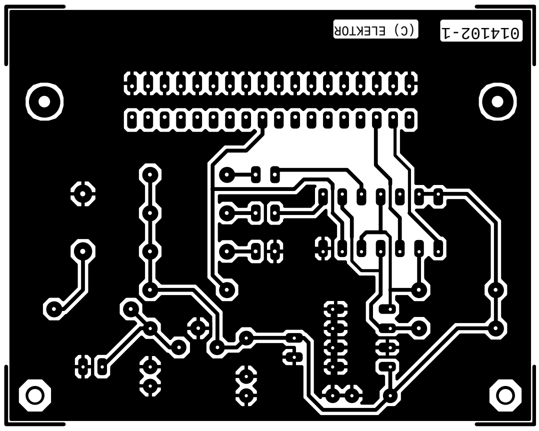
fck= 8000000 hz

Baudrate	UBRR	Error
110	255	94.4%
300	255	84.6%
1200	255	38.6%
2400	207	0.2%
4800	103	0.2%
9600	51	0.2%
14400	34	0.8%
19200	25	0.2%
28800	16	2.1%
38400	12	0.2%
57600	8	3.7%
76800	6	7.5%
115200	3	7.8%

Simple EEPROM Programmer 023







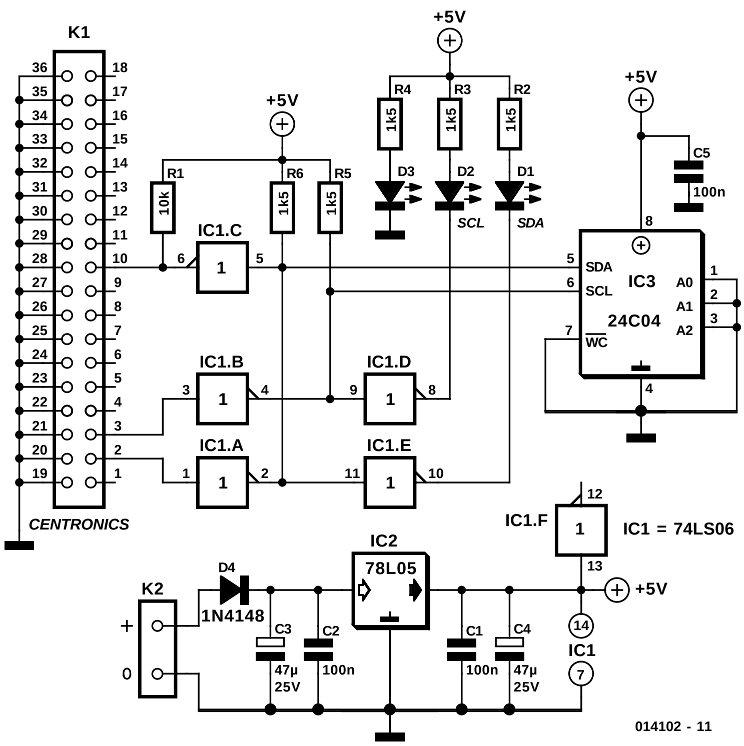
R. Weber

An extremely popular programmer for the PIC16C84 microcontroller has already appeared in *Elektor Electronics* (Summer Circuits, 1998): that design used the parallel interface and the popular PIP-02 shareware from Silicon Studio, together with a special driver written by Dave Tait. PIP-02 is capable of programming not just PICs but also EEPROMs equipped with an I^2C interface.

This works with essentially the same hardware as we presented then, and the circuit in **Figure 1** shows how the device to be programmed can be connected. The connection for the special programming voltage has gone, since the EEPROM does not require it.

What remains is a hex inverter with open-collector outputs (type 74LS06), which buffers the serial clock SCL before taking it to the appropriate EEPROM pin. The serial data line is, in contrast to the clock signal, bidirectional. For this reason two separate buffers are required, IC1B for signals from PC to EEPROM and IC1C for the reverse path.

Since a PCB is hardly worthwhile for just a couple of ICs and a connector, we have added a little extra: two spare inverters from the 74LS06 are connected to the two bus lines and drive LEDs, which allow the programming process to be monitored. A third LED is connected to the supply to verify operation. And



COMPONENTS LIST

Resistors:
R1 = 10kΩ
R2-R6 = 1kΩ5

Capacitors:
C1,C2,C5 = 100nF
C3 = 47µF 25V
C4 = 4µF7 25V

Semiconductors:
D1 = LED, green, low current
D2 = LED, red, low current
D3 = LED, yellow, low current
D4 = 1N4148
IC1 = 74LS06
IC2 = 78L05
IC3 = 8-way IC socket

Miscellaneous:
K1 = Centronics connector, angled pins, PCB mount
K2 = 2-way PCB terminal block, lead pitch 7.5mm

finally, IC2 and the capacitors provide a regulated power supply on the PCB so that an ordinary (9 V) mains adaptor can be connected to K2 to power the programmer. Nothing can go wrong if the supply is connected backwards: D4 protects the hardware (and the PC) from damage.

The PIP-02 software, along with the **`dtait.exe`** driver, is available on the Internet from Dave Tait's very informative website www.thepicarchive.cwc.net/dtpa/links.html and of course it is all free. Although the link to Silicon Studio is broken, the software (along with much else) is archived on Dave's site.

(014102-1)

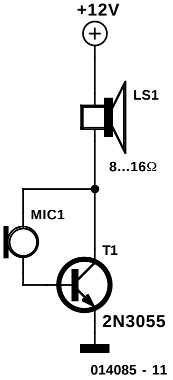
Three-component Oscillator

024

P. Lay

At first glance, this circuit appears to be just a primitive microphone amplifier. Why then is the title of this article ‘Three-component Oscillator’? The answer is very simple: the microphone is not intended to pick up speech; instead, it is placed so close to the loudspeaker that massive positive feedback occurs. Here we intentionally exploit an effect that is assiduously avoided in public-address systems — the positive feedback results in a terribly loud whistle. The loudspeaker is connected directly to the 12-V supply voltage and the power transistor, so it must be able to handle a power of at least 1.5 W, and it should have an impedance of 8 to 16 Ω. An outstanding candidate can be cannibalised from an old television set or discarded speaker box. The microphone should be a carbon-powder type from an old-fashioned telephone handset. If you place a switch in series with the power supply, this sound generator can also be used as an effective doorbell or siren. Surprisingly enough, the circuit can also be used as a simple microphone amplifier — hardly hi-fi, of course, but still usable.

(014085-1)

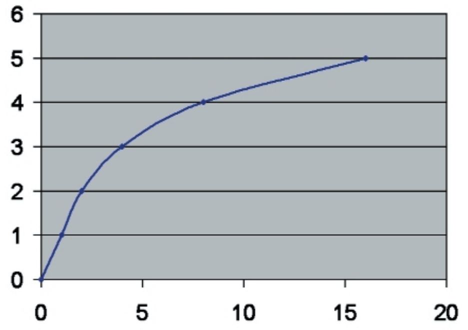


Graphs in Excel

025

Drawing nice-looking graphs requires both feeling and skill. In the past, this was taught at school using grid paper, but these days anyone can grab a computer and even a steady hand is no longer a requirement. But which program lends itself best for the drawing of graphs? The familiar Microsoft Excel, which is installed on practically any computer nowadays works quite well: simply enter a table of numbers, choose the desired type of graph and voilà, a beautiful graph, which can be pasted into a document or printed!

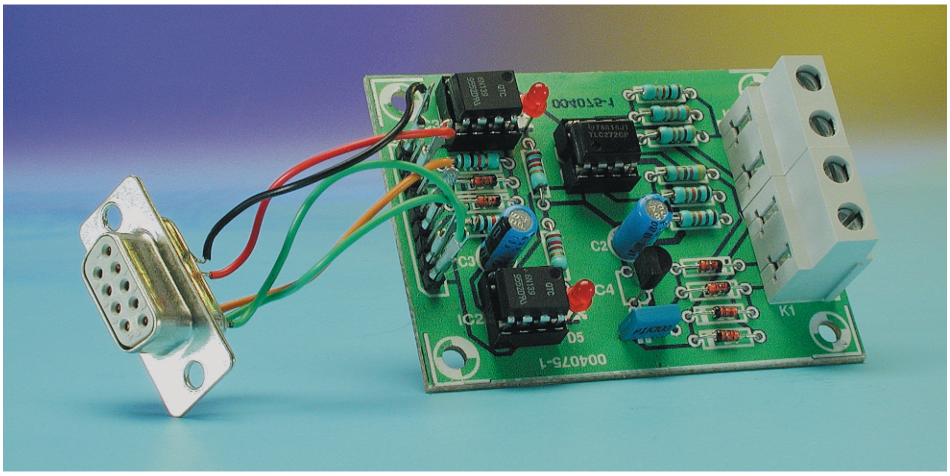
On certain occasions however, you will be disappointed. This is because Excel assumes that all the intervals are equal, and this is not the case with many measurements. Selecting the 'scatter' type of graph can solve this problem; this version of the graph is able to deal with irregular intervals, as is illustrated by the accompanying picture.



(000168-1)

Opentherm Monitor

026



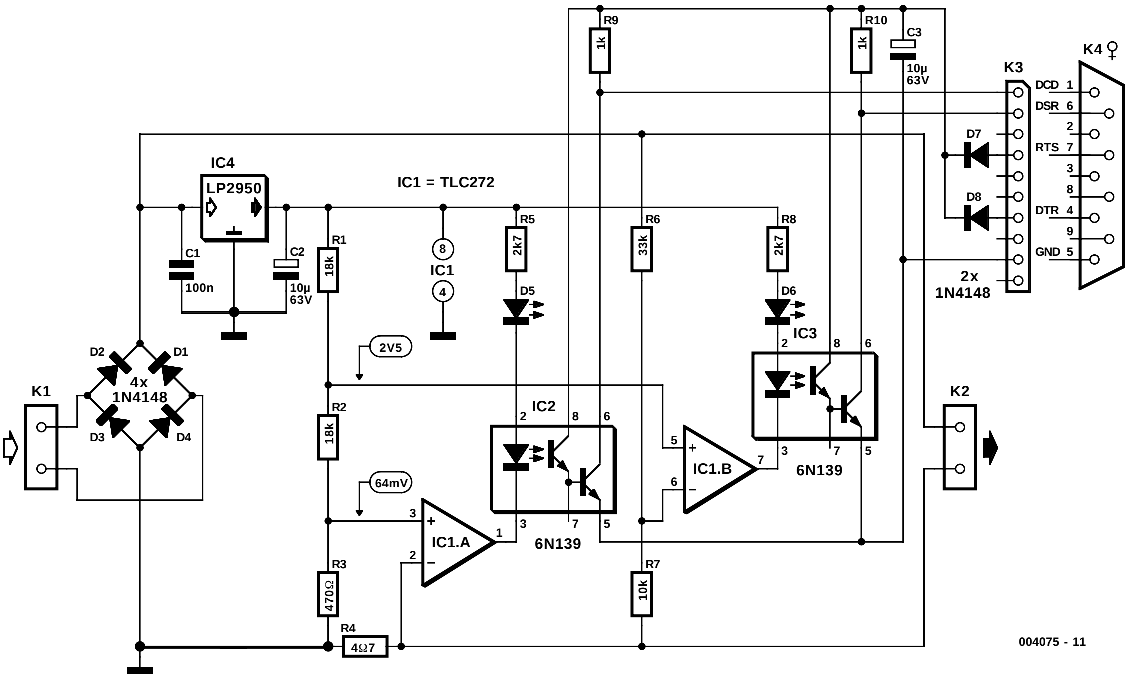
If you say that the term ‘Opentherm’ is unfamiliar to you, then this will not surprise us the least. Opentherm is a protocol, which can control central heating boilers and hot water systems digitally. ‘Open’ indicates that it is not specific to a single brand. Anyone can, in principle, make use of this protocol, provided you are prepared to hand over several thousand pounds for ‘membership’ and are prepared to keep the information secret (talk about ‘open’…). As a consequence we unfortunately do not know a great deal about it, but we do have a few technically interesting pieces of information we would like to share with you.

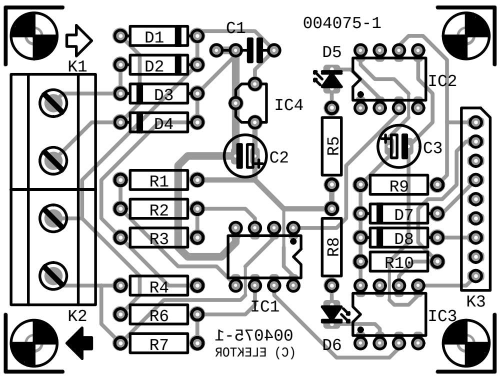
The connection between the master device (usually the room thermostat) and the slave (typically the central heating boiler) consists of two wires, which permits the use of existing cabling. Via this cable the boiler powers the thermostat with DC. In order to prevent wiring errors, the thermostat is fitted with a bridge rectifier, allowing the conductors (positive and negative) to be reversed. The installer cannot make any mistakes here.

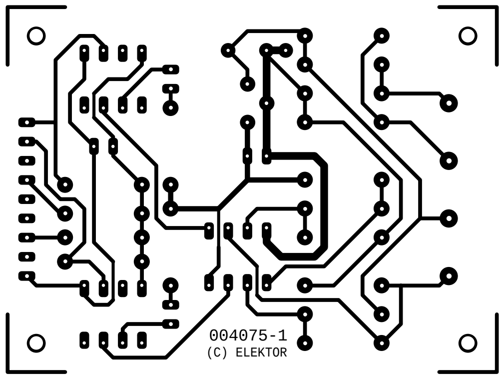
The master places on this connection a digital signal. Every second, 32-bits are transmitted in Manchester-code and after about 0.2 seconds the slave responds with the return message. Every bit lasts 1 ms, and a message consists of:

1	Start bit (logical zero)
1	Parity bit
3	Message type
4	Spare
8	Data ID
16	Data
1	Stop bit (logic zero)

From the electrical perspective, an interesting solution has been selected. The boiler sources **current**, a logic Low is a current between 5 and 9 mA, a logic High a current between 17 and 23 mA. This way the thermostat is always powered. In the opposite direction, the thermostat signals







COMPONENTS LIST

Resistors:
R1,R2 = 18kΩ
R3 = 470Ω
R4 = 4Ω7
R5,R8 = 2kΩ7
R6 = 33kΩ (30kΩ)
R7 = 10kΩ
R9,R10 = 1kΩ

Capacitors:
C1 = 100nF
C2,C3 = 10µF 63V radial

Semiconductors:
D1-D4,D7,D8 = 1N4148
D5,D6 = LED, high-efficiency
IC1 = TLC272 CP
IC2,IC3 = 6N139
IC4 = LP2950 CZ 5.0

Miscellaneous:
K1,K2 = 2-way PCB terminal block, lead pitch 7.5mm
K4 = 9-way sub-D socket (female)

by pulling down the open circuit boiler **voltage** of 24 V to a voltage less than 9 V (logic Low) or between 15 and 18 V for a logic High. So, at the risk of over-emphasising: the boiler provides information by modulating the current, and the thermostat by changing the voltage. All this can easily be observed on an oscilloscope.

In order to follow the activities, we have designed a circuit that does not unduly influence the operation, although it causes an unavoidably small voltage drop of course. The boiler is connected to K1; the polarity is of no consequence because the connector is followed by a bridge rectifier (D1-D4). The thermostat is connected to K2. R4 and IC1a look if the current corresponds with a logic ‘Low’ or a ‘High’ and signal this, electrically isolated, to the DCD of the serial input of your computer. The voltage of the connection is monitored by R6, R7 and IC1b and copied to DSR. An oscilloscope connected to these points easily shows you the messages going back and forth. It is likely that the current channel shows both messages. When the voltage on the wires changes, there is also an inevitable change in current because the thermostat is a capacitive load.

The circuit is powered from the RTS and DSR handshaking lines. They have to be made logic Low first, of course. Naturally, it is also possible to connect a power supply of around 10 to 12 V **behind** the diodes.

Those who are keen can write a program to read the serial inputs and decode the Manchester-code to data. Certain information, such as room and boiler temperature can easily be found.

Unfortunately we do not have any more information and neither do we have a program. Every now and then there is something to be found in the Internet, so it may be sensible to keep an eye this.

(004075-1)

VHF Test Transmitter

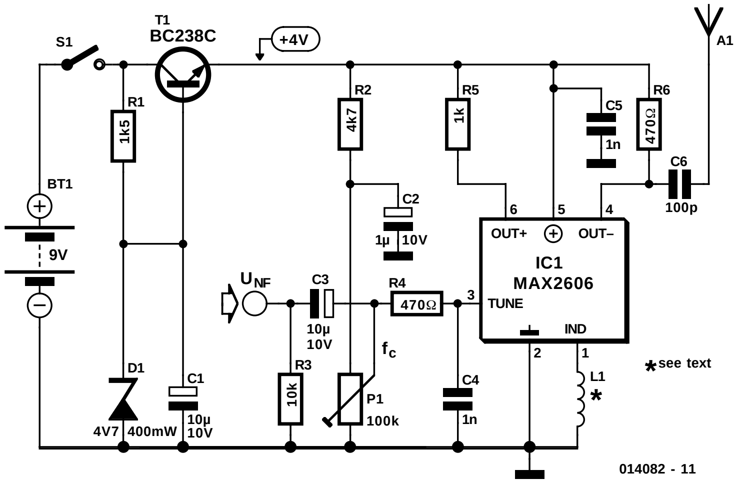
027

If you want to be independent of the local radio stations for testing VHF receivers, you need a frequency-modulated oscillator that covers the range of 89.5 to 108 MHz — but building such an oscillator using discrete components is not that easy. Maxim now has available a series of five integrated oscillator building blocks in the MAX260x series (see the May 2001 issue of *Elektor Electronics*), which cover the frequency range between 45 and 650 MHz. The only other thing you need is a suitable external coil, dimensioned for the midrange frequency.

The MAX2606 covers the VHF band, although the frequency can only be varied by approximately ±3 MHz around the midrange frequency set by the coil L. The inductance values shown in the table can serve as starting points for fur-

ther experimenting.
The SMD coils of the Stettner 5503 series are suitable for such oscillators. In Germany, they are available from Bürklin (www.buerklin.de), with values between 12 nH and 1200 nH. You can thus directly put together any desired value using two suitable coils. If you want to wind your own coils, try using 8 to 14 turns of 0.5-mm diameter silver-plated copper wire on a 5-mm mandrel. You can make fine adjustments to the inductance of the coil by slightly spreading or compressing the coil.
The circuit draws power from a 9-V battery. The BC238C stabilises the voltage to approximately 4 V. Although the MAX2606 can work with a supply voltage between +2.7 V and +5.5 V, a stabilised voltage improves the frequency stability of the free-running oscillator.
The supply voltage connection Vcc (pin 5) and the TUNE voltage (pin 3) must be decoupled by 1-nF capacitors located as close as possible to the IC pins. The tuning voltage TUNE on pin 3 may lie between +0.4 V and +2.4 V. A symmetric output is provided by the OUT+ and OUT– pins. In the simplest case, the output can be used in a single-ended configuration. Pull-up resistors are connected to each of the outputs for this purpose. You can use a capacitor to tap off the radio signal from either one of these resistors. Several milliwatts of power are available. At the audio input, a signal amplitude of 10 to 20 mV is enough to generate the standard VHF frequency deviation of ±40 kHz.

(014082-1)

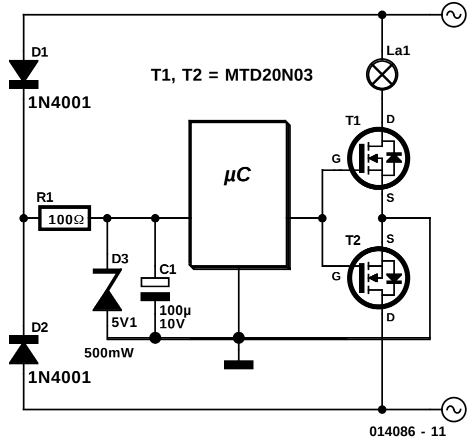


f (MHz)	89–95	93–99	97–103	100–106	103–109
L (nH)	500	470	420	390	350

AC Controller using MOSFETs 028

Particularly with low voltages, triacs are usually used as control elements for ac voltages. The disadvantage, as so often is the case, is in the power dissipated in the control element, which is quite evident for currents greater than 1 ampère. In such cases, it is essential to use a heatsink for the triac. If you want to control the brightness of a halogen lamp using such an arrangement, for example, the voltage drop across the triac also results in a significant reduction in the maximum brightness of the lamp.

This disadvantage can be avoided by using two MOSFETs for the control element, in place of a triac. The trick here is to connect the two MOSFETs in series with opposite polarity, with the gates connected in parallel to the control circuit. The junction of the two gate leads represents the virtual ground of the circuit, which forms the reference for all other potentials. Modern MOSFETs, such as the 20N03 from On Semiconductor (www.on-semi.com) with an $R_{DS(ON)}$ of 0.035 Ω, can be used in this circuit for controlling a 50-W halogen lamp without any supplementary heatsink. The loss in brightness is negligible, since the voltage drop is only (0.035 Ω × 4.2 A) = 0.147 V. Of course, you do not necessarily have to use the 20N03; in principle, any n-channel MOSFET with a low gate voltage (preferably a 'logic FET') can be used.

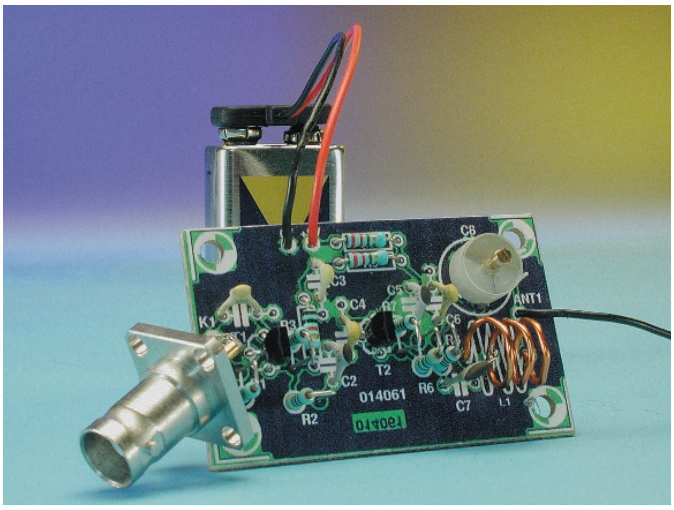


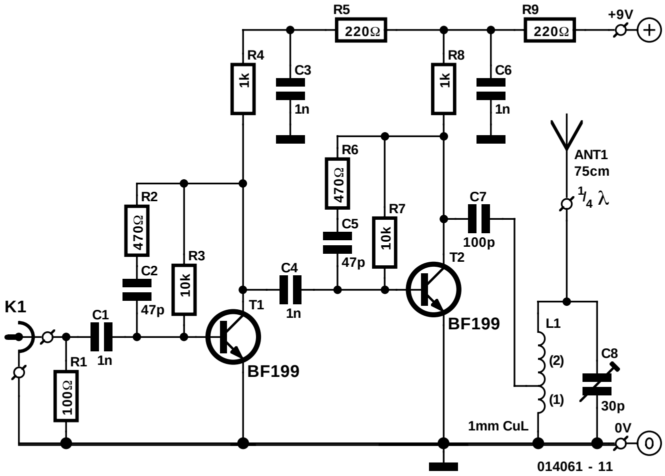
Another benefit of this circuit is its 'zero-power' gate drive, in contrast to triacs, which require drive currents of 10 mA or more. This means that any microcontroller, TTL gate or 555 timer IC can be used as the controller.

(014086-1)

Booster for Cable Radio

029





With the aid of this circuit it is possible to listen, using a portable VHF FM radio, to listen to stations that transmit only your local cable network. Both from its properties and its design this 'cable booster' appears similar to an antenna amplifier, because this is a two-stage amplifier with two common RF transistors type BF199. Only this time, the input is connected to the cable connection instead of an antenna while the output does not contain a coaxial connection but a tuned circuit that acts as impedance matching for a 1/4λ-antenna. If the circuit is tuned correctly (using trimmer C8), the amplified cable signal is radiated by the vertical antenna and can be easily received by a portable receiver up to three metres away.

It is always possible to build the circuit on a piece of prototyping board, but because an RF-circuit is usually a little more critical it will probably work a lot better if you make use of the PCB layout shown here. During the design, the essential connections have been kept short and the ground plane has been made as large as possible. Capacitor C7 is best directly connected to the tap on L1, as can be seen in the photo. The (air-cored) coil consists of three turns of 1-mm enamelled copper wire (ECW) wound around a pencil (diameter about 8 mm).

During the construction make sure that you keep the connecting wires from the coax connector K1 to the PCB as short as possible. This prevents the circuit from picking up signals from the air and possibly showing an undesirable tendency to oscillate. The PCB must be fitted in a metal enclosure.

The power supply of the cable booster can either be a 9 V battery or a small, regulated mains power supply. The current consumption amounts to about 2.5 mA.

(014061-1)

COMPONENTS LIST

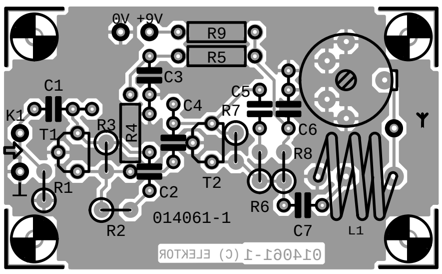
Resistors:
R1 = 100Ω
R2,R6 = 470Ω
R3,R7 = 10kΩ
R4,R8 = 1kΩ
R5,R9 = 220Ω

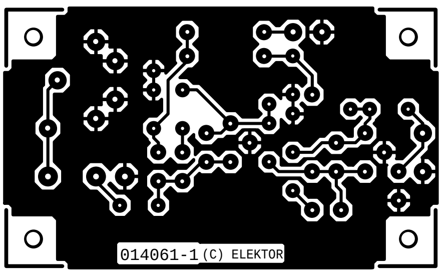
Capacitors:
C1,C3,C4,C6 = 1nF
C2,C5 = 47pF
C7 = 100pF
C8 = 30pF trimmer capacitor

Inductors:
L1 = 3 turns 1mm dia. ECW, internal dia. 8mm, tap at 1 turn

Semiconductors:
T1,T2 = BF199

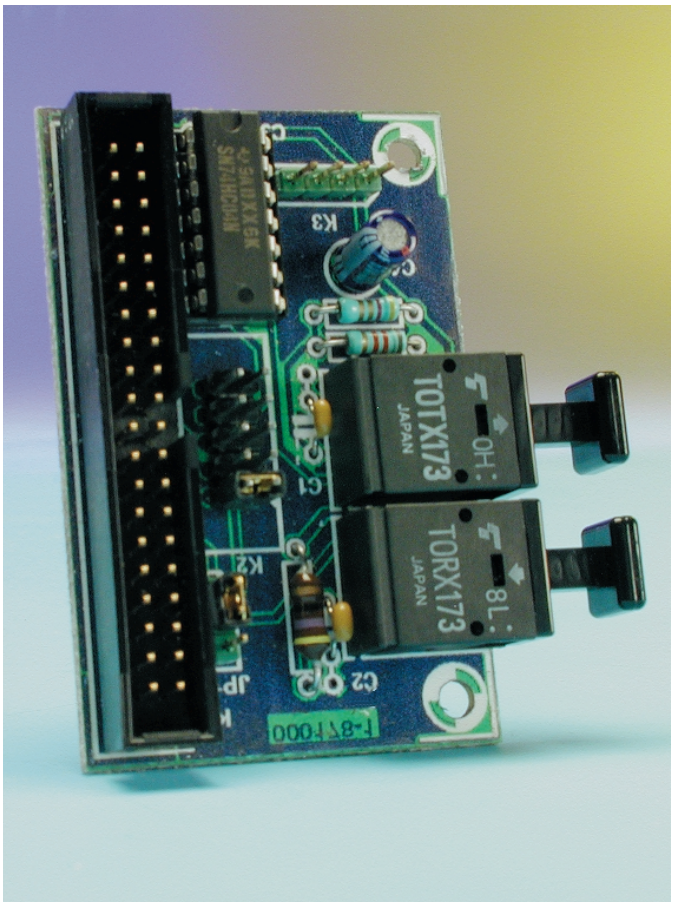
Miscellaneous:
K1 = coax socket, chassis mounting
ANT1 = telescopic or whip antenna, length approx. 75cm
9V battery with holder and wires
Diecast enclosure

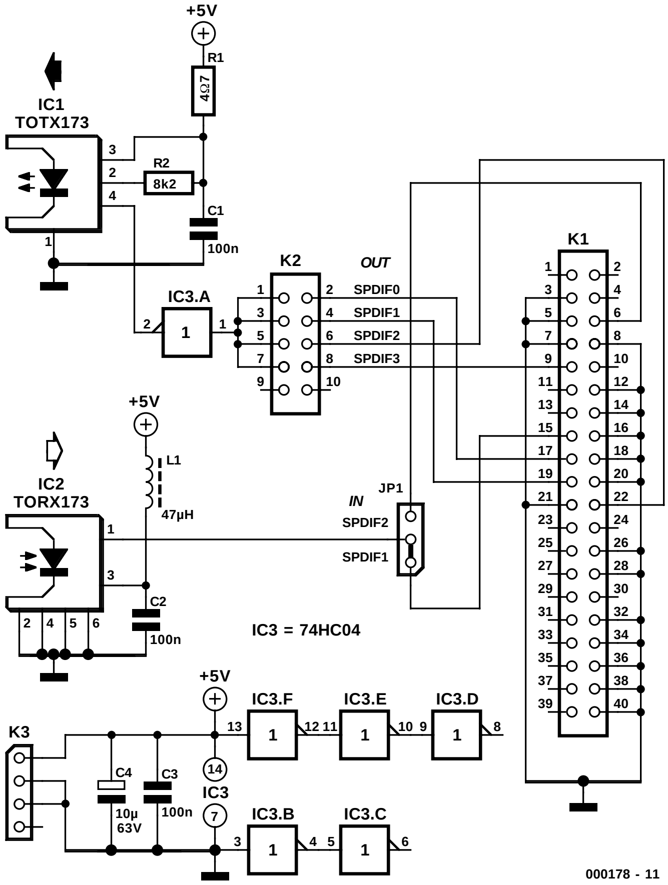




Simple Adapter for SB Live! Player 1024

030

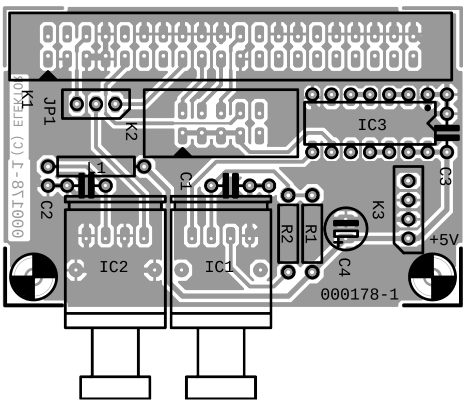


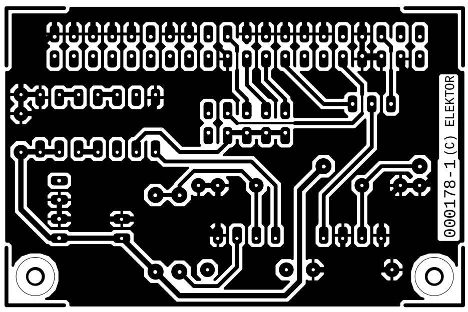


F. Brandt

The 2000 Summer Circuits Collection contained an adapter that made it possible to connect the digital extension (PCB **990079-1**) from December 1999 in the correct manner with the ‘Sound Blaster Live! 1024’. This digital extension, fitted with both coaxial as well as optical inputs and outputs, was originally designed for the 12-pin expansion connector (Audio-Extension-connector) on the ‘Sound Blaster Live! Player (Value)’. The 1024 model has a 40-pin connector.

This circuit combines the two in a simplified fashion. There is now only one optical input and one optical output. Using jumper K2 you can select one of the four outputs. Similarly, JP1 lets you select one of the two inputs. It appears that Live!Ware 3.0 supports only the first input. For those who are interested, the pin assignment details of the expansion connector can be found in the help menu, or with the aforementioned circuit description (‘Adapter for SB Live! Player 1024’) in the 2000 Summer Circuits Collec-





tion. To make the connection to a Home-MD recorder a Toslink-to-Toslink-cable is required. To link to a portable MD recorder a Toslink-to-miniplug is necessary.

This simplified adapter has been specifically designed for use with MD recorders, because these are usually fitted with optical inputs and outputs only. The construction of the circuit with the aid of the PCB design shown here should be a piece of cake. The power supply for the circuit is obtained from a small PC power supply connector, which is connected to 4-way pin header K3. Pay careful attention to the polarity when attaching the connector; the red wire is the +5 V connection!

(000178-1

COMPONENTS LIST

Resistors:
R1 = 4Ω7
R2 = 8kΩ2

Capacitors:
C1,C2,C3 = 100nF ceramic
C4 = 10µF 63V radial

Inductor:
L1 = 47µH

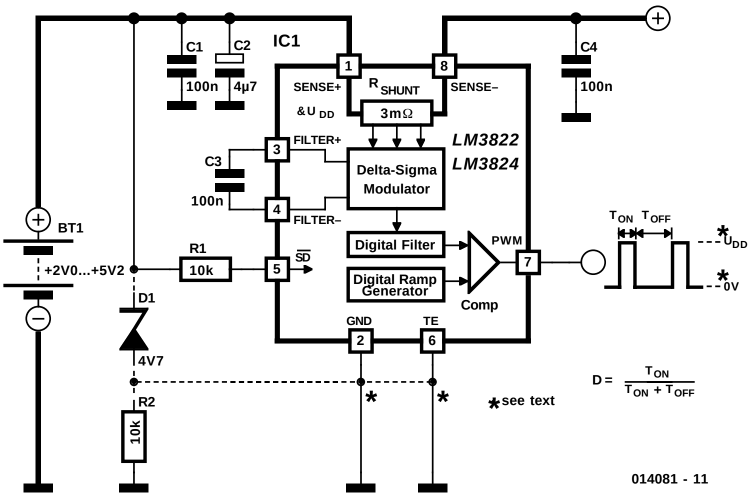
Semiconductors:
IC1 = TOTX173
IC2 = TORX173
IC3 = 74HC04

Miscellaneous:
JP1 = 3-way pinheader with jumper
K1 = 40-way boxheader
K2 = 10-way double row pinheader with jumper
K3 = 4-way pinheader

LM 3822/24 Current Meter

031

ICs for measuring currents usually employ external sense resistors with values of a few tens of milliohms. Not only are such resistors difficult to obtain, the circuit board layout can have a disturbing effect on the accuracy of the measurement. This problem is eliminated by the LM3822 and LM3824 ICs from National Semiconductor (www.national.com), which have built-in sense resistors with a value of only 3 mW. A delta-sigma modulator converts the measured value into a digital value. A digital filter takes the average value of the current every 50 ms (LM 3822) or every 6 ms (LM 3824). A pulse-width modulated signal (PWM) that is proportional to the current level is generated by comparing this to a digital ramp signal. According to the manufacturer, the LM3822/24 provide the highest measurement accuracy of any currently available high-side current measurement IC. In the case of the LM3824, the accuracy is ±2%.



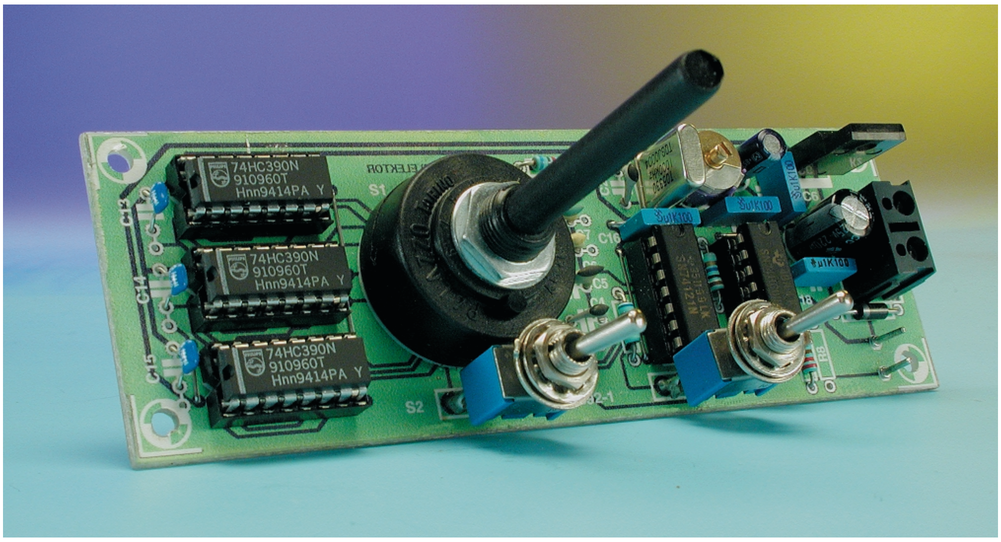
Type	Measurement range	Error	Sampling interval	PWM resolution
LM3822-1.0	–1.0...+1.0 A	±2 %	50 ms	0.1 %
LM3822-2.0	–2.0...+2.0 A	±2 %	50 ms	0.1 %
LM3824-1.0	–1.0...+1.0 A	±3 %	6 ms	0.8 %
LM3824-2.0	–2.0...+2.0 A	±3 %	6 ms	0.8 %

On the output side, the LM3822/24 deliver a pulse-width modulated signal (PWM) whose duty cycle D indicates the measured value of the current, including its sign. If the current is equal to zero, D is exactly 50 %. Positive currents yield duty cycle values ranging from 50 % to 95.5 %, and negative currents yield duty cycle values ranging from 50 % to 4.5 %. A value of 95.5 % thus corresponds to +1 A (or +2 A), while a value of 4.5 % corresponds to –1 A (or –2 A). The current is considered to be positive when it flows from SENSE to SENSE–.

The LM3822/24 ICs work with a supply voltage between 2.0 V and 5.5 V and have an internal current consumption of less than 150 µA. For operation at voltages greater than 5.5 V, the Zener diode shown in dashed outline in the schematic diagram can be use with a 10-kΩ series resistor. The Zener diode limits the operating voltage across the LM3822/24 to a safe 4.7 V. Note however that in this case, the output signal is not longer referenced to ground, but swings between the supply voltage level and 4.7 V below this level. A level converter is thus needed for signal processing. The GND and Test (TE) pins should be connected to the zener diode.

(014081-1)

Economical Timebase Calibrator 032

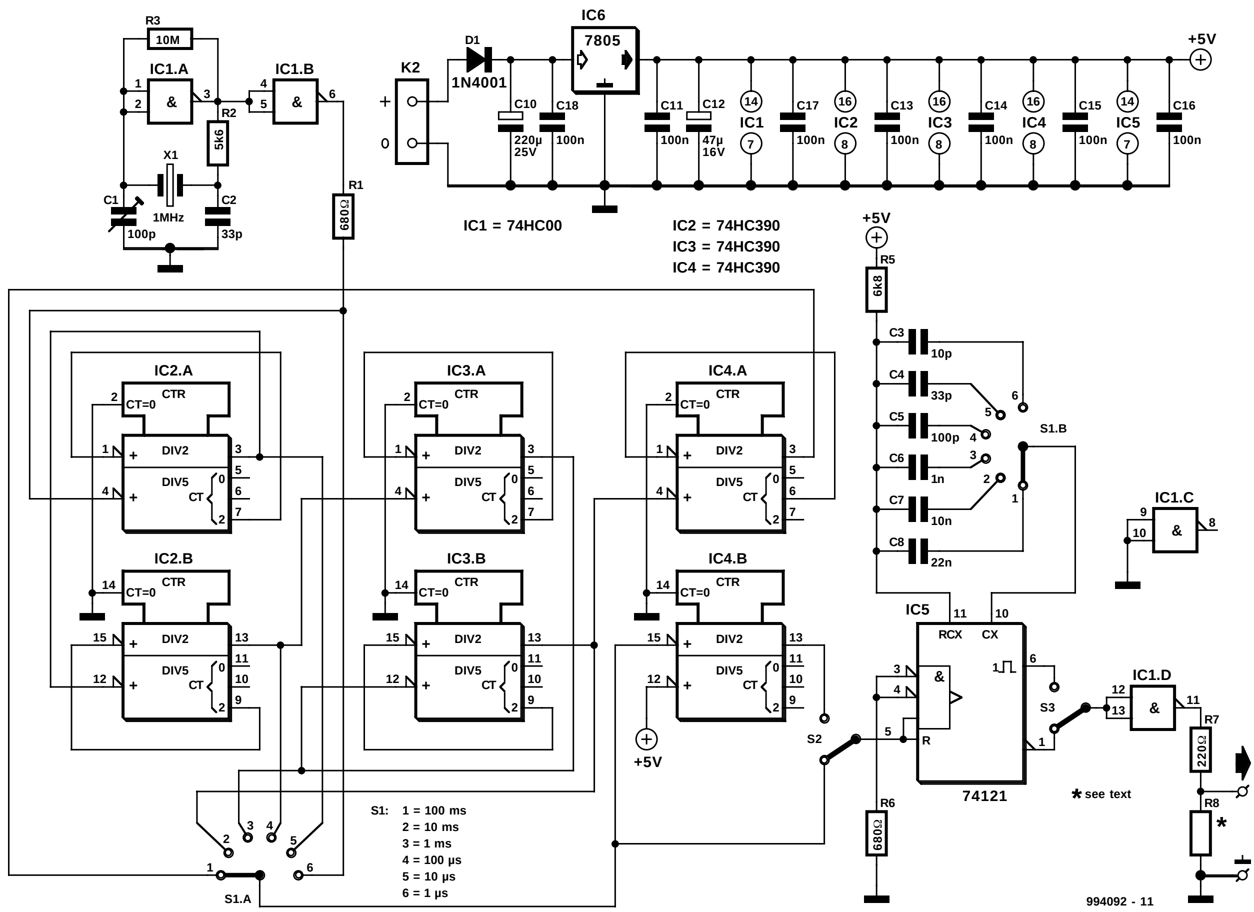


F. Hueber

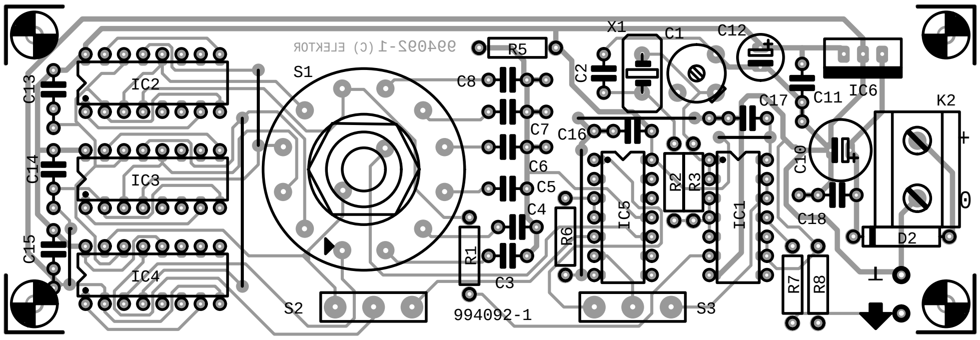
An external timebase calibrator is a useful accessory for any oscilloscope it provides precise, visible time markers on the scopes horizontal sweep. Basically the circuit is a pulse generator with accurate time intervals between pulses i.e. the pulse repetition frequency. If the pulse width is made relatively small compared to the repetition rate and the pulse edges are steep then the output signal will look like a series of illuminated dots. These can be conveniently used to measure time periods on the screen just as you use the graduation marks on a ruler to measure length.

The circuit diagram shown in **Figure 1** uses five commonly available ICs (excluding the power supply). A 1 MHz crystal provides an accurate time base for the oscillator circuit built around IC1A. Resistor R3 governs the switching threshold while trimmer C1 alters the loading on the crystal and allows its frequency to be

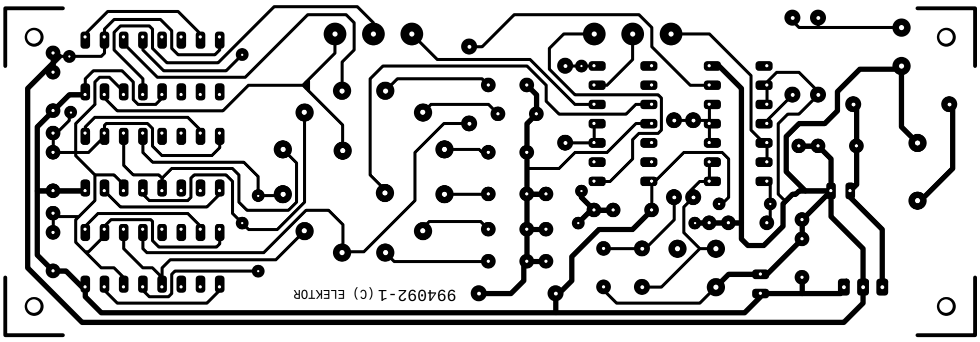
1



‘pulled‘ slightly which is necessary when calibrating the circuit. IC1B buffers the oscillator from the rest of the circuitry and R1 cleans up the square wave output by reducing any overshoot on the clock edges. The output signal is connected to five cascaded decade counters type 74HC390 (IC2 to IC4A) each counter divides its input frequency by 10. Switch S1A selects one of the frequencies or time intervals from 1 MHz (1 µS) to 10 Hz (100 ms) to route it to a pulse generator formed by IC5. The second half of counter IC4 is used to provide a divide-by-two function, this can be bypassed by switch S2. In total this gives 12 possible pulse repetition rates from 1 µS to 200 ms.



2



The output timing pulse is generated by IC5. This is a standard TTL monostable type 74121. Standard TTL devices can be interfaced directly with HC devices without any problem. The output pulse width of the monostable is a function of the resistor/capacitor value at pins 10 and 11. As the repetition rate is changed by switching the counter outputs with S1A so the second half of the switch (S1B) also switches different R-C components to the monostable. This ensures that the marker pulses shown on the oscilloscope screen will be the correct width for each selected range. The output stage of a standard TTL IC does not drive symmetrically so IC1D is used as a buffer to give a better output performance. Switch S3 allows the polarity of the output pulse to be switched and resistor R7 provides short circuit protection for the output buffer. Unfortunately in combination with the capacitance of the output lead, this resistor also forms a low pass filter that has the effect of rounding off the sharp edges of the output signal. Socket K2 is used for connection of an external 9 V mains unit to power the circuit and IC6 regulates this to 5 V for use on board. Current consumption is only a few milliamps so a heatsink is unnecessary.

Fitting the PCB into a case is greatly simplified by mounting the single-sided PCB directly to the back of the front panel switches.

Mounting the components on the board is begun by first soldering the six wires bridges and the smaller components to the board. It’s worth taking a little care here to ensure that the polarised capacitors and diode are correctly fitted. This design will produce RF interference so it is advisable to fit the unit inside a metal case or at least a screened plastic case, the screen or case should be connected to the power supply ground.

To test the circuit, first check that 5 V is available from the power supply. Next, connect a frequency counter to resistor R1 and adjust trimmer C1 until 1.000 MHz is achieved. If there is insufficient adjustment in C1 then try a different value for C2. If you do not have access to a frequency counter then just set the trimmer to mid-position or replace it with a 56 pF fixed capacitor.

The output of the calibrator can be connected to the scope input channel via a short length of 50-Ω coax cable. An output series resistor (R8) is used to dampen ringing on the output pulses introduced by the cable capacitance. R8 can be fitted directly to the output BNC socket and its value will be in the range of 220 Ω to 470 Ω.

The best output pulses will be produced by hooking the tip of a 10x scope probe directly on the output pin of the

COMPONENTS LIST

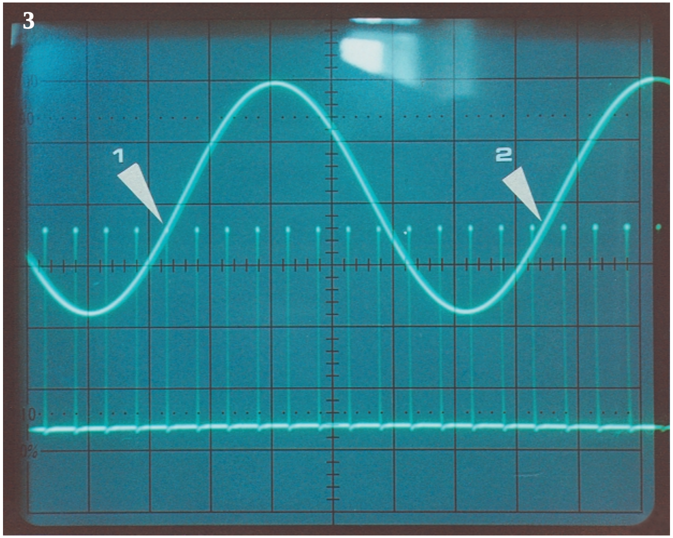
Resistors:
R1,R6 = 680Ω
R2 = 5kΩ6
R3 = 10MΩ
R5 = 6kΩ8
R7 = 220Ω
R8 = *

Capacitors:
C1 = 100pF trimmer
C2,C4 = 33pF
C3 = 10 pF
C5 = 100pF
C6 = 1nF
C7 = 10nF
C8 = 22nF
C10 = 220µF 25V radial
C11,C13-C18 = 100nF
C12 = 47µF 16V radial

Semiconductors:
D1 = 1N4001
IC1 = 74HC00
IC2,IC3,IC4 = 74HC390
IC5 = 74121
IC6 = 7805

Miscellaneous:
S1 = rotary switch, 2 poles, 6 contacts
X1 = 1MHz quartz crystal
S2,S3 = toggle switch,1-change-over contact
K2 = 2-way PCB terminal block, lead pitch 5mm

3



BNC connector, most scope probes will be able to manage this without any problem. A useful addition to the front panel next to the BNC output would be a solder/test point connected to the circuit earth. This provides a convenient parking spot for the scope probe earth clip.

To check the horizontal timebase of an oscilloscope first make sure that and variable time base controls are set to the ‘calibrate‘ position then select a sweep speed so that each output pulse corresponds to one square of the screen graticule. Use the horizontal position adjustment to place the pulses exactly under the graticule lines Check carefully that the pulses occur exactly at each graticule line intersection across the full width of the screen. This will not always be the case with budget priced oscilloscopes!

If you have a two-channel scope it is also possible to use the calibrator to perform quick and easy frequency measurements so that in many cases you will not need a frequency counter at all. First of all connect the signal to be measured to channel A of the scope input and the calibrator output to channel-B input. Adjust the scope timebase generator so that one whole period of the unknown frequency is displayed on the screen. With the scope trigger mode set to ’alternating’ adjust the vertical positions of the channels until they are superimposed and the edge of one of the pulses coincides exactly with a point on the channel A waveform (see (1) in **Figure 3**). Now to find the frequency just count the number of pulses that occur until the channel-A waveform has completed one complete period (2). In the screen shot shown here there are 12.3 intervals of 1.0 µs therefore the frequency is given by

$$f = 1/\ 12.3 \times 10^{-6}\ s = 81.3008\ kHz.$$

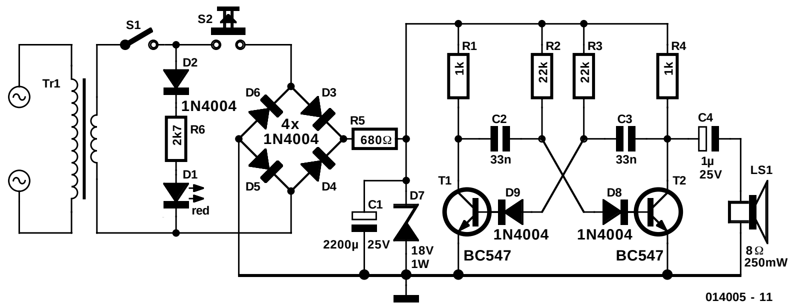
These are only two applications of this versatile circuit, no doubt you will find many more.

(994092-1)

EMD-immune Electronic Doorbell

033

P. Lay



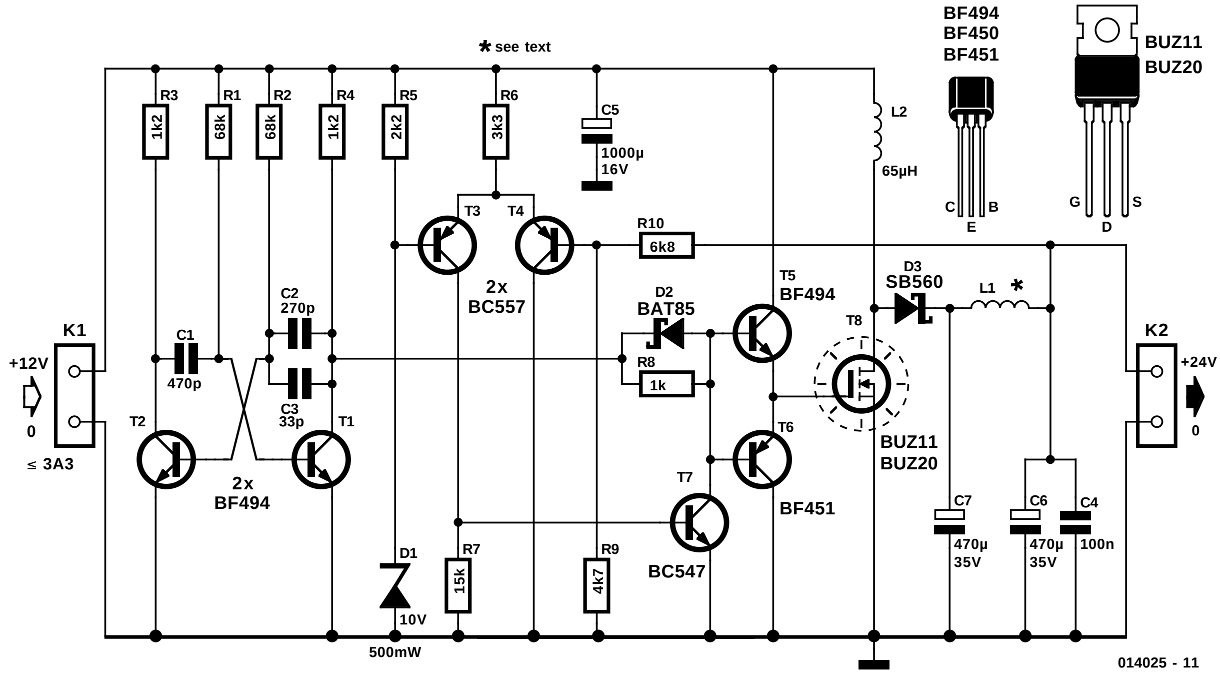
Whenever an antediluvian electric doorbell is used in an apartment building, the rain of sparks that is generated when the Wagnerian hammer pounds against the ‘sounding body’ infests the bell network with interference pulses. These can significantly disturb electronic doorbells, or even cause them to give up the ghost. If you cannot convince your neighbour to convert to something more modern, or at least to build in a noise suppression network, you can use the electronic doorbell described here, since it is immune to EMD.

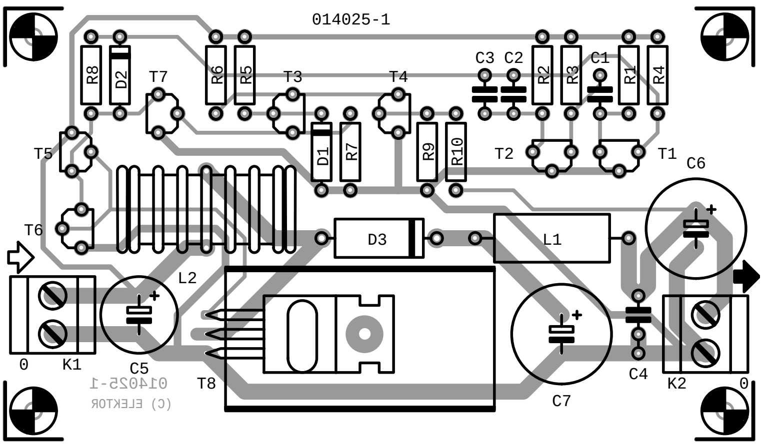
This circuit is based on a simple multivibrator stage to which a loudspeaker is connected. Capacitor C4 provides dc isolation between the multivibrator and the loudspeaker (8 Ω, 0.25 W). The frequency is determined by the RC networks R2/C2 and R3/C3; it lies at around 0.7 RC = 2 kHz. The multivibrator stage receives its supply voltage from the bell transformer. For this purpose, the ac voltage must be rectified by D3-D6, and Zener diode D7 prevents the voltage from rising above approximately 18 V. EMD immunity is provided by the lowpass network R5/C1. The bell can also be silenced using switch S2. In this case, the only thing that happens when someone presses on the bell button is that D1 lights up.

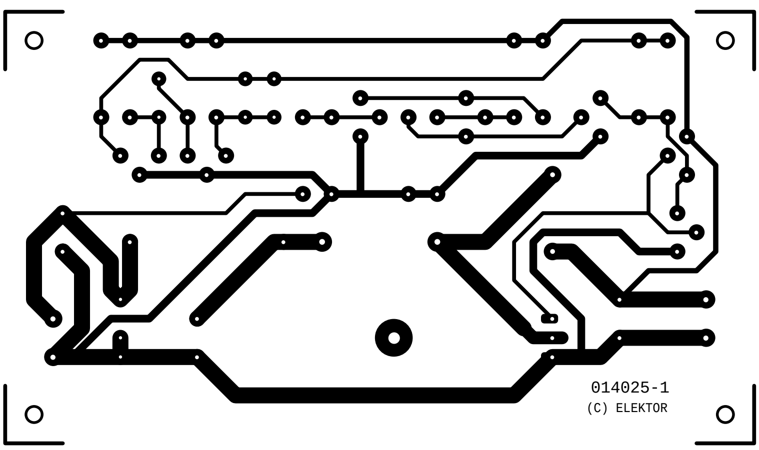
(014005-1)

12V-to-24V Converter

034







G. Baars

This DC-to-DC converter delivers a maximum power of about 36 watts at an efficiency of 90%. Apart from a modern FET and a Schottky diode, this circuit is comprised entirely of familiar and inexpensive parts. In spite of this, the specifications are excellent:

– Efficiency:	approx 90%
– Ripple voltage:	max. 10 mV
– Output current:	max. 1.5 A
– Switching frequency:	40 kHz
– Input voltage:	12 V
– Output voltage:	24 V regulated

The switching element is a fast power FET (T8). This FET has a relatively high input capacitance and is switched on and off by a push/pull stage consisting of two RF transistors (T5/T6). Schottky-diode D2 increases turn-off speed even further, which is crucial here because we are aiming to obtain the highest possible efficiency.

The switching signal is provided by a simple multivibrator, which is also made from two RF-transistors (T1/T2). Difference amplifier T3/T4 has been added to obtain a regulated output voltage of 24 V.

L2 is an off the shelf 5 A suppressor choke with a self-inductance of 65 µH. L1 is part of the output filter, the purpose of which is to eliminate RF noise. This is an air-cored coil, which you can easily make yourself by winding 25 turns of 0.5 mm dia. enamelled copper wire around a 10 mm diameter drill. Because of the high efficiency, the dissipation of T8 remains smaller than about 3.6 W so a modest heatsink of about 10 K/W will suffice. It is advisable that the 12 V input supply includes a fast fuse, rated about 3.5 A.

Considering that the duty cycle has a substantial effect on the efficiency, a second capacitor (C3) has been added in parallel with C2. The optimum setting can be determined by varying this additional capacitor.

The remaining components are not at all critical. Any 5 A suppressor choke will work for L2, any 5 A Schottky-diode for D3 and just about any power MOSFET for T8 (BUZ10, BUZ20, BUZ100).

(014025-1)

COMPONENTS LIST

Resistors:
R1,R2 = 68kΩ
R3,R4 = 1kΩ2
R5 = 2kΩ2
R6 = 3kΩ3
R7 = 15kΩ
R8 = 1kΩ
R9 = 4Ωk7
R10 = 6kΩ8

Capacitors:
C1 = 470pF
C2 = 270pF
C3 = 33pF
C4 = 100nF
C5 = 1000µF 16V radial
C6,C7 = 470µF 35V radial

Inductors:
L1 = 25 turns 0.5 dia. ECW, 10 mm dia., no core
L2 = 65 µH/5 A suppressor coil (ring core)

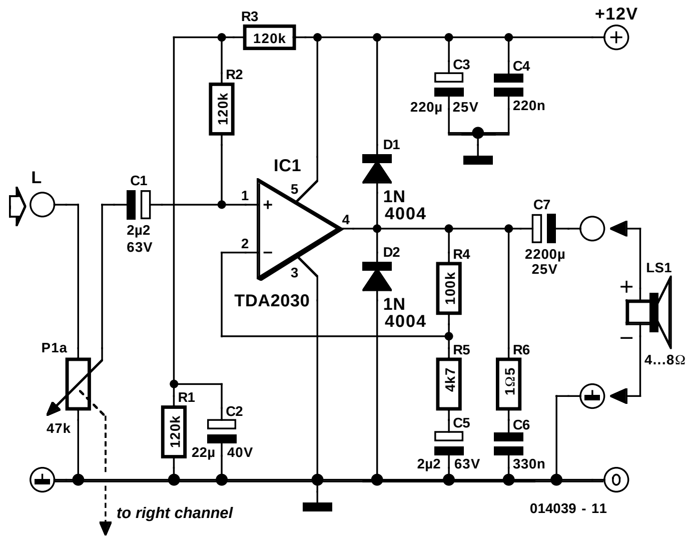
Semiconductors:
D1 = zener diode 10V 500mW
D2 = BAT85
D3 = SB650 (PBYR745)
T1,T2,T5 = BF494
T3,T4 = BC557
T6 = BF450 (BF451)
T7 = BC547
T8 = BUZ11 (BUZ20)

Miscellaneous:
K1,K2 = PCB terminal block, lead pitch 5mm
Heatsink, e.g., Fischer ICK35SA (Dau Components)
PCB, order code **014025-1**

Active PC Loudspeaker

035

P. Lay



With the well-known TDA2030V integrated power amplifier in the Pentawatt package, it is easy to 'activate' a PC loudspeaker or upgrade the quality of an inexpensive active loudspeaker. The TDA2030 combines ease of use with low levels of harmonic and crossover distortion, and it is also incorporates short circuit and thermal overload protection.

No creative brilliance is needed to arrive at the circuit shown in **Figure 1**, which is practically the same as the standard application circuit for single-supply operation as shown in the device data sheet from its manufacturer, ST Microelectronics:

http://us.st.com/stonline/books/pdf/docs/1458.pdf .

The two resistors R1 and R3 set the operating point of the amplifier, and the non-inverting input is biased via R2. The audio signal reaches the power opamp via C1. The gain is determined by the ratio of R5 to R4. Capacitor C5, like C1, affects the lower roll-off frequency. The two diodes protect the IC against positive and negative spikes in the output signal. The RC network C6/R6 ensures stable operation of the amplifier in the high frequency range. The load is connected via the output electrolytic capacitor C7. In the data sheet, you can see which parameters change if you 'play around' with the values of the resistors and capacitors.

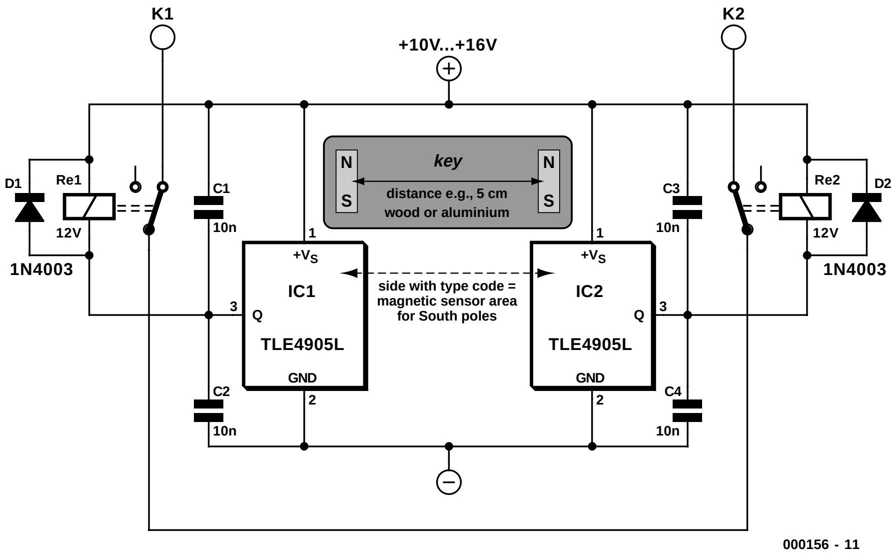
Any individual speaker with an impedance of 4 to 8 Ω or a multi-way loudspeaker can be connected to the output. The maximum achievable power is 6 to 12 W, so a heat sink with a thermal resistance of 8.3 K/W to 4.2 K/W is mandatory.

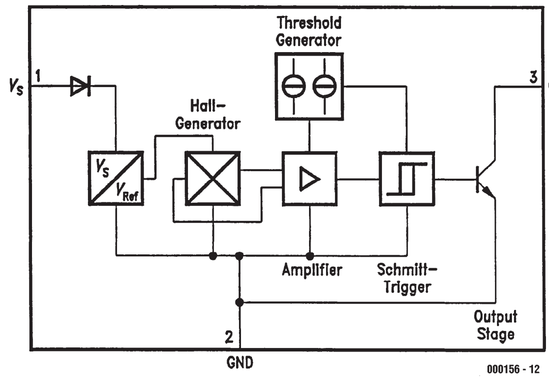
(014039-1)

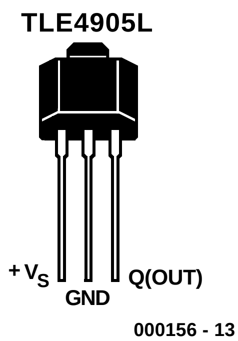
Secret Lock

036

W. Zeiller







This secret lock, unlike a conventional code lock, gives away no hints to the unwanted visitor as to its existence: there are no buttons, switches or keypads. No code sequence need be learnt: you simply need an inconspicuous key.

The idea is based on two magnetically-operated switches which, when operated simultaneously, cause two relays to close. These in turn could actuate an electric door latch or start a garage door motor. This would not be particularly noteworthy (and rather easy to defeat) if simple reed switches were used, since they do not depend on the polarity of the magnetic field: they react equally to the north or the south pole of a magnet. Instead we use Hall effect ICs, which only react to south poles.

In this way the would-be intruder, carrying just a powerful permanent magnet in his pocket, is frustrated in his nefarious deeds: horseshoe and bar magnets do not have two south poles. And if that is not secure enough, you can always add further Hall effect ICs and relays: just like a lock with more levers.

The sensor used in the circuit shown in **Figure 1** is smaller than a transistor, and yet contains rather more: a unipolar sensing surface for the magnetic field, Hall generator and threshold generator, amplifier, Schmitt trigger and output transistor. With a field stronger than 20 millitesla the open-collector output transistor is turned on. The series-connected contacts of the 12 V miniature relays then complete the circuit via connection L. Relays with a coil current of 50 mA or less should be used in order not to overload the ICs.

The Hall effect ICs are fitted or glued at least 5 cm apart behind a sheet of glass, plastic or aluminium (perhaps the letterbox or doorbell), at most 4 mm thick, with the component marking towards the key. In no circumstances should iron or steel be used as these screen the sensors from the magnetic field. The sensors can either be wired to directly or fitted on a piece of perforated board. The position of the sensors should be suitably marked on the outside.

The simplest way to make a key is from a piece of square section wood in which two small holes are bored for two cylindrical magnets (as used with reed switches). The two magnets should be glued in the same way round, which can easily be tested by checking that the poles repel. Alternatively, of course, the magnets can be fixed in a flat plastic box using hot-melt glue. Remember that only one side of the key will open the lock.

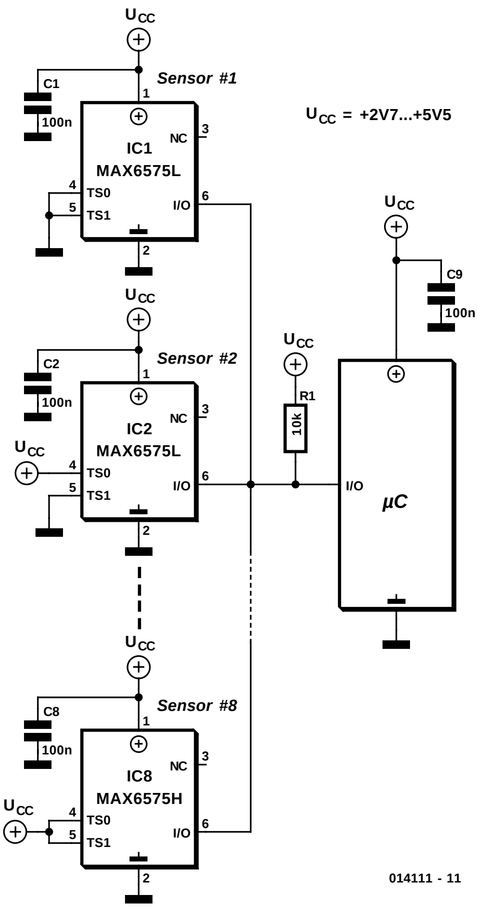
The secret lock can be safely used outside as long as it is fitted in a suitable watertight enclosure. It can save money compared to the services of a locksmith, and it will resist even the professional burglar. The lock is vandal-proof, operates independent of temperature, requires no battery in the key, can be cheaply extended and provided with any number of keys. The Hall effect ICs (Conrad Electronics order code 147508) are inexpensive. The operating voltage depends on the relays chosen, and should lie between 6 V and 24 V. The standby current for two ICs is about 7 mA at 12 V.

(000156-1)

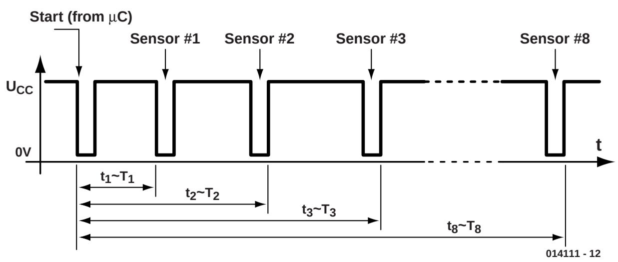
Temperature Sensor with Single-wire Digital Interface

037

1



2



A temperature measurement system with up to eight distributed temperature sensors can be realised using only a single signalling lead. This objective is supported by the Maxim MAX6575 temperature sensor (www.maxim-ic.com), which can be used to measure temperatures between –40 °C und +125 °C. It is housed in a small SMD transistor package (SOT23). As shown in **Figure 1**, all the ICs are connected to the signalling line via their open-drain input/output pins. Resistor R1 pulls the voltage on the signalling line to Vcc. The microcontroller can initiate a measurement cycle by placing a Low pulse on the signalling line for an interval of 2.5 µs to 1 ms. The MAX6575 ICs recognise this pulse, and each one starts a timer whose period is proportional to the temperature T*n* of sensor *n* (in degrees Kelvin). One of four different timer coefficients can be selected for each MAX6575 using the TS0 and TS1 inputs. The timing is illustrated in **Figure 2**.

In order to allow eight different sensor positions to be used, the MAX6575 comes in two versions: the H version and the L version. The table shows the configurable timer coefficients in microseconds per Kelvin for the two versions. As can be seen, overlaps in the pulse durations can occur in case of large differences between the temperatures of the individual sensors (e.g. sensor *n* at +125 °C, sensor *n*+1 at –40 °C). To the extent that such an unlikely situation can arise, it may be necessary to omit one of the timer regions, which would mean that the maximum number of sensors connected to a single line would be reduced to seven or six.

The temperature of sensor *n* in Kelvin is given by

T*n* = t*n* / M*n*

where

T*n* = temperature of sensor *n* in Kelvin;
t*n* = time between the Start pulse and the pulse from sensor *n*:
M*n* = temperature factor of sensor *n* in µs/K

The temperature can be converted to degrees Celsius using the formula

T*n* (in °C) = T*n* (in K) – 273.15 K

A new measurement requires the microcontroller to first generate a Reset pulse, which is a Low pulse with a duration of at least 4.6 ms so that it can be reliably distinguished from the Start pulse. The maximum allowable length of the Reset pulse is 16 ms. The MAX6575 also allows a new measurement to be made without a Reset pulse if the elapsed time since the previous Start pulse is more than 520 ms.

(014111-1)

TS1	TS0	MAX6575L	*tn* for –40°C to +125°C
GND	GND	5 µs/K	1.16 ms to 2.0 ms
GND	VDD	20 µs/K	4.66 ms to 8.0 ms
VDD	GND	40 µs/K	9.32 ms to 16.0 ms
VDD	VDD	80 µs/K	18.64 ms to 32 ms
TS1	**TS0**	**MAX6575H**	***tn* for –40°C to +125°C**
GND	GND	160 µs/K	37.28 ms to 64 ms
GND	VDD	320 µs/K	74.56 ms to 128 ms
VDD	GND	480 µs/K	111.84 ms to 192 ms
VDD	VDD	640 µs/K	149.12 ms to 256 ms

Wire Tracer (Transmitter)

038

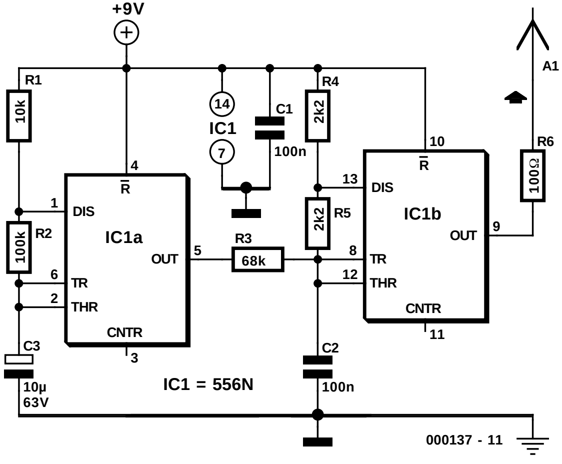
E. de Leeuw

The circuit depicted here forms one half of a device that will prove extremely handy when tracing the path of electrical wiring in a building or to locate a break in a wire. The system is based on similar equipment that is used by technicians in telephone exchanges.

The operation is straightforward. You require a generator that delivers an easily recognisable signal which, using a short antenna, is inductively coupled to a simple, but high gain, receiver.

To create a useful transmitter it would suffice to build a simple generator based on a 555. But as the adjacent diagram shows, a 556 was selected instead. The second timer (IC1a) is used to modulate the tone produced by IC1b. The output frequency alternates between about 2100 Hz and 2200 Hz. This is a very distinctive test signal that is easily distinguished from any other signals that may be present. Resistor R6 is connected to a piece of wire, about ten centimetres long, that functions as the antenna. The ground connection (junction C2-C3) is connected to ground.

When the antenna is connected directly to a cable, it is possible to determine at the other end of the cable, with the aid of the receiver, which conductor is which (don't do this with live conductors!).



The schematic for the matching receiver may be found elsewhere in this issue.

(000137-1)

Wire Tracer (Receiver)

039

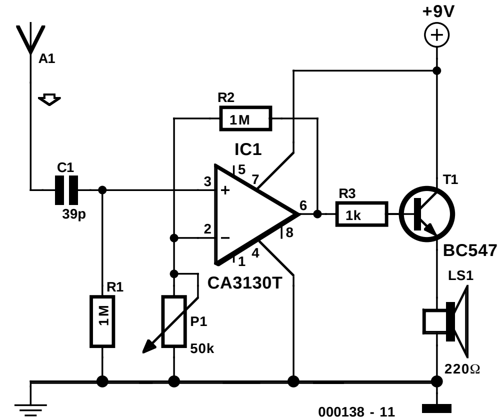
E. de Leeuw

The circuit depicted is the receiver device of a transmitter/receiver combination that will prove extremely handy when tracing the path of electrical wiring in a building or to locate a break in a wire.

The corresponding transmitter may be found elsewhere in this issue. The transmitter produces a distinctive tone which alternates between 2100 Hz and 2200 Hz.

The matching receiver for the wire tracer is possibly even simpler than the transmitter, as is shown by the schematic. It consists of no more than a short wire antenna (a piece of wire, 10 cm long is adequate), a high-pass filter (C1-R1), an amplifier stage (IC1), an output stage (T1) and a loudspeaker. The prototype used a high impedance loudspeaker from a telephone handset, and this worked remarkably well.

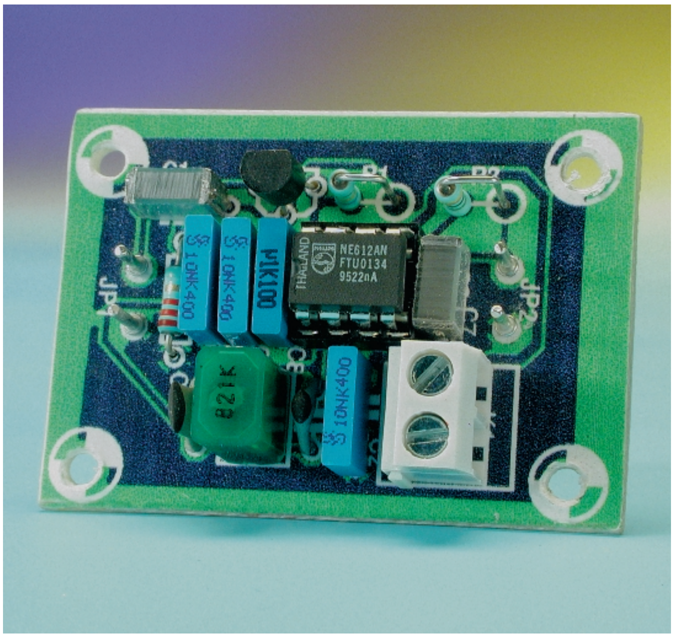
The purpose of P1 is to adjust the amplification. At the highest amplification, the wire energised by the transmitter can be traced from several tens of centimetres away. A

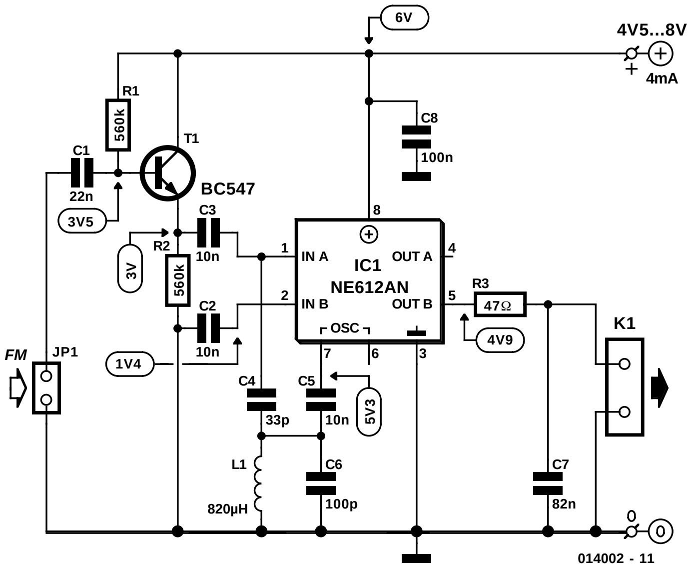


direct electrical connection is therefore not required. However, it is important that you hold the ground connection (earth) in your hand.

(000138-1)

Alignment-free FM Detector 040





G.Baars

This 455-kHz quadrature detector for narrow-band FM signals boasts two important advantages: it is pleasantly simple and it does not require any alignment.

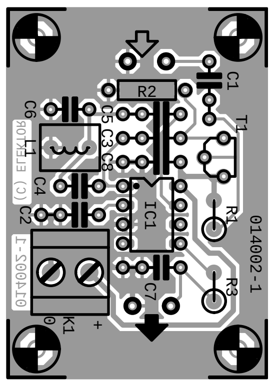
The heart of the circuit is formed by the well-known NE612 IC, which is a double-balanced mixer cum oscillator in an 8-pin DIL package.

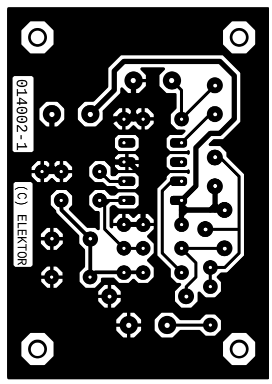
The signal is first buffered by T1 and then fed to the input of the NE612. At the same time, a small portion of the signal is passed to the mixer via a low-value capacitor (C4). The operation of the circuit is such that when the input frequency matches the resonant frequency of the parallel L-C network, the signal on pin 7 has a phase lead of 90 degrees with respect to the signal on pin 2. The phase angle increases when the input frequency rises and decreases when the input frequency drops. Since the signals on pins 2 and 7 are multiplied together, the average output level is maximum when the signals are in phase and zero when they are anti-phase. This is the operating point of the detector. Consequently, an input signal with a varying frequency produces an output signal with a varying level. The operating range of the detector is inversely proportional to the *Q* factor of the parallel resonant network.

This circuit works best with an input signal level of 0.5–2 V_{pp}. Since it is linear over a very wide range (420–500 kHz), it does not need alignment, and normal tolerance variations in the values of the inductance and capacitance in the resonant circuit have little effect. The output level varies by approximately 1 V over the working range, so the detection sensitivity is around 13 mV/kHz. This is adequate for most narrow-band FM applications with an intermediate frequency of 455 kHz.

The supply voltage may lie between 4.5 and 8 V. The current consumption is limited to approximately 2.5 mA. Using the small printed circuit board shown here, you should have no difficulty assembling this FM detector in less than half an hour.

(014002-1)





COMPONENTS LIST

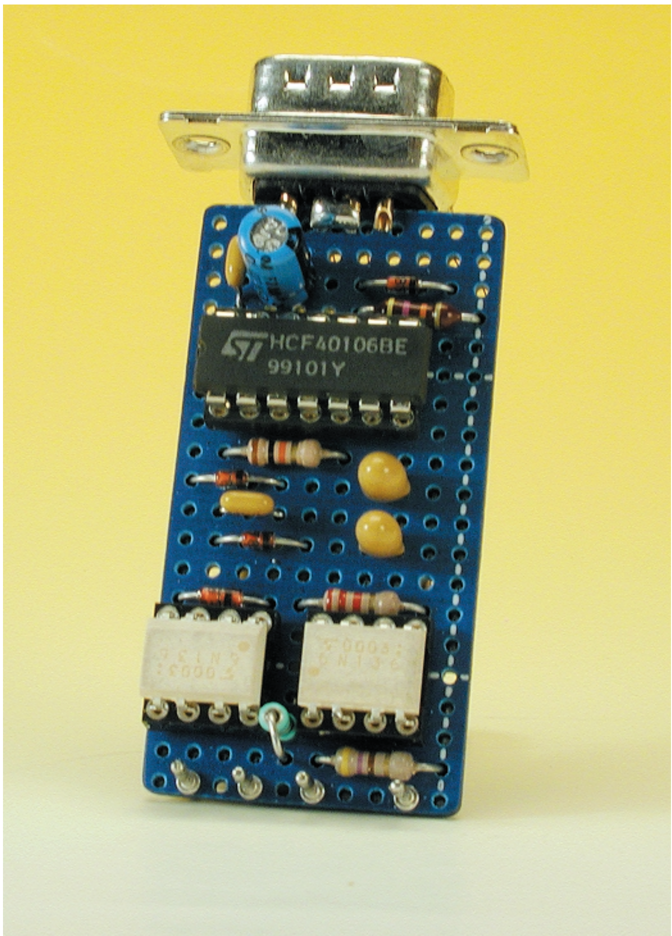
Resistors:
R1,R2 = 560kΩ
R3 = 47Ω

Capacitors:
C1 = 22nF
C2,C3,C5 = 10nF
C4 = 33pF
C6 = 100pF
C7 = 82nF
C8 = 100nF

Inductors:
L1 = 820µH

Semiconductors:
T1 = BC547
IC1 = NE612AN

Electrically Isolated RS232 Adapter 041



A. Schiefen

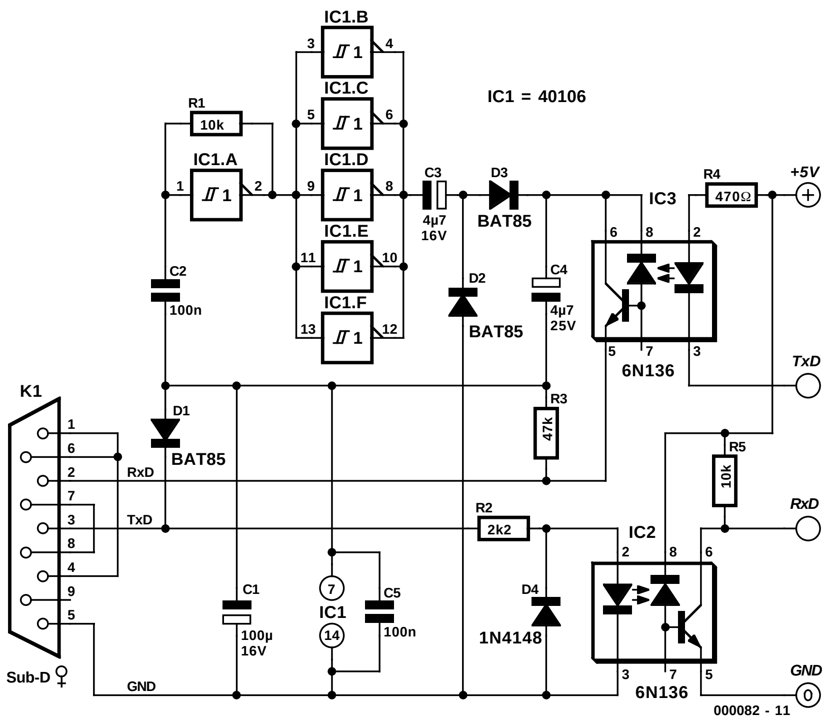
This circuit represents an interface converter between the UART pins of a microcontroller (with TTL levels) and a 'standardised' RS232 port with symmetric ±15-V levels. In contrast to the commonly used IC solutions such as the MAX232, it also provides electrical isolation between the two sides of the converter. This interface converter inverts the signals, so the usual inverters on the microcontroller side can (and must!) be omitted.

In most cases, the data lines RxD and TxD are all we need for communications with microcontroller systems. Fortunately, handshake signals are very seldom exchanged. The related RS232 leads are thus interconnected in such a manner that communications can take place without any problems.

All that is needed for the electrical isolation of a signal is an optocoupler. If the data flow from an external device to the microcontroller, the solution is easy. Since the RxD input of the microcontroller works with a +5-V level, all that we need is an optocoupler (IC2) whose LED is directly driven by the TxD output of the external device via resistor R2. This resistor also limits the current through D4 when TxD is inactive and thus has a negative level (usually around –9 V). During data transmission, the level of the pulses changes to around +9 V. The collector of IC2 is connected directly to the RxD input of the microcontroller. Resistor R5 is needed if microcontroller RxD input does not have an internal pull-up resistor. In any case, the microcontroller side of IC2 thus works with TTL levels.

If we now want to send data from the microcontroller to the external device, the microcontroller level (+5 V) must be converted into an RS232 level of at least +6 to +7 V. To achieve this, the negative voltage present at the RS232 TxD output is tapped off by D1 and buffered by C1, which acts as a storage capacitor. IC1 is a CMOS 40106 IC containing six inverting Schmitt triggers.

One of these Schmitt triggers (IC1a) is wired with C2 and R1 as an oscillator. It generates a frequency of around 1.5 kHz. This signal is fed to the other five Schmitt triggers, which are connected in parallel and act as a driver. They provide the necessary output current. When the output is Low, C3 charges to the supply voltage level via D2 (less the voltage drop across the diode). When the output changes to High, the voltage on C3 rises and adds to the voltage already present; D2 blocks and C4 is charged via D3 to nearly twice the



supply voltage. A voltage of around +9 V is thus available from C4, which is connected to the collector of optocoupler IC3. In principle, the voltage level at an RS232 interface should be +12 V to +15 V, but PCs can generally work with significantly lower voltages. Notebook computers in particular sometimes have a voltage of only +8 V.

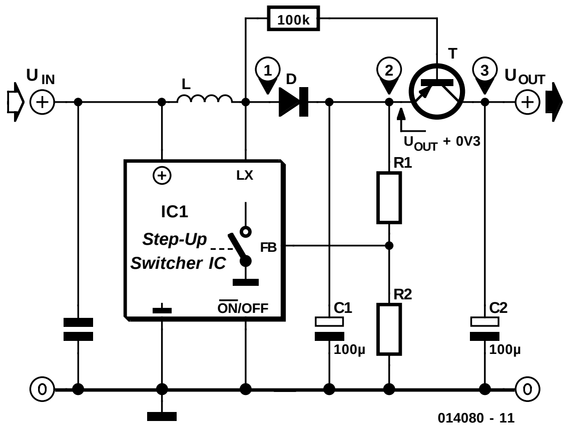
The emitter of IC3 leads to the RxD input of the RS232 port and is held at around –9 V by R3. When the microcontroller transmits data, the pulses from the TxD output of the microcontroller arrive at the LED of optocoupler IC3. The transistor of IC3 switched on and applies the positive voltage to the RxD input of the external device.

Normal diodes (1N4148) can also be used in place of the Schottky diodes, although the generated voltages will be somewhat lower. The 6N136 optocoupler is a high-speed type; normal optocouplers are not suitable. The circuit can theoretically transmit data at up to 57,600 baud, but in practice microcontroller circuits only use 9600 baud. These data transmission rates have been successfully used with both older-model and more recent notebook computers.

(000082-1)

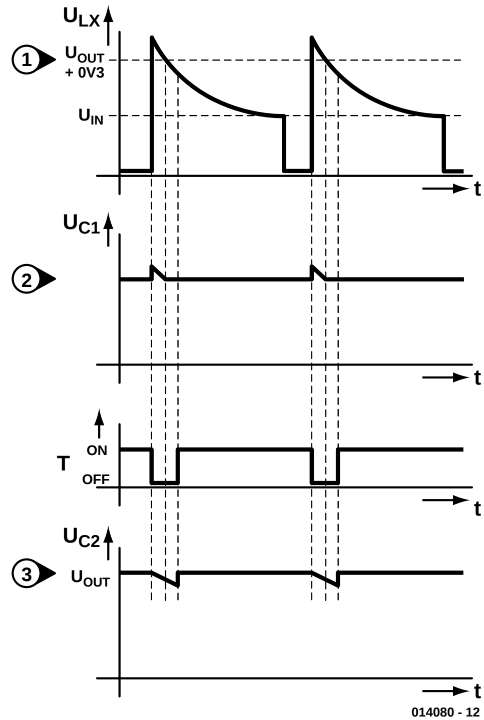
Output Cutoff for Step-Up Switching Regulator

042



Nowadays, there is a whole series of switching regulator ICs that work according to the step-up principle and thus convert the input voltage to a higher output voltage. This takes place using coil L, which is periodically switched to ground via the LX connection of the IC. This causes a magnetic field to build up in the coil L, and this field stores energy. When the step-up regulator IC switches off, the collapsing magnetic field in L forces the current to continue to flow. Now, however, the current must flow through diode D to the output capacitor and the external load connected to Vout. In this way, a voltage is generated that is greater than the input voltage. Resistors R1 and R2 form a voltage divider that is used to set the value of the output voltage, according to the formula shown. The value of V_{ref} is usually around 1.2 V.

One problem with the step-up regulator is that if the IC is inactive, there is always a current path from the input to the output via coil L and diode D. This means that the output voltage is not zero, but instead Vin. This problem can be eliminated with the aid of a simple transistor and a series base resistor. The pnp transistor, in this case a BCP69, is placed in series with the output circuit and periodically passes the dc output voltage of the switching regulator to output capacitor C2. The base of transistor T is connected via the series resistor R to the switch pin LX of the step-up regulator IC.



$$V_{out} + 0,3V = V_{ref} \cdot \left(1 + \frac{R1}{R2}\right)$$

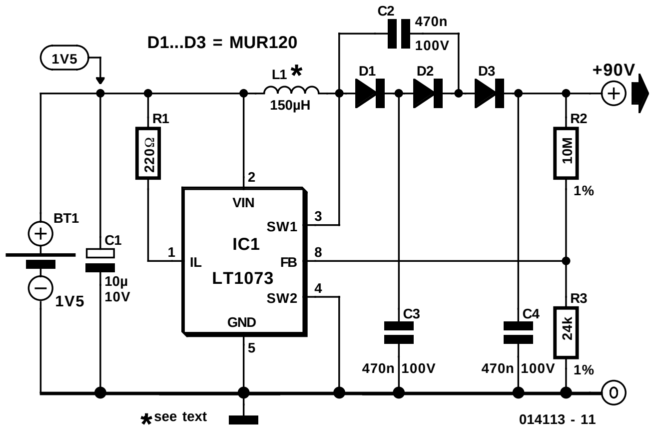
The voltage waveforms are shown in the diagram. Pin LX is periodically switched to ground. As soon as the switch goes open, a voltage pulse that adds to the input voltage appears at LX. Diode D conducts briefly and passes this voltage on to C1, which charges up to a voltage, determined by the voltage divider R1/R2, that is 0.3 V higher than the output voltage. The small charging peaks shown in curve 2 are not drawn to scale. If V_{LX} is more than 0.7 V lower than V_{C1}, transistor T conducts and passes the voltage across C1 on to C2. The small voltage sags shown in curve 3 are also not drawn to scale, for the sake of clarity. If the step-up regulator IC is disabled, the voltage across C1 will be only as high as the input voltage. This voltage is also present at LX, so there is not enough base bias voltage to switch on the transistor, and it is cut off.

(014080-1)

High Voltage Converter: 90 V from 1.5 V

043

The circuit shows one way of obtaining a voltage of 90 V from a 1.5 V battery supply. The LT1073 switching regulator from Linear Technology (www.linear-tech.com) operates in boost mode and can work with an input voltage as low as 1.0 V. The switching transistor, which is hidden behind connections SW1 and SW2, briefly takes one end of choke L1 to ground. A magnetic field builds up in the choke, which collapses when the transistor stops conducting: this produces a current in diode D1 which charges C3. The diode cascade comprising D1, D2, D3, C2, C3 and C4 multiplies the output voltage of the regulator by four, the pumping of C2 causing the voltage developed across C4 via C3, D2 and D3 to rise. Finally, the regulator control loop is closed via the potential divider (10 MΩ and 24 kΩ). These resistors should be 1 % tolerance metal film types. With the given component values, fast diodes with a reverse voltage of 200 V (for example type MUR120 from On Semiconductor www.onsemi.com) and a choke such as the Coilcraft DO1608C-154 (www.coilcraft.com) an output



voltage of 90 V will be obtained. The output of the circuit can deliver a few milliamps of current.

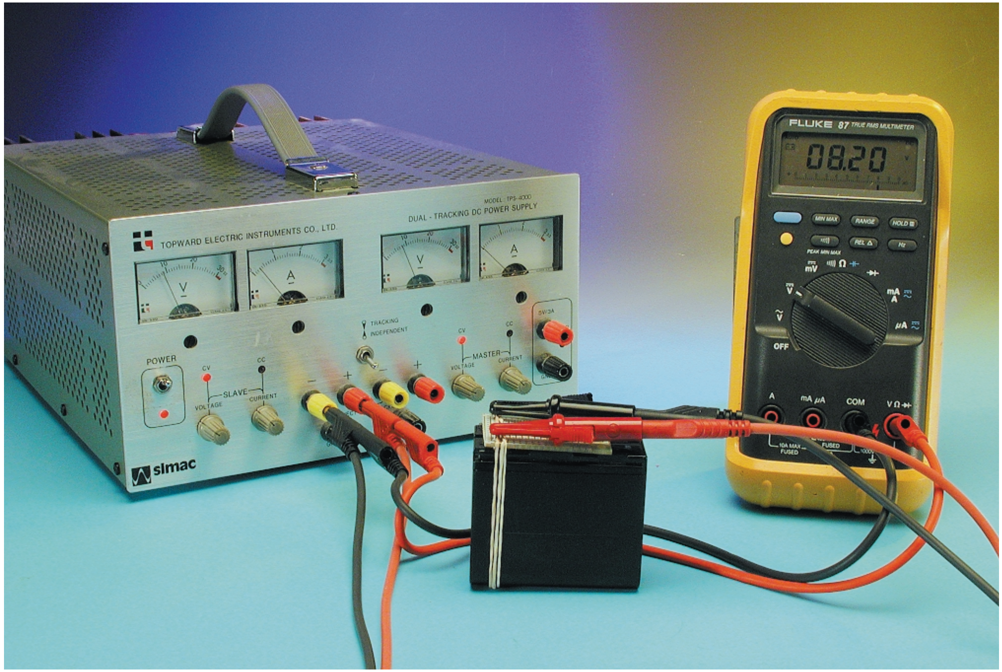
(014113-1)

Lithium-Ion Charger II

044

In the December issue we'll describe a fancy Li-Ion charger based on a specially designed IC and boasting many bells and whistles. However, it can also be done in a much simpler way, provided you are prepared to work carefully. The latter is particularly important, because we will point out again that charging Li-ion batteries with a voltage that is too high can cause explosions! In this respect Li-ion batteries are not the least comparable with the much less critical NiCd- or NiMH-types.

Li-ion batteries may, just like lead-acid batteries, be charged with a constant voltage. The charging voltage for a 3.6 V cell is 4.1 V **maximum**, and for 3.7 V cells this is 4.2 V. Higher voltages are **not permissible**; lower voltages are, but every 0.1 V results in a reduction of capacity of about 7%. As a consequence, great precision is required and it is therefore highly recommended to measure the output voltage with an accurate (less than 1% error) digital voltmeter. A good stabilised lab power supply is in principle perfectly suited as a Li-Ion charger. Adjust it to 4.1 V (or 8.2 V if you are charging two cells in series) and also adjust the current limiting to an appropriate value, 1 *C* for example (where *C* is the capacity, e.g.,. 1 A for a 1 Ah battery). A too low value



is preferred over one that is too high; when the value is a little low it will simply take a little longer to fully charge the battery, but it makes no difference otherwise. Li-Ion batteries are not suitable for high currents, so limiting the value to 1C is a safe maximum.

You can now connect the battery. If the battery is discharged, the power supply will deliver the maximum adjusted current at a voltage less than 4.1 V. As the battery is charging, the voltage will rise. Once the value of 4.1 V is reached, the voltage will cease to rise and the current will begin to fall. When the current is less that 0.2 of the adjusted value, the battery can be considered charged. It is not a disaster if the battery is connected for longer; overcharging is not possible provided the voltage is less than 4.1 V per cell.

Keep children, cleaning housewives, pets and other possible disturbances away to avoid an inadvertent change of the voltage knob. It may not be a silly idea to provide the adjustment knob of the power supply with some method of mechanical locking.

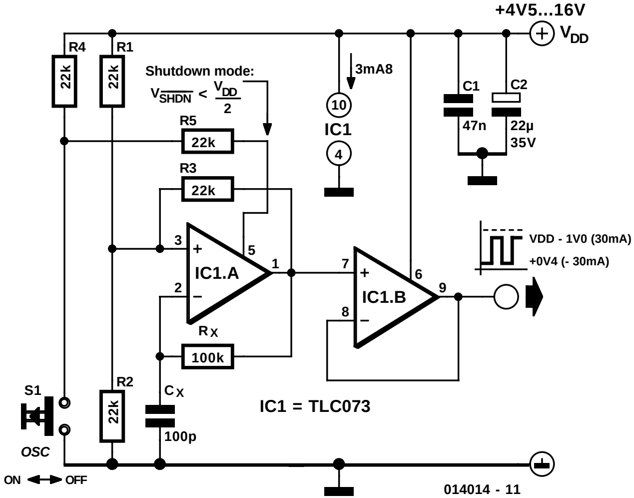
Note. Although they can hardly be called new, Li-Ion batteries are still difficult to obtain as spare parts. It may be a useful hint to also look at replacement batteries for camcorders and laptops as in these applications Li-Ion batteries are very common.

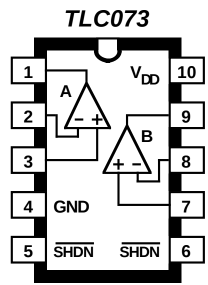
(014133-1)

Squarewave Oscillator Using TLC073

045

K. Thiesler





The new range of low-noise, high-speed and low-distortion BiMOS op-amps from Texas Instruments, type TLC070 to TLC075, is intended for use in instrumentation, audio and automotive applications. This oscillator is an ideal example of its application: a stable, highly accurate squarewave at frequencies up to 60 kHz can be produced with an output current of ±30 mA.

The TLC073, a dual op-amp with shutdown function, is used here. IC1a is configured as a standard squarewave generator, IC1b as a driver. The frequency of oscillation depends on Cx and Rx and is calculated (for frequencies up to 20 kHz) as follows:

$$f = \frac{1}{\frac{1}{7000} \times \sqrt[3]{Rx \times Cx} + \sqrt{2} \times Rx \times Cx}$$

where Rx is measured in Ohms and Cx in Farads.

The table shows preferred values that give various frequencies. Note that the frequency variation is largely determined by the capacitor, since Rx must always be significantly larger than feedback resistor R3. The effect of supply voltage, at –130 dB, is negligibly small, and the temperature coefficient of frequency is very low: only 1.5 %. At frequencies above 20 kHz the oscillator remains stable, but increasingly non-linear.

The mark-space ratio of the signal can be adjusted in the range 10% to 90% by changing the ratio of resistors R1 to R2. If the two resistors are equal, the output is symmetrical. The output of the driver swings between +0.3 V (low) and 1 V below the supply voltage (high).

The oscillator is switched on and off via the shutdown input of IC1a. The output of the opamp goes to high impedance and the current consumption drops to 35 nA.

The oscillator can of course be built using the common or garden TL071 (U_b = 7 V, U_{out} = 1.2/6.2 V, I_{out} = 1.75 mA, f_{max} = 50 kHz). As can be seen, the output drive capability is rather lower.

(014014-1)

BiMOS opamp family TLC07x

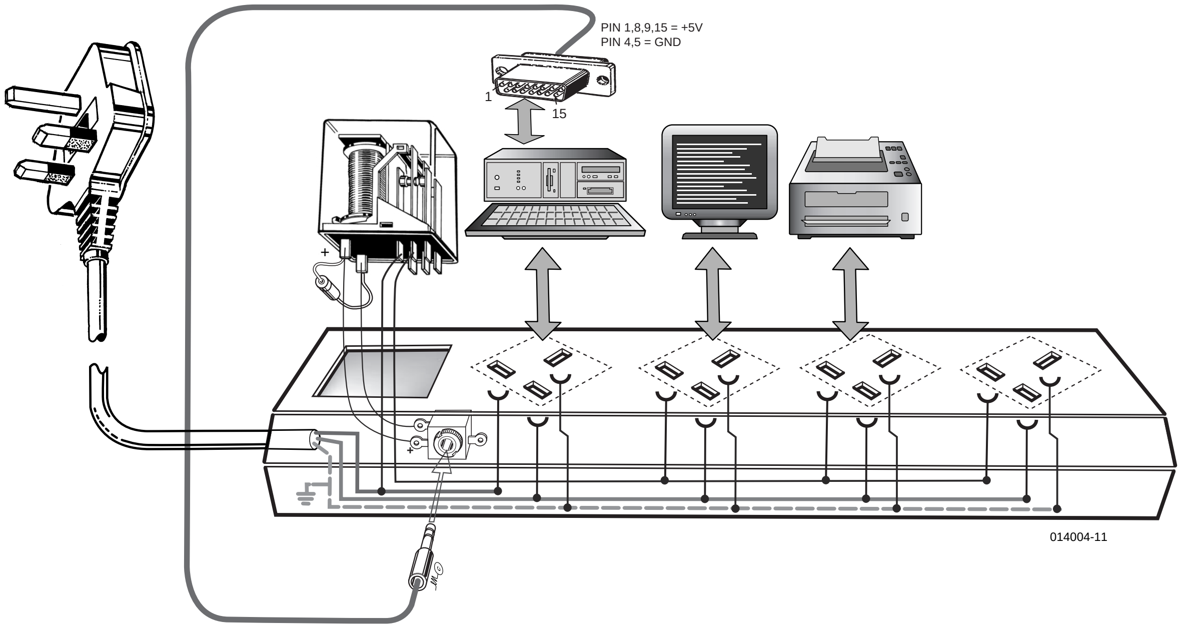
The new family of BiMOS opamps types TLC070 to TLC075 replaces the older TL070 family of BiFET amplifiers. The new components incorporate some significant advances:

- Very low noise (7 nV/√Hz)
- Low harmonic and non-harmonic distortion (0.002 %) at A = 1
- Bandwidth 10 MHz, slew rate 16 V/µs
- Input quiescent current only 1.5 pA
- Offset voltage 60 µV
- Output current ±50 mA
- Supply voltage rejection –130 dB
- Quiescent current consumption 1.9 mA per opamp
- Symmetric (±2.25 to 8 V) or single supply voltage (+4.5 to16 V)
- Shutdown function for each opamp (TLC070, TLC073 and TLC075 only)
- Single, dual and quad opamps available in DIP, SO and TSSOP packages

f	60 kHz	10 kHz	6 kHz	3 kHz	400 Hz	50 Hz
Cx	100 pF	680 pF	1 nF	1 nF	10 nF	68 nF
Rx	100 kΩ	100 kΩ	100 kΩ	220 kΩ	180 kΩ	220 kΩ

Computer Off = Monitor Off

046



P. van Geens

Older PCs had, despite their slowness and other shortcomings, in comparison with their modern descendants at least one important advantage: they almost universally were fitted with a switched mains output socket for the monitor. The main power switch on the PC controlled this socket, therefore: computer off = monitor off!

Modern PCs make use of a 'soft' power switch, which puts the power supply in standby mode only; as a consequence the switched mains output on the back of the power supply is usually omitted. Progress therefore, compels the user once again, to separately switch off the monitor by hand. Naturally, this is often forgotten.

Fortunately, there is an easy way to do something about this. It so happens that when the PC is switched on, a potential of +5 V is present at the game port. Therefore, it is enough to simply tie a relay to this signal, which then switches the monitor (and printer, etc.). This uncomplicated relay circuit restores an old convention: computer off = monitor off!

(014004-1)

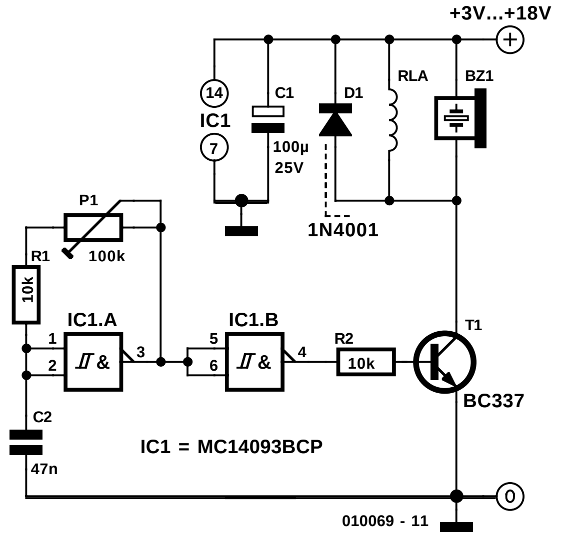
Piezo Amp

Rev. T. Scarborough

This circuit takes advantage of back-e.m.f. (electromotive force) to amplify the voltage across a piezo sounder. Ordinarily, IC1 would only achieve a gentle beep. However, the addition of a very high inductance choke of a few Henry — in this case the coil of a miniature reed relay is used — achieves a penetrating screech, and represents an easy method of obtaining considerably more volume in such a circuit.

The usual protective diode (D1) may be included across the choke, at the expense of a little volume. In practice, it was found that no harm was done by omitting D1. The operating voltage of the relay is immaterial, as long as it is not less than the supply voltage. Preset P1 should be adjusted to find the piezo sounder's resonant frequency. A higher supply voltage means greater volume — as long as T1's ratings are not exceeded.

(010069-1)



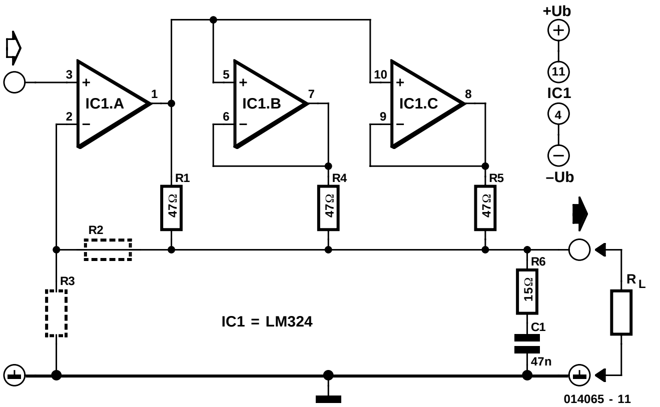
Parallel Opamps

048

National Semiconductor application note

Some applications notes are real evergreens. This one originally dates from 1979(!) but has lost nothing of its relevance and is always very interesting when you're looking for something like this.

Opamps can only deliver a limited current; typically only about 10 mA max. When more current is required, several opamps can be connected in parallel. But this usually doesn't work very well because opamps are never 100% equal. In practice they will fight each other and only get warm, which was not the intention of course.



In the adjacent application note, IC1a is the boss and is supported by IC1b and IC1c or as many stages as you require. IC1a delivers, via R1, current to the load R_L. The ‘helper-opamps’ are connected to the voltage drop across R1. This way they will all deliver an identical current, because the resistors R4 and R5 have all the same values. Make sure that the whole thing does not oscillate — the addition of an RC-network R5-C1 across the load can work wonders.

The circuit can be used with symmetrical or single-ended power supplies. In the latter case you will have to connect the negative lead of the power supply to 0 V.

IC1a may also be configured as an amplifier. In this case you will have to add the dotted resistors. To obtain unity gain, omit R3 and use a wire link for R2.

(014065-1)

Dual Switching Regulator

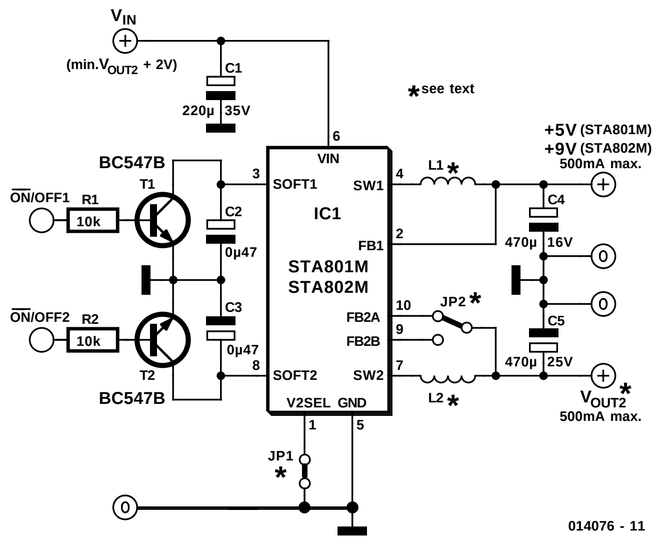
049

There are presently many switching regulator ICs. However, the STA801 and STA802 provide two switching regulators in a single package, each capable of supplying a maximum current of 0.5 A. Each device in the Allegro Microsystems STA800 series (www.allegromicro.com) contains a first step-down switcher with an output voltage of +5 V (STA801M) or +9 V (STA802M) and a second switcher that can be jumper-programmed for an output voltage of +9 V, +11.5 V, +12 V or +15 V. Jumpers 1 and 2 in the schematic diagram must be installed according to the table to achieve the desired output voltage.

The input voltage must be at least 2 V greater than the output voltage. The storage inductors L1 and L2 have values of 100 µH for a +5-V output and 150 µH for output voltages between 9 V and 15 V. Capacitors C1 and C2 are Softstart electrolytics, which cause the output voltages to ramp up gradually. Each of the converters can be disabled via transistors T1 and T2 respectively (High = shutdown).

The STA800 components described here may be obtained from Spoerle distributors, see www.spoerle.com. Suitable inductors can be found in the Coilcraft DO3316 series, for example (www.coilcraft.com).

(014076-1)



Jp1	Jp2	STA 801M	STA 802M	required Vin
open	Pin 9	9,0 V	9,1 V	> 11 V
open	Pin 10	11.5 V	11.7 V	> 14 V
closed	Pin 9	12.1 V	12.1 V	> 14 V
closed	Pin 10	15.5 V	15.7 V	> 18 V

Transistor Tester

050

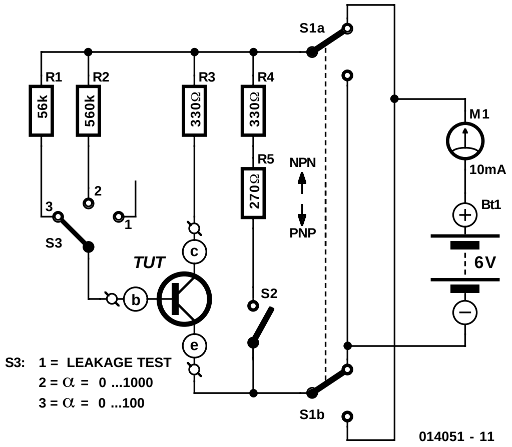
H. Kemp

This tester is intended to quickly check whether a transistor is functional or not and possibly also select two or more transistors with (approximately) equal gains. This is about the simplest conceivable test circuit, so don't expect super accuracy. The circuit has been designed only to quickly carry out a brief check, when there is no time or equipment to carry out a thorough test.

The operation is simple: in the position 'battery test' (S2 closed), the 10 mA moving coil meter M1 in series with a 600 Ω resistor (R4 + R5) is connected to a 6 V battery. A current of 10 mA will flow, resulting in full-scale deflection of the meter.

When a transistor is being tested (S2 open, S3 in position 2 or 3) a current will flow through the base-emitter junction of the transistor under test, the value of which can be computed by dividing the voltage across R1 or R2 by its resistance. With S3 in position 2 this will be (6 V – 0.6 V)/560 kΩ = approx. 10 µA. If the transistor has a gain of 1000 it will cause a collector current (and therefore a meter current) of 10 mA, causing full-scale deflection of the moving coil instrument. Therefore, the value indicated by the meter, when S3 is in position 2, has to be multiplied by a factor of 100 to obtain the gain of the transistor. In position 3 the base resistor is 10 times lower (R1 = 56 kΩ), so in this case the reading has to be multiplied by 10 to obtain the gain.

It will be clear that position 2 of S3 is intended for high gains of up to 1000 and position 3 for gains of 0 to 100. The purpose of S1 is to reverse the polarity: the upper position drawn is for NPN transistors, the bottom for PNP types. If you have no moving coil instrument available, it is of course also possible to replace M1 with a digital meter.

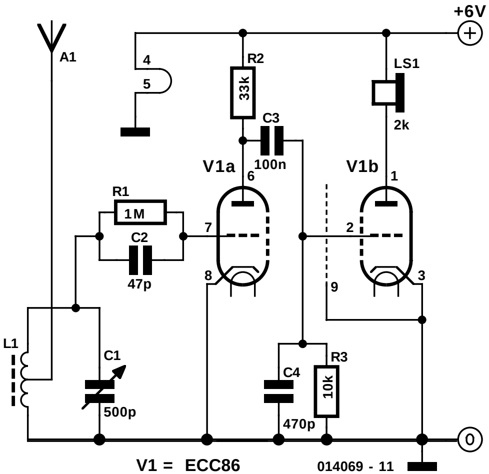


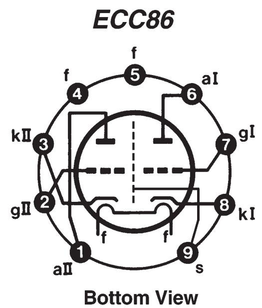
(014051-1)

ECC86 Valve Radio

051

B. Kainka





Actually, the age of valves is already past — but valves just refuse to go away! There's many a valve radio still in use, and there are many valves lying in the 'junk box' waiting to be rediscovered. If only we could do without the high voltages! However, there is a valve that can manage with only 6 V — the ECC86. At the beginning of the 1960s, the electronics industry was faced with a problem. The transistor had just been born, so it was finally possible to build car radios without vibrators and large transformers. However, the cut-off frequencies were still too low to allow usable VHF mixer stages to be built using transistors. This meant that a valve had to be used in a transistor circuit. This valve was the ECC86, which was intended to be used for short wave input stages and self-oscillating mixer stages in car receivers powered directly from the car battery. According to the data sheet, an anode voltage of 6.3 V or 12 V may be used. The heater voltage is always 6.3 V. We owe the ECC86 low-voltage valve to this unique bottleneck in the history of electronics technology.

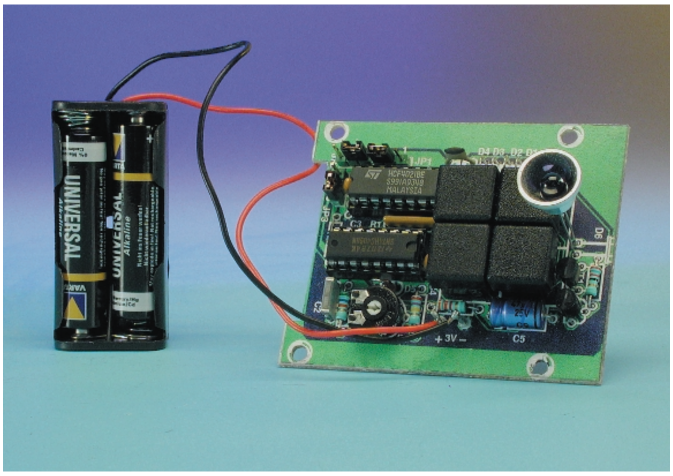
Our circuit is a nearly classical valve audion for the medium-wave range. Power is supplied by a 6-V lead-acid gel battery. The circuit is nearly the same as that of a two-stage amplifier. The first stage provides the demodulation and preamplification. The second stage is the audio output amplifier, which directly drives a headphone with an impedance of 2 kΩ. A 500-pF capacitor between the two stages ensures that RF signals will not be further amplified. Otherwise the valve might easily recall its original intended use and start oscillating in the short-wave range. A ferrite rod with a diameter of 10 mm and a length of 100 mm, with a winding of 50 turns of enamelled copper wire, serves as the aerial.

The radio has a good sound and can receive local signals. In the evening, with a sufficiently long external aerial, it can receive numerous MW stations. It feels just like being back in the good old days.

(014069-1)

Simple IR Transmitter

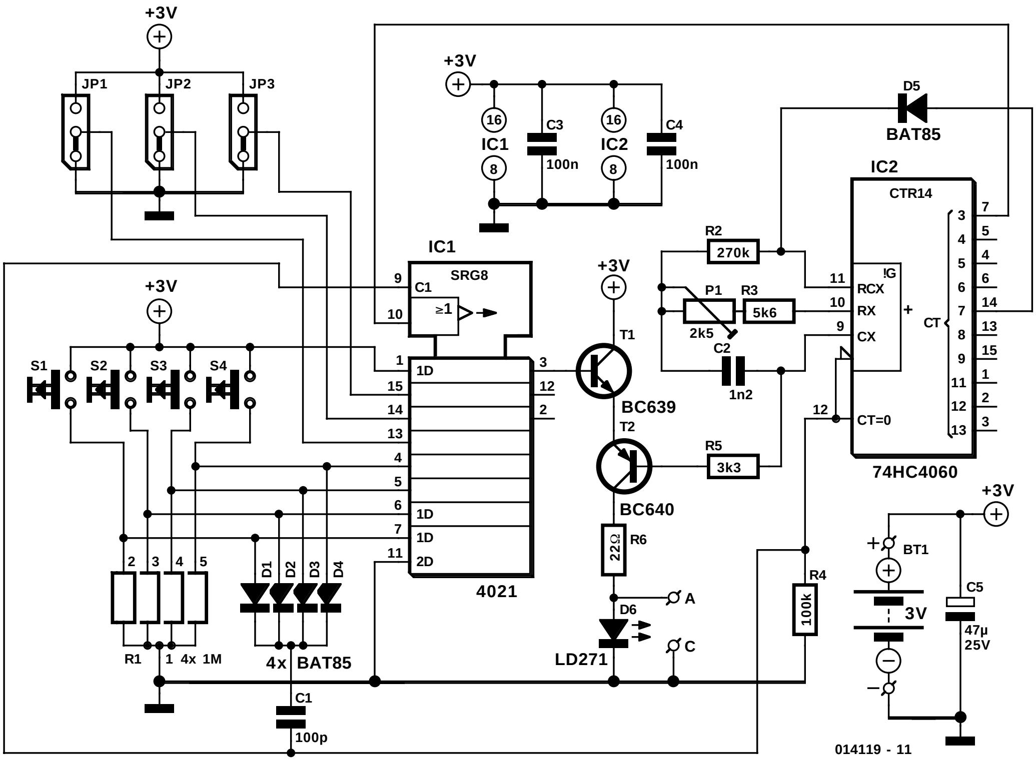
052

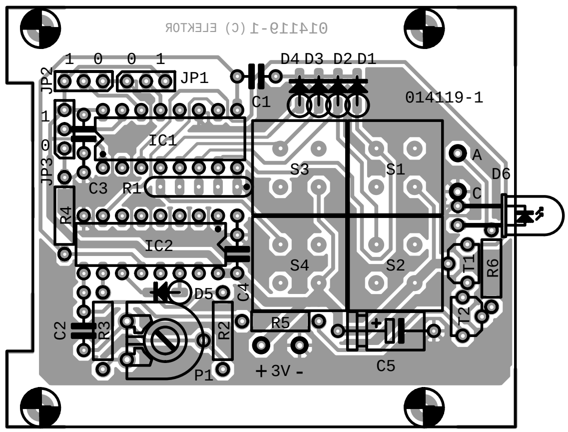


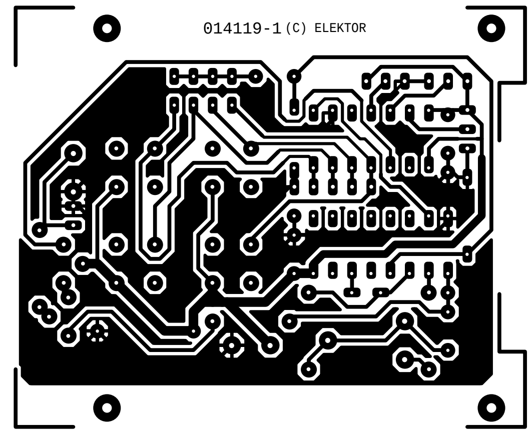
This circuit uses just two standard logic ICs which, with the accompanying receiver, forms a four-channel remote control and has been designed for use with the 'Audio/Video Switch' and the 'Switchbox for Loudspeakers' (shown elsewhere in this issue, as is the IR Rreceiver).

Each pushbutton is connected to an input of a shift register (4021), which is clocked by a binary counter/oscillator (74HC4060). A cycle is started via one of the diodes connected to each pushbutton and a differentiator-network (C1/R4), creating a short pulse that is fed to the shift register and counter/oscillator. The parallel-load input at the shift register then becomes momentarily active, causing the shift register to latch the data at the parallel inputs. At the same time, since the pulse is very narrow, one of the four pushbutton inputs will be high (in spite of any longer pulses that may be caused by switch bounce). The pulse also goes to the reset input of the 4060 and starts the oscillator.

The oscillator around P1/R2/R3/C2 is set to about 36 kHz because IR receiver modules are widely available for this frequency. Pin 7 is the Q3-output of the 4060 and clocks the shift register. The data at the parallel input is now output in a serial format at QH (pin 3). When QH is high the emitter of T2 is made high via T1, and a pulsed current at 36 kHz will flow through LED D6 via R5 and T2. Pin 1 (MSB) of the 4021 is permanently high and is clocked first to the output. This bit functions as the start-bit for the receiver. Since the receiver clocks the data on the rising edge, the start-bit has a length of only 8 cycles at 36 kHz. The rest of the data is modulated at 16 cycles per bit. Output Q7 (pin 14) of the 4060 is connected to the oscillator via a diode, which causes the oscillator to stop after 8 clock cycles of the Q3 output (pin 7) and the circuit becomes idle. The relevant code is therefore sent only once for every button press. A new code will only be transmitted when a pushbutton is pressed again. The only current drawn now are various leakage currents and the current through D5/R2/P1/R3 which is about 10 µA. So even without an on/off switch the







COMPONENTS LIST

Resistors:
R1 = 4-way SIL array 1MΩ
R2 = 270kΩ
R3 = 5kΩ6
R4 = 100kΩ
R5 = 3kΩ3
R6 = 22Ω
P1 = 2kΩ5 preset H

Capacitors:
C1 = 100pF
C2 = 1nF2, MKT
C3,C4 = 100nF ceramic
C5 = 47µF 25V axial (lead pitch 12.7 mm)

Semiconductors:
D1-D5 = BAT85
D6 = LD271
T1 = BC639
T2 = BC640
IC1 = 4021
IC2 = 74HC4060

Miscellaneous:
JP1,JP2,JP3 = 3-way pinheader with jumper
S1-S4 = pushbutton, 1 make contact, PCB mount,e.g., D6-Q-BK-SWITCH + D6Q-BK-CAP (ITT/Schadow)
BT1 = 2 x mini penlite battery (AAA) with holder
Enclosure, e.g., Conrad Electronics #52 28 64-24 (dim. 101x60x26 mm)

batteries should last for years (assuming a capacity of 750 mAh for AAA cells).

P1 has been added to compensate for the various component tolerances and to tune the transmitter and receiver to each other. JP1, JP2 and JP3 are a bonus and can be used for addressing purposes or for a possible expansion with more pushbuttons. At the receiver side these bits are made available on three outputs. The PCB has been designed to fit inside a plastic box with an integral battery compartment (see parts list). If required, the PCB can be made a bit smaller by cutting off the blank areas (where the mounting holes are). That makes it possible to use a smaller enclosure, especially if a 3 V lithium cell is used for the supply.

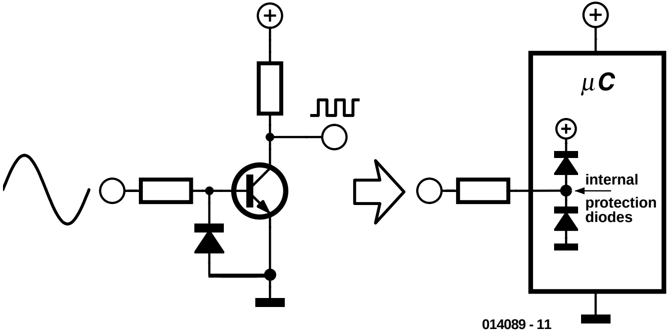
(014119-1)

Zero-Crossing Detector for Microcontrollers

053

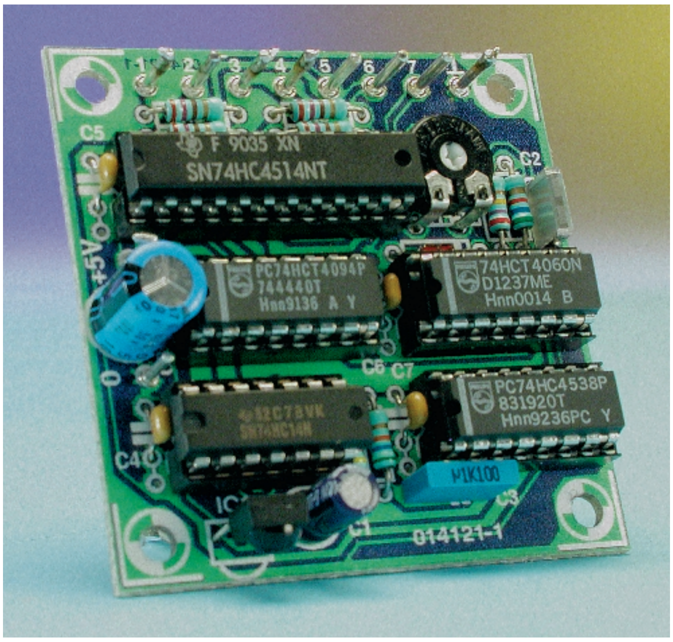
In lighting controllers and clock circuits that need the mains frequency as a parameter for evaluations carried out within a microcontroller, you will often find a transistor stage to convert the mains voltage (reduced by the transformer) into a 50-Hz squarewave signal that is suitable for input to the microcontroller. Generally speaking, this stage is unnecessary with modern microcontrollers if the port input is wired as a Schmitt trigger. The only additional component that is needed is a resistor to limit the port current to a safe value, as specified by the data sheet. The Schmitt trigger ensures reliable edge detection by the software.

(014089-1)



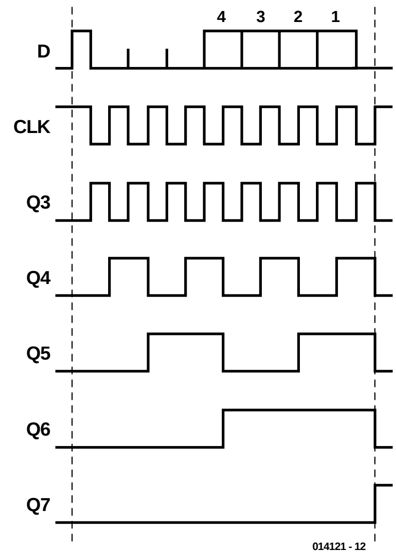
Simple IR Receiver

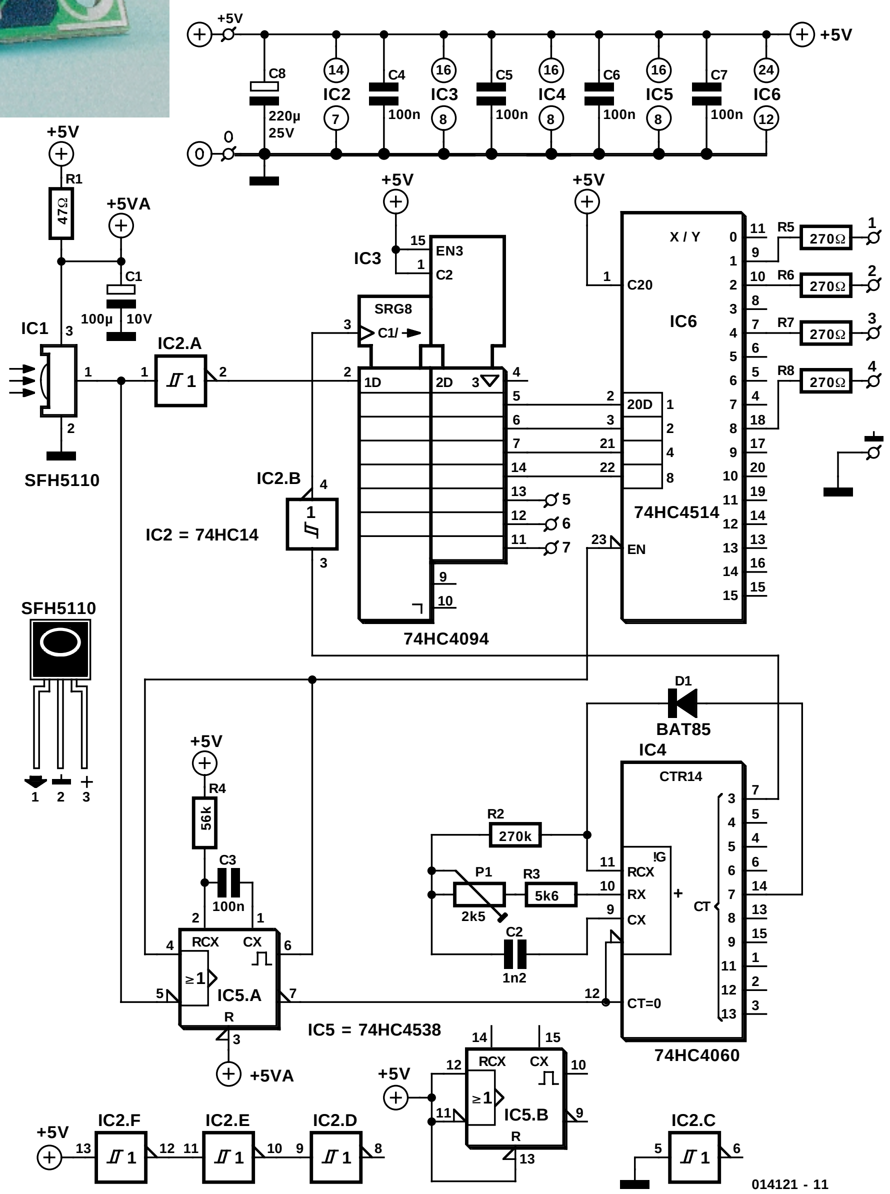
054



This circuit has been designed to complement the 'Simple IR Transmitter' and to decode its transmitted signals. The similarity to the transmitter can be clearly seen: the received data is decoded by a shift register (74HC4094), which again is clocked by a counter/oscillator (74HC4060). The receiver is started by the first edge from the IR-receiver module, which triggers monostable IC5a. The output of the module is active-Low, so the negative trigger input is used. The monostable used is a 74HC4538, which is re-triggerable. By connecting the Q-output to the positive trigger input, IC5 is prevented from being triggered whilst it has an active output.

When IC5a is active, the $\overline{Q}$ output clears the reset input of IC4, thereby enabling it. The oscillator is again tuned to 36 kHz, making the clock from Q3 of the 4060 to the shift register run almost synchronously with the clock of the transmitter. By tying the strobe and output-enable of IC3 to logic '1', the internal latch becomes transparent and its outputs are always enabled. The received pulses are inverted by IC2, as otherwise outputs 5/6/7 would be active low. At first sight outputs 1/2/3/4 could have been simply connected to the other outputs. Instead, these four outputs are fed to a 4-to-16 demultiplexer, making sure that there can



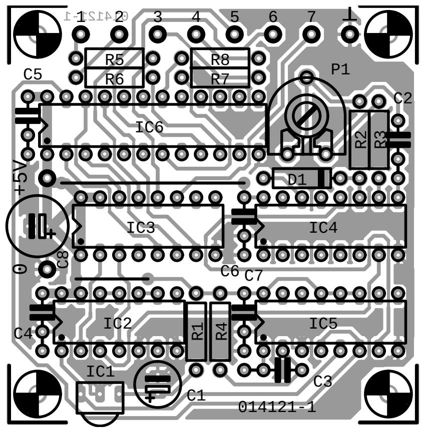


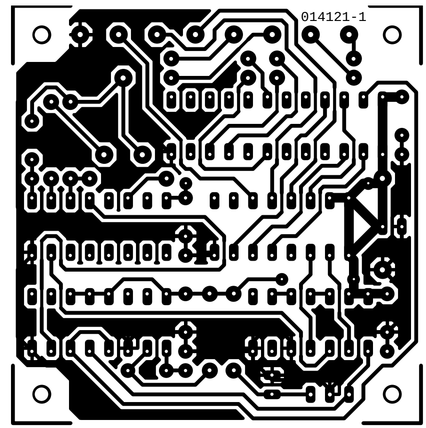
never be more than one active output. In case of the ‘Switchbox for Loudspeakers’, when several amplifiers are connected to a loudspeaker, there can never be a short circuit, or conversely, an overload of the amplifier. For this reason the ‘inhibit’ is also connected to the output of IC5a, stopping any transient pulses from appearing at the outputs during the clocking in of the data and giving time for the relay contacts to release before another relay is activated (break-before-make).

The pulse-width of monostable IC5a is slightly longer than that required to deal with the data (3.9 ms). Depending on the relays used, it may be advisable to increase this time a little (by increasing the value of R4). This time has to be greater than the difference between the operate and release times. Normally the release time is less than the operate time, but better safe than sorry. Signal Q3 from IC4 is inverted by IC2b, causing the data to be clocked halfway through the period that a bit is active. The four outputs of the demultiplexer are therefore suitable for the ‘Switchbox for Loudspeakers’ or the ‘Audio/Video-Switch’, which can also be found in this issue.

In standby mode this circuit has a current drain of only 3 mA. The resistors in series with the outputs are there for protection against an overload or short circuit. When the receiver is used to drive the ‘Audio/Video-Switch’, The output voltage drops to 4.2 V when three boards are driven in parallel, which is still sufficient to activate the relays. When more boards are driven in parallel, for example six are required for 5.1 surround, then the values of R5-R8 should be at least halved.

(014121-1)





COMPONENTS LIST

Resistors:
R1 = 47Ω
R2 = 270kΩ
R3 = 5kΩ6
R4 = 56kΩ
R5-R8 = 270Ω

Capacitors:
C1 = 100µF 10V radial
C2 = 1nF2
C3-C7 = 100nF ceramic
C8 = 220µF 25V radial

Semiconductors:
D1 = BAT85
IC1 = SFH5110 (IS1U60, TSOP1836)
IC2 = 74HC14
IC3 = 74HC4094
IC4 = 74HC4060
IC5 = 74HC4538
IC6 = 74HC4514

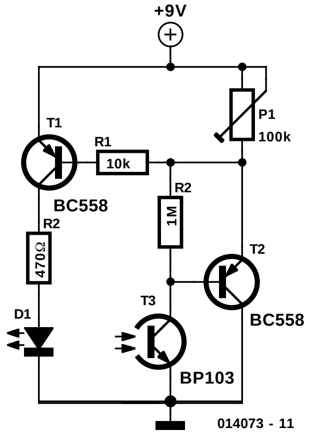
Simple Remote Control Tester 055

F. Jensen

Nearly always when a remote control doesn't work, the underlying problem is elementary: the unit does not emit light. The cause may be dry solder joints, defective LEDs etc., but also a flat battery (perhaps due to stuck key).

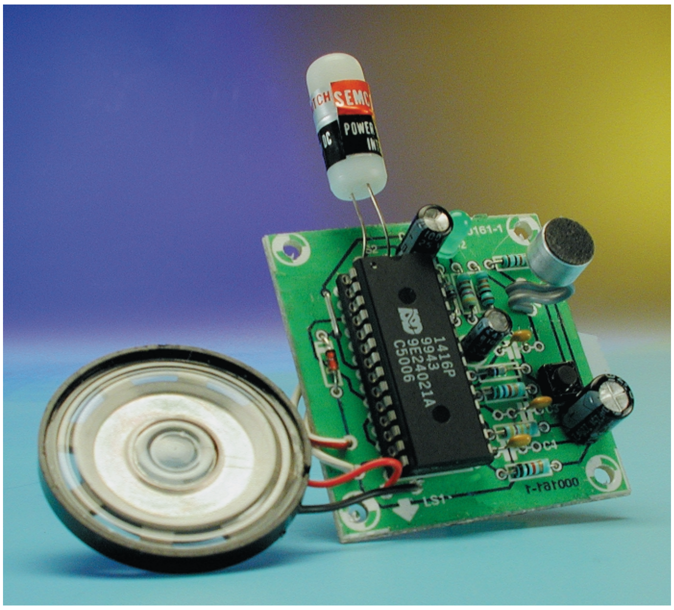
The human eye is unable to perceive infra-red light. By contrast, an ordinary photo transistor like the BP103 has no problems working in the infrared spectrum, so in the circuit here it simply biases the BC558 which, in turn, makes LED D1 flash in sympathy with the telegram from the remote control. The preset in the circuit determines the sensitivity.

(014073-1)



Integrated Voice Memory

056



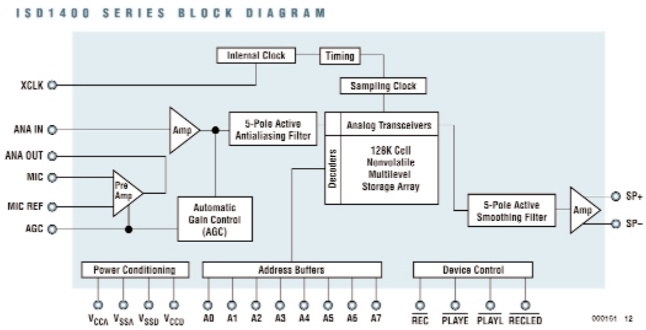
Features of the ISD1416

– High quality recording and playback
– 16 s recording time
– Edge- or level-sensitive playback control, allowing push button operation
– Automatic power down
– Power down current consumption about 1 µA
– Non-volatile memory
– Memory retention: typically 100 years
– Typical life: 100,000 record cycles
– On-chip clock generation
– Operating voltage: 4.5 V to 6.5 V

There are lots of exciting applications for a voice memory. The circuit presented here has been installed in the author's toilet in order to advise potential users of the facilities to do so sitting down rather than standing! A mercury tilt switch detects when the seat is lifted and activates the (remotely connected) voice memory: the admonitory text can be chosen at the whim of the householder.

At the heart of the circuit is a voice memory device from ISD (Integrated Storage Devices, now part of Winbond), which is also used in various answering machines and clocks made by Braun. The data sheet is in three parts

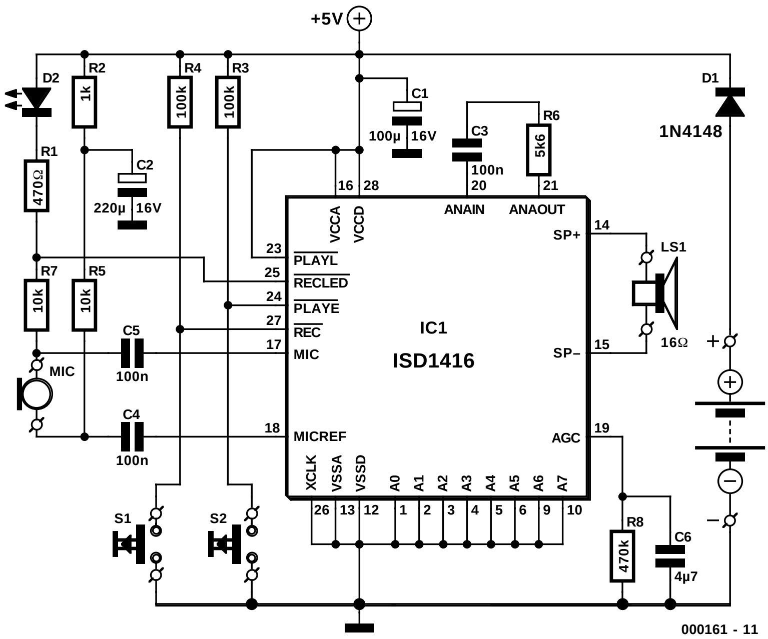
1



(...1400_1.pdf, 1400_2.pdf, 1400_3.pdf) and can be downloaded from the Winbond website at

http://www.winbond-usa.com/products/isd_products/chipcorder/datasheets/1400/1400_1.pdf

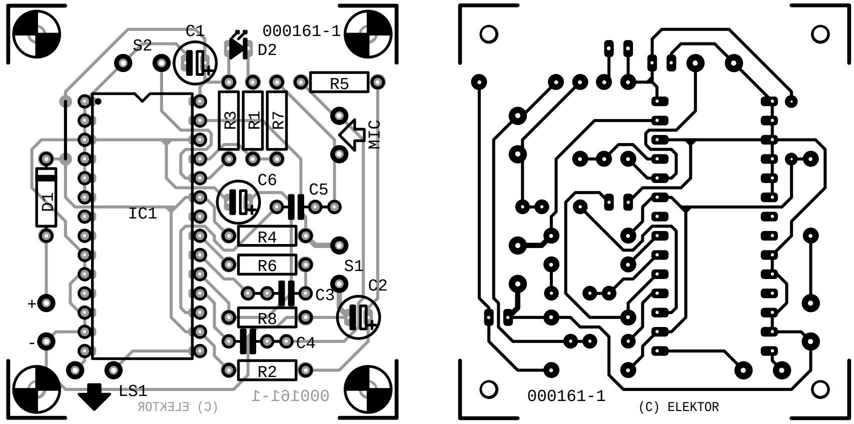
2



The block diagram in **Figure 1** shows that the ISD1416 contains all the electronics required to record and play back speech or music. Even a practically independent microphone preamplifier with differential inputs is provided. An automatic gain control (AGC) prevents the circuit from being overdriven. The time constant of the AGC circuit is set by R8 and C6. The amplified microphone signal is filtered externally by C3 and R6 and then passes through a line-level amplifier and five-pole anti-aliasing filter before being sampled at 8 kHz. The timing of the A/D converter is governed here by an internal clock: an external clock can also be used.

The samples are stored in a 128 k non-volatile EEPROM array, which makes for a maximum recording time of 16 s. Winbond offers voice memories with recording times

3



COMPONENTS LIST

Resistors:
R1 = 470Ω
R2 = 100kΩ
R3,R4 = 100kΩ
R5,R7 = 10kΩ
R6 = 5kΩ6
R8 = 470kΩ

Capacitors:
C1 = 100µF 16V radial
C2 = 220µF 16V radial
C3,C4,C5 = 100nF
C6 = 4µF7 16V radial

Semiconductors:
D1 = 1N4148
D2 = LED, high efficiency
IC1 = ISD1416 (Conrad Electronics #164984)

Miscellaneous:
S1 = pushbutton with make contact
S2 = pushbutton with make contact or tilt switch (Conrad Electronics #700444) or photodiode (BPW34)
Mi1 = electret (condenser) microphone (Conrad Electronics #302155)
PC1,PC2 = solder pin
LS1 = loudspeaker 16Ω

of up to 2 minutes. It is interesting to note that the samples are not stored digitally, but in quasi-analogue form with one of 256 different levels in each memory cell. This gives a considerably higher storage density than is possible with conventional digital storage technology, as well as guaranteeing a high quality recording.

The EEPROM array need not be written all in one go: several messages can be recorded and played back independently. Inputs A0-A7 are used to configure the device and to address the memory.

The IC has four control connections: an edge-sensitive and a level-sensitive playback input, a record input and an output which is pulled low during recording. This output activates the microphone and lights a LED. An active five-pole smoothing filter is used during playback, connected to an output amplifier with symmetrical outputs. As can be seen from a glance at the circuit of **Figure 2**, a 16 Ω loudspeaker can be connected directly to these outputs. The quality of this loudspeaker is largely responsible for the final quality of playback. The external circuitry required for the ISD1416 is minimal. The electret microphone is connected symmetrically via two coupling capacitors and only activated in recording mode, when the RECLED connection is low. Only then does the LED light.

The record input is connected to a push button, while the playback input can be connected to a (tilt-) switch, a push button or a photodiode. The edge-sensitive playback input is used, and so once under way, playback will not stop. The photodiode (type BPW34) can be fitted in parallel with or instead of a switch or push button. It could be fitted at the middle of a target: when a laser pointer is fired at the sensor, the marksman is greeted with applause or adulation. The applications are endless.

The small circuit can be constructed on the printed circuit board shown in **Figure 3** (not available from Readers' Services). The layout and component mounting plan can be obtained from the downloads area of the *Elektor Electronics* website under ref**. 000161-1**. The circuit is also sufficiently simple that construction on perforated board (Veroboard) is perfectly possible.

Current consumption during playback is around 25 mA. After playback the IC goes into a power down mode, in which the circuit draws only 90 µA. The two lithium cells (type CR2032) used as the power supply should therefore last for a long time.

(000161-1)

Alternating Blinker

057

K. Lorenz

The circuit represents a general-purpose astable multivibrator that alternatively energises two heavy loads via a relay (in this case, the loads are 12-V incandescent lamps).

In contrast to an 'analogue' flip-flop, here it is not necessary to use power transistors with heatsinks. This alternating blinker can thus be built at a lower cost, more easily and more compactly.

In the idle state, capacitor C1 is charged via R1 and at the same time discharged via R2 and P1. Here P1 must be adjusted such that sufficient current is available to switch on transistor T1. This should occur when the voltage on the capacitor is around 1.2 V, if a BC517 is used. As a consequence, the relay pulls in.

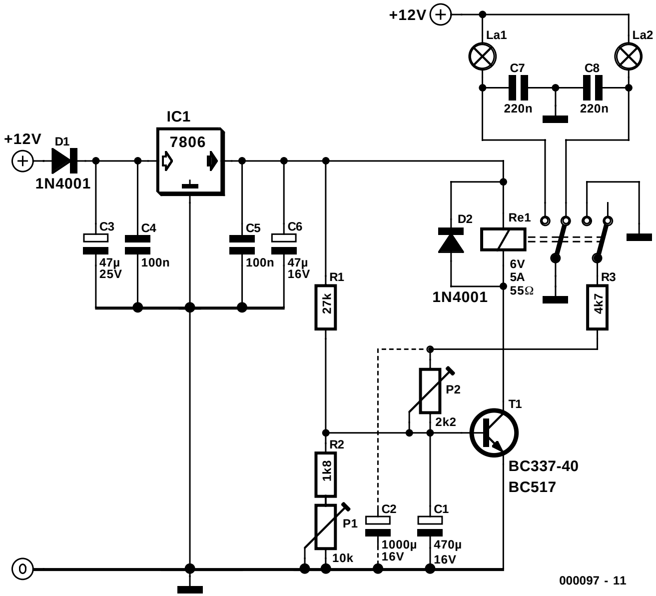
This causes R3 and P2 to be connected in parallel with R2 and P1. P2 must be adjusted such that there is not enough current left to provide the base current for T1. This causes the voltage on C1 to drop, and a short time later the transistor is cut off. The relay then drops out, and the cycle starts over again.

Operating power can be supplied by an unregulated 12-V mains adapter (for example). The current consumption essentially depends on the two loads, since the alternating blinker circuit only draws the rated current of the relay.

Each load is connected directly to the supply voltage, while the blinker circuit receives a stabilised supply voltage via the fixed voltage regulator IC1. Diode D1 protects the circuit against an incorrectly polarised input voltage.

To set up the circuit, first turn P1 to minimum and P2 to maximum resistance. Now turn up P1 slowly (!) until the relay pulls in. Repeat the same process with P2 until the relay again drops out. Using this basic procedure, you can select both the blinking rate and the desired on/off ratio.

The author used a BC337-40 for T1. If this is difficult to obtain, a BC517 (Darlington) can also be used. The proper operation of the circuit also depends on the type of relay



used. In one prototype model, the relay pulled in OK and energised R3 and P2, but it refused to do anything further. If your construction exhibits similar behaviour (and you are dependent on a particular type of relay), it may help to include capacitor C2 in the circuit (as shown in dashed outline) in order to slightly delay the effect of switching in P2 and R3.

(000097-1)

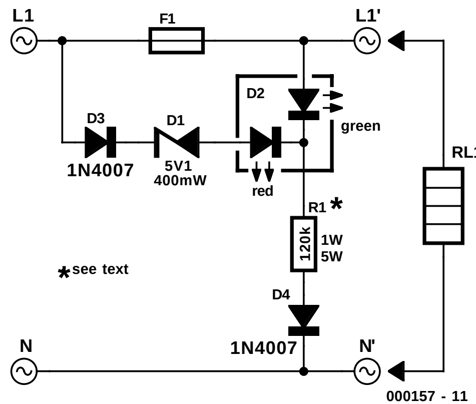
Fuse Failure Indicator

058

S. Lenke

This circuit indicates when a device is functioning or when its fuse has blown. It is a development of the Mains/Fuse Failure Indicator published in *Elektor Electronics* July/August 1995. It is smaller and cheaper than the previous design, even though it works on any mains supply voltage. A single bi-colour LED (D2) with separate anode connections indicates **operating** (green) or **fuse failure** (red). Resistor R1 limits the current through the LED to around 2 mA: the LED is thus reasonably bright. If higher brightness is desired, the resistor value can be reduced.

The zener diode prevents the red and green LEDs from lighting simultaneously in normal operation. With the fuse intact, the LEDs are effectively in parallel, but the greater voltage drop in the red LED's arm of the circuit means that only the green LED lights. General-purpose diodes D3 and D4 prevent damage to the LEDs in the negative half-cycle of the AC supply. If the circuit is used on a DC supply, the diodes can be removed.



If the circuit is used to monitor the fuse on mains-operated equipment, it is vital to note that the components are not isolated from the mains and the voltages present on them can be lethal: do not touch!

(000157-1)

Pump Protector

059

C. van Lint

This circuit has been developed to limit the running time of a sump pump, since the pump can be damaged if it runs too long when the sump is dry. The circuit detects how long the pump has been switched on, and if this time exceeds a previously set limit (30 minutes in this case), the supply voltage to the pump is interrupted.

The protector circuit is connected in series with the pump's mains supply cable. The 230-V input is on the left-hand side of the schematic diagram, and the output is on the right. The schematic diagram consists of three main elements: the power supply, the timing circuit and the in-use detector.

The supply voltage is taken from the mains connection to the pump via transformer Tr1. Since voltage stabilisation is not necessary, the power supply can be limited to the standard combination of a transformer, a bridge rectifier and a smoothing capacitor. LED D5 acts as an on/off indicator.

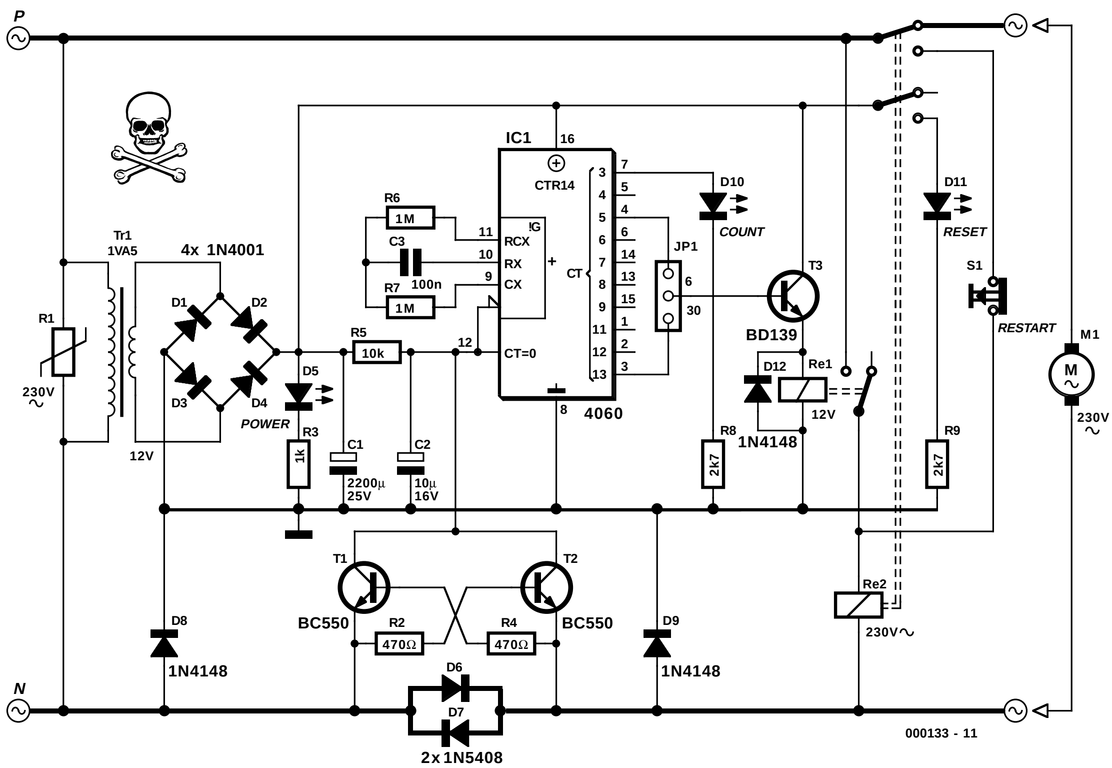
A 4060 (IC1) is used for the timing function. LED D10 (Count) blinks as long as power is supplied to the load. Output Q14 of IC1 goes High after 30 minutes. Alternatively, the Test jumper position can be used to select output Q6. This output interrupts the power to the pump after 6 seconds for testing purposes.

Two diodes connected anti-parallel (D6–D7) are placed in series with one of the supply leads to detect whether the pump is running. When the pump switches on, the voltage drop across these diodes is sufficient to cause T1 and T2 to conduct. These transistors pull down the Reset input of IC1, so the timing circuit starts to count. Diodes D8 and D9 provide a return path to ground from the Reset pin; a direct connection at this point would short out the detection diodes, which is not what we want! These diodes cause the Reset level to lie at around 0.8 V. Capacitor C2 suppresses the crossover spikes from the ac signal, which could otherwise cause the circuit to malfunction.

If the pump is still running when the time interval has expired, T3 energises the 12-V relay Re1, which in turn drives a 220-V relay with two changeover contacts. One of these contacts interrupts the supply voltage to the pump, while the other one is used to activate the Reset LED (D11). The pump can be started again by pressing the Restart button.

We can conclude with some practical remarks. First, a Eurocard relay relay may be used for Re1, and second, the Reset pushbutton switch must naturally be a normally-closed 230-V type. Finally, since the entire circuit is connected to the mains network, full consideration must be given to electrical safety in its construction, and a well-insulated enclosure is mandatory.

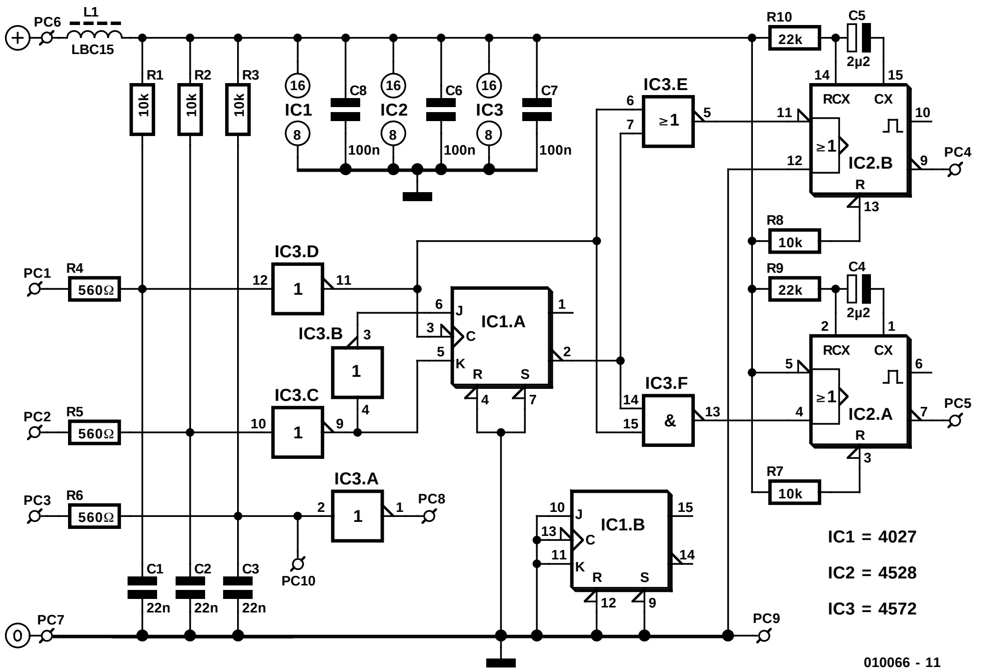
(000133-1)



Rotary Encoder for Digital Volume Control

060

A. Ziegler



The digital volume control published in *Elektor Electronics* October 1997 can be used either with an RC5 remote control or with two pushbuttons (louder/softer). If for whatever reason you cannot do without the feeling of turning a real potentiometer, then with a little effort it is possible to add a shaft encoder to provide rotational control. The outputs of the circuit presented here can simply be connected in place of the two pushbuttons.

The shaft encoder produces two trains of pulses at PC1 and PC2, with a different relative phase depending on the direction of rotation. A complete revolution produces 15 pulses. In order to drive the two pushbutton inputs correctly, not only the number of pulses, but also the direction information (clockwise = louder, anticlockwise = softer) must be taken account of.

First of all the pulses must be debounced using R4/C2 and R5/C2: the shaft encoder is after all just a mechanical rotary switch. R1...R3 are pull-up resistors. The JK flip-flop, connected as a D-type flip-flop, determines the direction of rotation. The clock input is connected to PC1 via inverter IC3.D, while the other output of the encoder drives the K input of the flip-flop via inverter IC3.C. IC3.B provides an inverted form of this signal at the J input to the flip-flop. When a pulse arrives at the clock input the flip-flop is set or cleared according to the direction of rotation.

The 4572 contains a variety of gates: three inverters, a NAND (IC3.F) and a NOR (IC3.E). These are used the produce pulses from the static signals. At one input to the two gates is the clock signal PC1, while at the other input we have the output of the flip-flop. The NAND gate passes the pulses to its output only when the second input is high; likewise, the NOR gate only propagates pulses when the second input is low. Thus only one of the gates can ever be propagating pulses at a time.

The signals thus generated have the disadvantage that in the quiescent state, when the encoder is not being turned, they can equally well be either high or low. A low level, however, will drive the volume control continuously, so winding the volume up to the maximum or down to the minimum. This is clearly not desirable: to rectify the situation we use a monostable to deliver a brief negative-going pulse. The pulse width is determined by R9-C4 and R10-C5.

The inverting input to monostable IC2.B is connected to the NOR gate, and the non-inverting input to logic one. For monostable IC2A the NAND gate is connected to the non-inverting input, and the inverting input is tied low. The Reset inputs (pin 3/pin 13) must be tied high. On a positive-going clock edge monostable IC2B produces a low-going pulse, and if the input stays high, no further pulses are produced. IC2A behaves in a similar way.

The outputs of the two monostables can be connected directly to the pushbutton inputs of the digital volume control. The supply voltage is +5 V, which is obtained from the potentiometer circuit via inductor L1 to avoid interference: you may find that the inductor can be dispensed with. The current consumption of the circuit is just 1 mA.

Now to the pushbutton function of the shaft encoder. The relevant connection is wired to PC3, buffered, and then not used. The pulse at PC8 could be used to switch another circuit (with a +5 V supply) on or off. Alternatively the signal at PC10 can be used to drive the digital volume control directly by connecting PC10 and PC5. Here, an extra resistor (4.7 kΩ) is required to protect the monostable's output, between the IC and PC5/10. Then, if the encoder is pressed, the audio signal will become gradually softer, providing a kind of mute function. Or alternately, connect PC10 with PC4 instead of PC5: then rather than softer, the audio signal will become louder. (010066-1)

Literature:

Infra-red controlled noiseless volume control, Elektor Electronics October 1997 54

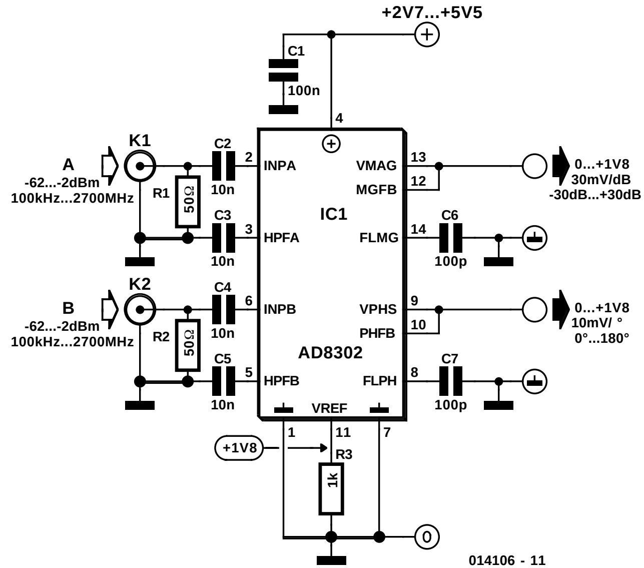
Gain and Phase Meter

A simple way of measuring the amplitude and phase difference between two high-frequency signals is provided by the AD8302 from Analog Devices (www.analog.com).

The two input signals A and B are terminated with 50 Ω and fed to the internal logarithmic demodulators. Taking the difference of the outputs leads to a voltage which represents the amplitude difference in decibels (dB); by multiplying the internal signals an output voltage proportional to the phase difference between A and B is produced.

The circuit produces a voltage at output VMAG (‘magnitude’) between 0 V and +1.8 V. 0 V represents –30 dB while +1.8 V represents +30 dB, each 30 mV step thus representing one decibel. The amplitude of input B is taken as the reference. The phase output also varies between 0 V and +1.8 V, each 10 mV step representing one degree of phase difference. The outputs can drive up to 15 mA, and so the load impedance must be at least 120 Ω.

The AD8302 can be used, for example, as a level meter by applying a signal with a known amplitude to input B. The input level range runs from –62 dBm to –2 dBm. Error in the device is typically less than 0.5 dB in amplitude and 1 degree in phase. The device operates from a supply voltage between 2.7 V and 5.5 V. If modulation is present on the input signals, the modulation envelope will appear on the outputs.



The IC has a bandwidth of 30 MHz, which can be reduced by fitting a capacitor between pins 8 and 14. Pin 11 is a +1.8 V reference voltage output which can be used when further processing the outputs of the device.

(014106-1)

Graphical Compiler for the MCS-51 Microcontroller

062

J. C. Bracker

In both hobby and semi-professional electronics the use of microcontrollers is becoming more and more popular. This is mainly down to the Internet, where anyone can discuss their problems and experiences with microcontrollers, and application and programming software is as a rule freely downloadable.

Whereas in the past programming had to be done in hard-to-read machine code or assembler, these days high-level languages such as Pascal, C, Basic and a host of others are used. Spend a little time searching, and you will find a wide range of possibilities available on the Internet (or in the advertisements in *Elektor Electronics*!).

The GraphCom package described here belongs to the so-called fifth generation of programming languages. The term ‘programming language’ is not really the correct one here: it is more of a graphical compiler. Together with a graphical editor (in this case the freeware version of the Eagle schematic editor, downloadable from www.cad-soft.com) it is possible to use GraphCom to draw a block diagram of the desired system, just as when programming PLCs with the ‘C-Control-Software’ package available from Conrad Electronics. The schematic is converted into a netlist using the Export command in the editor. From this data GraphCom produces an assembler listing, which can then be converted into a HEX file using for example the Elektor EASM51 assembler.

The program comes with a library of functions which are used by GraphCom and converted into meaningful MCS-51 instructions. The GraphCom environment is a fully ‘open system’. The functions can be extended at will by the user and tailored for a particular microcontroller. It is worth noting that GraphCom (in contrast to some other graphical compilers) is very frugal in its use of the microcontroller’s resources, and so it is possible to write complex programs even for simple Atmel microcontrollers such as the 89C2051.

The package includes a terminal program which can be used to set parameters and observe the outputs of functional blocks in the target system. GraphCom is available in English and German versions, occupies about 4 MB (or only 350 MB as a ZIP file), and runs under Windows 95, Windows NT or Linux. A DOS version is also available. The program is shareware and can be downloaded from www.bracker-automation.de.

(014018-1)

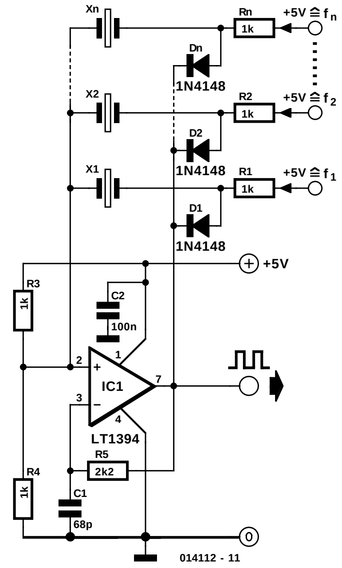
Switchable Crystal Oscillator

063

The circuit shows a switchable crystal oscillator which can generate any one of a number of set frequencies. Using the high-speed LT1394 comparator from Linear Technology (www.linear-tech.com) it is possible to build a crystal oscillator by putting the crystal in the negative feedback path, while an RC network in the positive feedback path provides the required phase lag.

Switching between the crystals is simply achieved using diodes (type 1N4148). The diode corresponding to the crystal to be selected is forward biased via its 1 kΩ series resistor, while all the other inputs to the circuit must remain at ground potential. Any crystals suitable for fundamental frequency operation in the range 1 MHz to 15 MHz can be used. Use of a comparator guarantees that the output signal is a squarewave.

(014112-1)



Pulse Selector

064

B. Schädler

The circuit presented here can be useful in triggering, test and measurement applications. It converts a rising edge into a square pulse whose length is equal to the period of an input pulse train.

In the quiescent state, flip-flop IC1B is clear, holding flip-flop IC1A set.

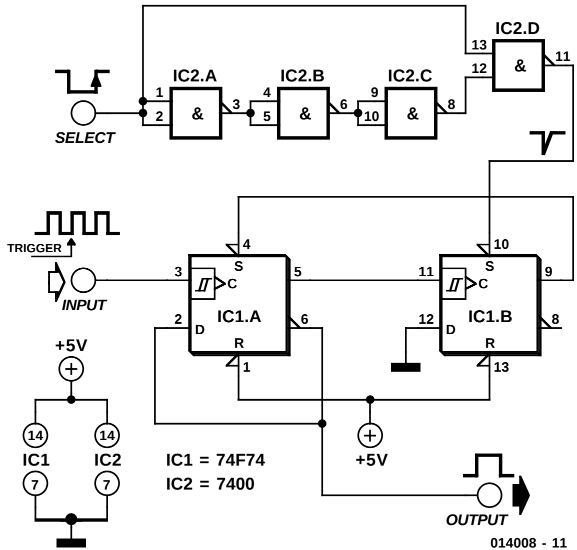
A TTL-level rising edge at the SELECT input causes a brief spike to appear at the output of gate IC2D. The spike is only a few nanoseconds long, and depends on the propagation delay through NAND gates IC2A, IC2B and IC2C, which are connected as inverters.

The spike sets flip-flop IC1B. Its output (pin 9) goes high, releasing the set input on flip-flop IC1A. This state is stable and persists after the trailing edge of the spike, IC1A remaining set.

However, the inverting output of IC1A is connected to its D input, and so the next positive edge arriving at the trigger input ('INPUT') clears it. The inverting output goes high and the non-inverting output goes low. On the next rising edge of INPUT IC1A is set again. The inverting output, connected to OUTPUT, goes low again, and the non-inverting output goes high. This rising edge on its clock in turn clears IC1B, since its D input is tied to ground. With IC1B cleared, IC1A is again held in the set state, and this situation will persist, independently of TRIGGER pulses, until the next SELECT edge arrives.

The result is that the output is high for one period of the input following the spike. The circuit works equally well with CMOS gates, although it should be observed that the spike must be short compared to the period of the input.

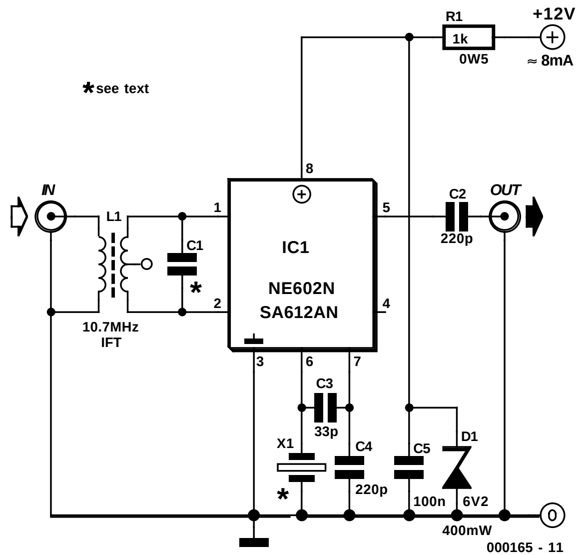
(014008-1)



SW Converter for AM Radio

065

P. Laughton, VK2XAN



Apart from chucking it in the bin, what can you do with old AM car radio or clock radio in your junkbox? How about turning it into a crystal controlled, stable, short wave radio receiver, for a minimum investment in time and money? Read on.

The heart of the circuit shown here is an IC which goes by the name NE602, NE612 or SA612. It is a double balanced mixer that includes an oscillator that can be crystal-controlled, free running or even driven externally from a PLL, etc. It was originally designed for mobile telephones and is probably available in junked car phones from the tip.

The NE602/612 contains a differential input amplifier (called a Gilbert Cell), an oscillator/buffer, a temperature compensated bias network and a power regulator. Typical frequency response is in excess of 500 MHz for the input and 100 MHz for the oscillator. Supply current is 2.4 mA and the absolute maximum supply voltage is 9 V. Input and output impedances are approx. 1.5 kΩ.

As you can see from the circuit diagram, the input from the aerial is passed through a 10.7 MHz IF (intermediate frequency) transformer. This gives isolation from the aerial and reduces the effect of strong local AM radio break-through. The transformer can be salvaged from a dead FM radio or stereo or even the FM section of an old clock radio. (The AM section is what we want to use anyway so ratting a bit from the FM section saves cost).

A number of 10.7 MHz IF coils from Toko and other far-Eastern manufacturers may be used, including the 94AES30465N and 94ANS30466N, but obtaining these as new parts may be more costly than a complete radio rescued from the tip. There is usually a small capacitor under the IFT coil, between the pins. If so, remove it by crushing it with a pair of pliers and ripping out the remains. The

capacitor is not needed as we add an external one according to the band wanted.
The input signal is fed into the balanced input of the IC. The crystal is connected to pin 6. It oscillates at its fundamental frequency and is mixed with the input signal giving a number of outputs.
The mixer output signal appears on pins 4 and 5. Here, only pin 5 is used for the output. By the way, the inputs and outputs are internally biased with pull-up resistors, so there is no need to tie the unused pins to ground or power. The 220 pF capacitor gives isolation to any DC into the AM radio aerial input. Note also that the same circuit can be used to extend the range of an existing short wave radio receiver in exactly the same manner. The AM radio is used as a tuneable intermediate frequency amplifier, with a tuning range of about 1.6 MHz.
You can try different values for C1 to get resonance at the NE602 input: 150 pF for up to 5 MHz, 47 pF for up to 8 MHz, and no capacitor for up to 10 MHz. In practice however 33 pF should do for all ranges.
Almost any crystal can be used. The author tried many types from FT-243 WW2 surplus ones to 27 MHz, 3rd overtone CB crystals. Every crystal tried worked. TV sub-carrier crystals work well, as do large oven types. Several crystals can be connected through a switch, giving a convenient way of switching bands. Keep the leads to the switch as short as possible though to prevent radiation of the crystal oscillator.
There are many ways to build the circuit. You could make it into an external metal box that can be connected to several radio's, depending on your location. For instance, if you are a traveller, make it in a small box with an internal 9-volt battery, and leave enough wire on the output to wrap a few dozen turns around the clock radio in your Hotel room. This will give you your short-wave reception on the go.
It is also possible to build the converter right into the car radio. Any sort of construction method can be used, from a small piece of perforated board that I used, to a more elaborate printed circuit board and even just lash all the small components underneath the IC socket. A small switch may be used to change from AM to short-wave.
Connect the circuit to the car radio with screened cable to prevent or lessen the effect of strong station breakthrough. To couple the output of the converter to a radio without an external AM aerial input, wind several turns of wire around the internal ferrite rod aerial. As suggested before, winding a dozen or so turns around the plastic radio case will also couple the converter to the radio. This will work at the expense of increased AM signal breakthrough.
Connect the positive power lead to the switch on the radio so that it switches the converter on and off as well.
The short-wave aerial can be 2 to 3 meters of wire strung around the room, but better results will be obtained with a outdoor aerial. The test aerial was about 100 meters long and 10 meters high.
At night there is a lot of activity on the short waves after dark. Find a weak station around 1 MHz on the AM dial and adjust the core of the IFT for minimum volume from the broadcast station. That's the only adjustment.
SSB signals can be heard, but as no beat frequency oscillator is fitted, you hear the "duck talk" of the signal.
The 10 kHz bandwidth of the radio means that on the ham bands, signals do overlap, but it also makes the broadcast stations sound better as most of them do broadcast with reasonable quality audio. Digital tuned AM radios are usually not suitable for the circuit as presented, because the tuning steps are 9 or 10 kHz apart and we want much smaller steps. The old manually tuned types of car radio are what you want.
The idea of the circuit is not to get too complicated, but to just enjoy listening on a simple, stable, cheap, short wave receiver. Experiment and enjoy!

(000165-1)

SDCC (Small Device C Compiler) 066

The subject of this Summer Special article is a valuable tip, rather than a circuit. For some time now, a free C compiler for microprocessors has been available via the Internet. This compiler, which is called SDCC, can be found at the Sourceforge site (http://www.sourceforge.net). It runs under Linux and Windows (in a DOS window).

There are distinct advantages to programming in C. For example, it is possible to reuse frequently used functions by packaging them in 'routines', which can be easily incorporated into new software projects. Furthermore, C has come to be a standard language that is intensively used in the professional world. This also means that many C functions can be found on the Internet, and you can directly use these functions in your own programs.

Another advantage of C is that you can write programs that are nearly independent of the processor used to run them. This means that, for example, you can try out a routine on the PC before using it in an embedded processor. This

drastically shortens the development time, and in addition, in many cases you do not need to have a special debugger for the target processor.
SDCC can generate machine code for all processors in the MCS-51 series. There is also work in progress to provide support for the following processors: Z80, Gameboy-Z80, AVR, DS390 and PIC. In short, SDCC is an ideal complier for anyone who works with microprocessors and would like to program in C without having to dig deep into his or her purse.

(010063-1)

Video Line Driver

067

This circuit is a video line driver specifically intended for use with a single-ended power supply. As a matter of fact, the synchronised outputs of a line driver for composite-video signals go negative with respect to ground. In order to be able to process these negative signals in a circuit powered from a single-ended supply, it is necessary to AC-couple the input of the opamp as well as level-shift the signal in the positive direction.

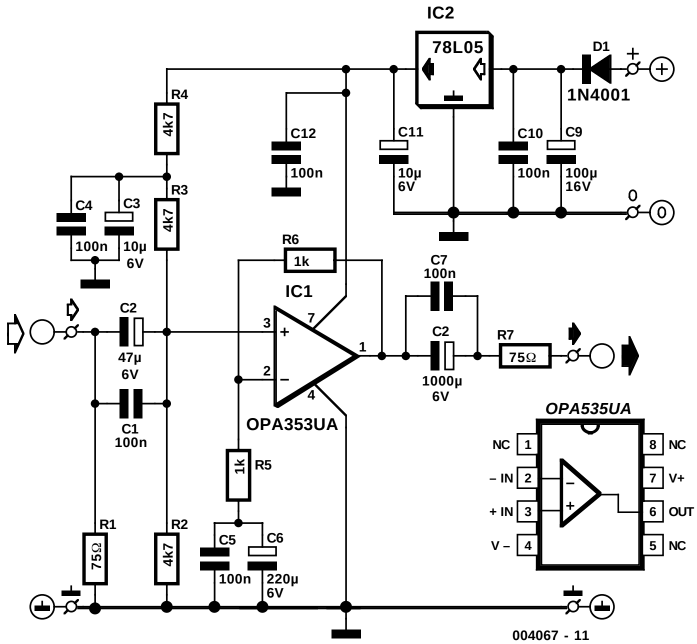
COMPONENTS LIST

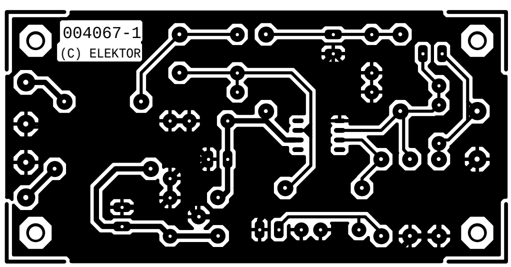
Resistors:
R1,R7 = 75Ω
R2...R4 = 4kΩ7
R5,R6 = 1kΩ

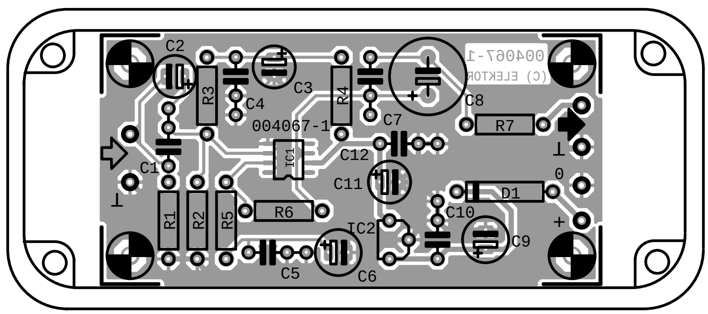
Capacitors:
C1,C4,C5,C7C10,C12 = 100nF
C2 = 47µF 16V radial
C3,C11 = 10µF 6 V radial
C6 = 220µF 6 V radial
C8 = 1000 µF 6V radial
C9 = 100µF 16V radial

Semiconductors:
D1 = 1N4001
IC1 = OPA353UA
IC2 = 78L05

Miscellaneous:
PC1-PC6 = PCB solder pin
Case, e.g., Hammond type 1590A





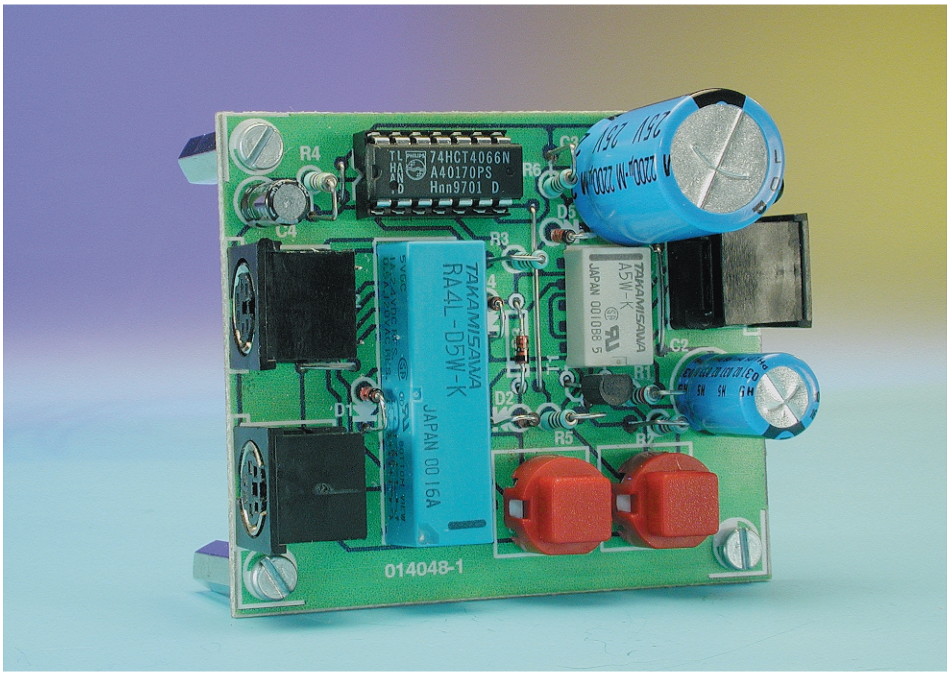


The input is terminated into a 75 Ω resistor (R1). From here, the signal passes through AC-coupling capacitor C2 and is applied to potential divider R2-R3, which provides the necessary DC-offset. The shift into the positive direction amounts to +1.7 V, with the values shown in the schematic. To avoid any misunderstandings we should add that this value is fairly critical. Deviating from the values shown can lead to distortion in the complementary input stage of the opamp that has been used here, and this of course, has to be avoided.

Because we provided the circuit with its own voltage regulator circuit (IC2), just about any mains adapter will suffice for the power supply. The current consumption is less than 20 mA. The construction of the line driver using the accompanying printed circuit board layout is no more than a simple, routine job.

(004067-1)

Keyboard/Mouse Switch Unit 068



H. Kraus

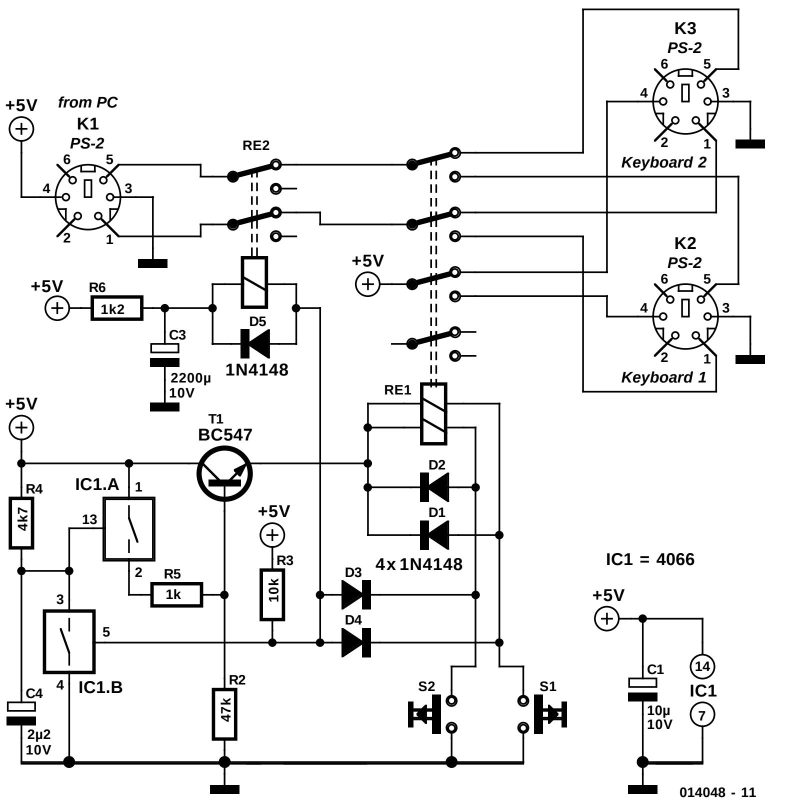
Unplugging or re-connecting equipment to the serial COM or PS2 connector always gives problems if the PC is running. Even if you only need to swap a mouse or changeover from a graphics keyboard to a standard keyboard. The chances are that the connected equipment will not communicate with the PC, it will always be necessary to re-boot. If you are really unlucky you may have damaged the PC or the peripheral device.

In order to switch equipment successfully it is necessary to follow a sequence. The clock and data lines need to be disconnected from the device before the power line is removed. And likewise the power line must be connected first to the new device before the clock and data lines are re-connected. This sequence is also used by the USB connector but achieved rather more simply by using different length pins in the connector.

The circuit shown here in **Figure 1** performs the switching sequence electronically. The clock and data lines from the PC are connected via the N.C. contacts of relay RE2 through the bistable relay RE1 to connector K3. Pressing pushbutton S1 will activate relay RE2 thereby disconnecting the data and clock lines also while S1 is held down the semiconductor switch IC1B will be opened, allowing the voltage on C4 to charge up through R4. After approximately 0.2 s the voltage level on C4 will be high enough to switch on IC1A, this in turn will switch on T1 energising one of the coils of the bistable relay RE1 and routing the clock, data and power to connector K2. When S1 is released relay RE2 will switch the data and clock lines through to the PC via connector K1. It should be noted that the pushbutton must be pressed for about 0.5 s otherwise the circuit will not operate correctly. Switching back over to connector K3 is achieved similarly by pressing S2.

The current required to switch the relays is relatively large for the serial interface to cope with so the energy

1



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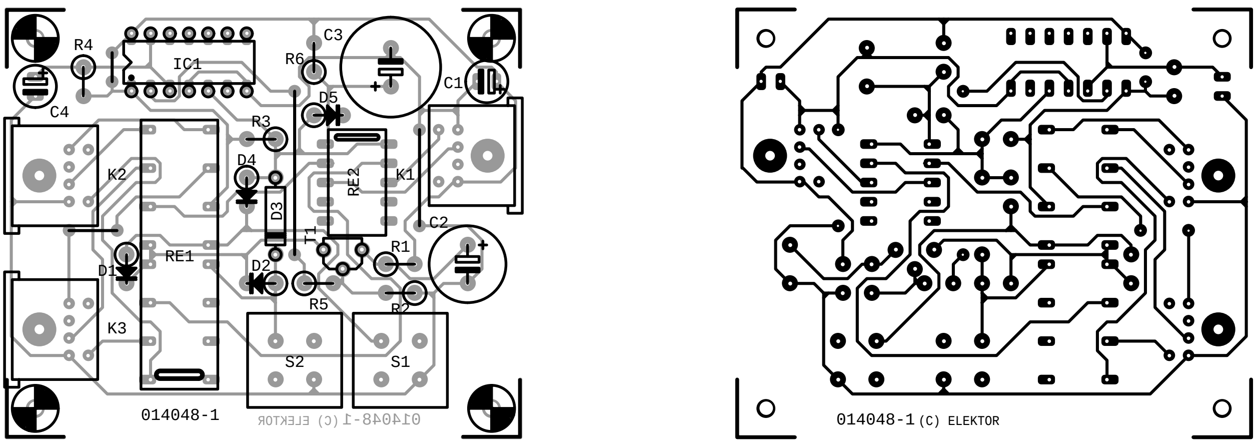


COMPONENTS LIST

Resistors:
R1 = 2kΩ2
R2 = 47kΩ
R3 = 10kΩ
R4 = 4kΩ7
R5 = 1kΩ
R6 = 1kΩ2

Capacitors:
C1 = 10µF 10V radial
C2 = 1000µF 10V radial
C3 = 2200µF 10V radial
C4 = 2µF2 10V radial

Semiconductors:
D1-D5 = 1N4148
T1 = BC547
IC1 = 4066 or 74HCT4066

Miscellaneous:
RE1 = bistable relay 4 c/o contacts (Takamisawa, Conrad Electronics #502936)
RE2 = monostable relay 2 c/o contacts (Takamisawa, Conrad Electronics #504700)
K1,K2,K3 = 6-way Mini-DIN socket (pins at 240°, PCB mount
S1,S2 = pushbutton (ITT D6-R)

necessary is stored in two relatively large capacitors (C2 and C3) and these are charged through resistors R1 and R6 respectively. The disadvantage is that the circuit needs approximately 0.5 minute between switchovers to ensure these capacitors have sufficient charge. The current consumption of the entire circuit however is reduced to just a few milliamps.

The PCB layout and component placement is shown in **Figure 2** and is also available from the *Elektor Electronics* website. The PCB is designed to accept PS2 style connectors but if you are using an older PC that needs 9 pin sub D connectors then these will need to be connected to the PCB via flying leads. In this case the mouse driver software configures pin 9 as the clock, pin 1 as the data, pin 8 (CTS) as the voltage supply pin and pin 5 as earth.

(014048-1)

LED–LDR Blinker

069

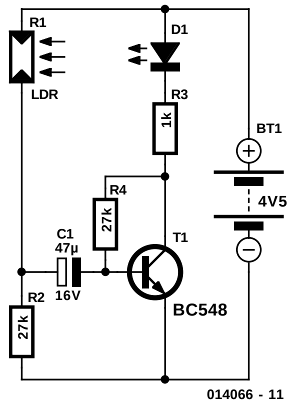
B. Kainka

It normally takes two transistors to build a blinker circuit (in order to make positive feedback possible). However, you can also use a photoresistor (LDR) that is illuminated by an LED. The feedback takes place here by means of light rays.

The circuit is easy to understand. When light falls on the LDR, the current increases. The capacitor then charges, and this increases the base current. This causes the transistor to switch the LED fully on. The stable 'on' state switches to the 'off' state as soon as the capacitor is fully charged. The LED is then completely off, the base voltage goes negative and the transistor is cut off. The circuit cannot switch back to the 'on' state until the capacitor has been discharged via the base resistor.

The circuit naturally reacts to external light sources as well. You will have to test it in different light environments to see whether it will work. In any case, it will not work in full sunlight. With an ultrabright LED and a very low-resistance LDR, it might be possible to build a blinker without using a transistor. The combination of the LED and the LDR would have to provide the gain that is needed to produce oscillations.

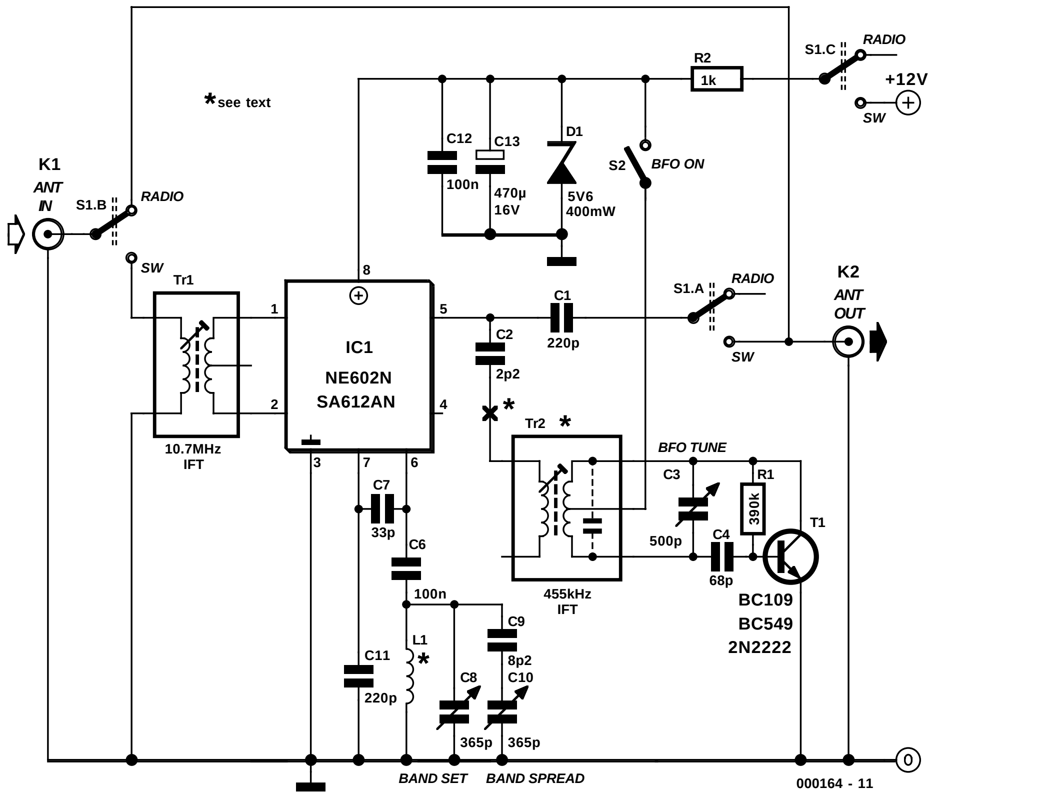
(014066-1)



SW Converter for Digital AM Car Radio

070

P. Laughton, VK2XAN



This circuit is purposely presented with many loose ends (not literally, of course) to stimulate experimenting with RF circuitry at a small outlay.

Looking at the circuit diagram you may recognize a modified version of the SW Converter for AM Radios described elsewhere in this issue. The modifications were necessary to make the circuit compatible with a digital rather than analogue AM car radio. The main difference between digital AM radios and their all-analogue predecessors is that tuning is in 9 kHz (sometimes 4.5 kHz steps) in compliance with the international frequency allocation for the band. Obviously, that particular step size, desirable as it may be on MW, is a stumbling block if you want to use a digital AM receiver in combination with a frequency step-up converter for SW, where chaos reigns and there is no fixed step size.

The first attempt was to make the crystal oscillator variable by about 5 kHz each way. Unfortunately, despite serious efforts, the crystal could not be pulled more than 1 or 2 kHz so another solution had to be found.
After studying the NE/SA602/612 datasheet, it was found that a variable LC based oscillator was the best alternative. The circuit worked after winding a resonant LC circuit and adding a 0.1 µF series capacitor to block the DC component on pin 6 of the NE602 (612). When the tuning was found to be a bit sharp with the original capacitor, a simple bandspread (or fine tuning) feature was added by shunting the LC resonant circuit with a lightly loaded 365 pF tuning capacitor (C10) which, like the main tuning counterpart, C8, was ratted from an old transistor radio.

The tuning coil, L1, consists of 8 to 10 turns of 0.6-0.8mm dia. enamelled copper wire (ECW) on a 6-8 mm dia. former without a core. With this coil, frequency coverage will be from about 4 MHz to 12 MHz or so.

Details on Tr1 may be found in the referring article. Note that no tuning capacitor is used on the secondary — the input stray capacitance of the NE602 (612) does the trick.

A BFO (beat frequency oscillator) was added to enable SSB (single sideband) signals to be received. The BFO built around T1 is simple, has a heap of output and is stable enough to hold an SSB signal for a few minutes without adjustment. The BFO frequency is tuned with C3. Tr2 is a ready-made 455 kHz IF transformer whose internal capacitor was first crushed and then removed with pliers. When S2 is closed the BFO output signal is simply superimposed on the NE602 (612) IF output to the MW radio.

The converter should be built into a metal box for shielding. If you find that the BFO gives too much output, disconnect it as suggested in the circuit diagram and let stray coupling do the work.

Sensitivity, even on a 1-metre length of car radio aerial, is quite amazing. Bearing in mind that most of the major international SW broadcasting stations like Radio NHK Japan, Moscow, BBC etc.) generate enough power to make sure that you will hear them, it is still quite exciting to hear such signals for the first time on your car radio.

(000164-1)

Keypad Encoder IC with Serial Output

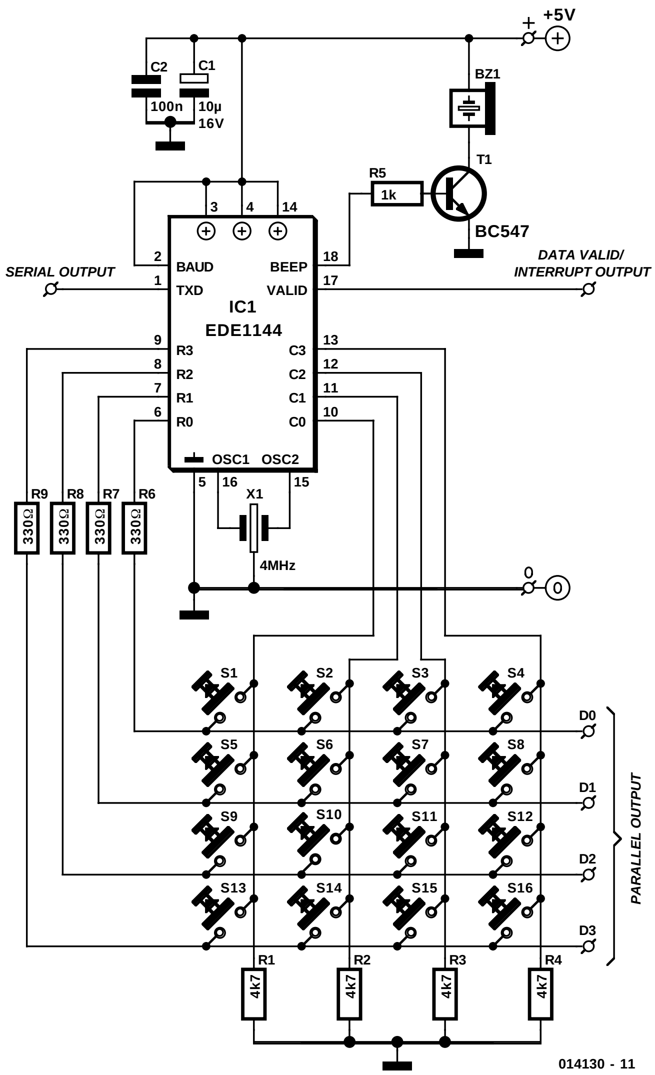
071

Source: E•Lab Digital Engineering Inc.

The EDE1144 Keypad Encoder IC from E•Lab Digital Engineering (www.elabinc.com) is designed to interface a matrix-type 4 row × 4 column (16-key or less) keypad to a microcontroller or other host processor. A 1-wire serial or 4-wire parallel interface returns the keypress data and can be used in conjunction with a 'data valid' signal for polled or interrupt-driven applications. The EDE1144 provides enhanced keypad features such as contact debouncing and key auto-repeat in an easy-to-use package that will lower software overhead in the host microcontroller and reduce the I/O pin requirements from eight to one, frequently resulting in the use of a less costly host microcontroller in your design.

In addition, the EDE1144 is electrically quiet. Many keypad encoders continually scan the keypad, radiating EMI noise from the wires leading to the keypad (resulting in trouble during emissions testing & final product certification & approval). The EDE1144 reduces this problem by monitoring the keypad with unchanging signals, and then scanning only once each time a keypress is detected.

The **schematic** shows the standard application circuit with the EDE1144 residing between the keypad and host microcontroller/ processor. The host microcontroller receives keypress data via either the four parallel data outputs (D0-D3, Pins 6-9) or the Serial Data Output (Pin 1). The Data Valid signal (Pin 17) is activated upon keypress (and upon each key repeat cycle if key is held). The Data Valid signal is activated prior to transmission of the serial data to allow polled (software-UART) style host serial systems such as the BASIC Stamp™ or a microcontroller without a hardware UART to enter the serial receive routine and receive the keypress data without needing to continually wait for the start bit. Note that the data outputs to the host microcontroller reside on the row output pins (Pins 6-9), therefore parallel-output data should only be read while the Data Valid (Pin 17) signal is active (Low). Upon power-up, the four data output pins will be high, and will remain high except when a key is pressed.



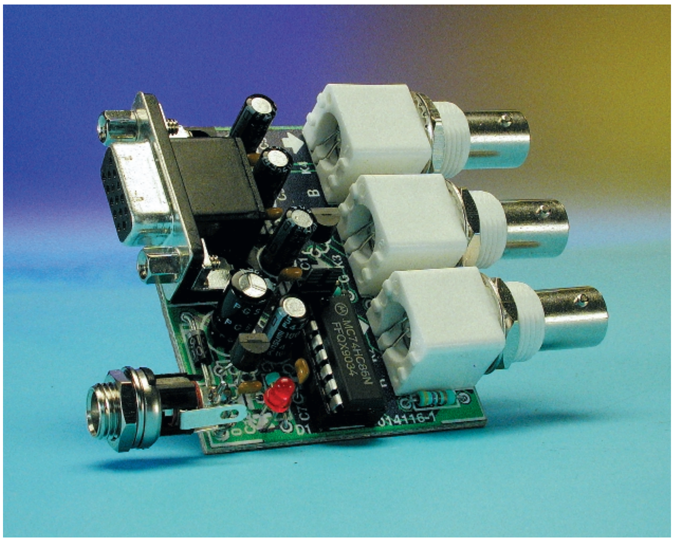
The **table** illustrates the data values returned by the serial and parallel outputs of the EDE144 upon each keypress. Note that the serial values are increased (by hexadecimal 30 ($30) for 0-9 and hex $37 for 10-15) to correspond to the ASCII equivalent (0-9, A-F) of the BCD (binary-coded decimal) value on the parallel outputs.

(014130-1)

Key	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
RS232:	$30 ('0')	$31 ('1')	$32 ('2')	$33 ('3')	$34 ('4')	$35 ('5')	$36 ('6')	$37 ('7')
D3-D0:	0000	0001	0010	0011	0100	0101	0110	0111
Key	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
RS232:	$38 ('8')	$39 ('9')	$41 ('A')	$42 ('B')	$43 ('C')	$44 ('D')	$45 ('E')	$46 ('8')
D3-D0:	1000	1001	1010	1011	1100	1101	1110	1111

VGA-to-BNC Adapter

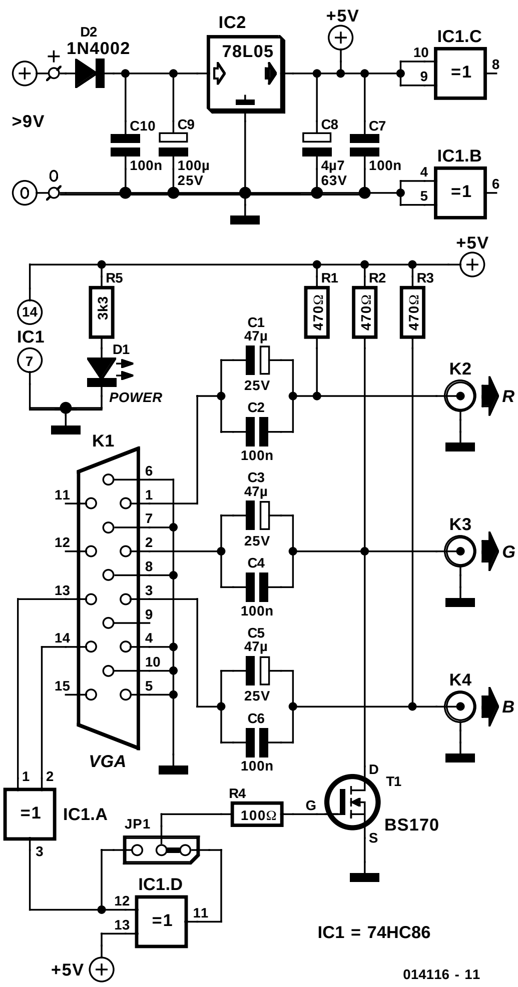
072

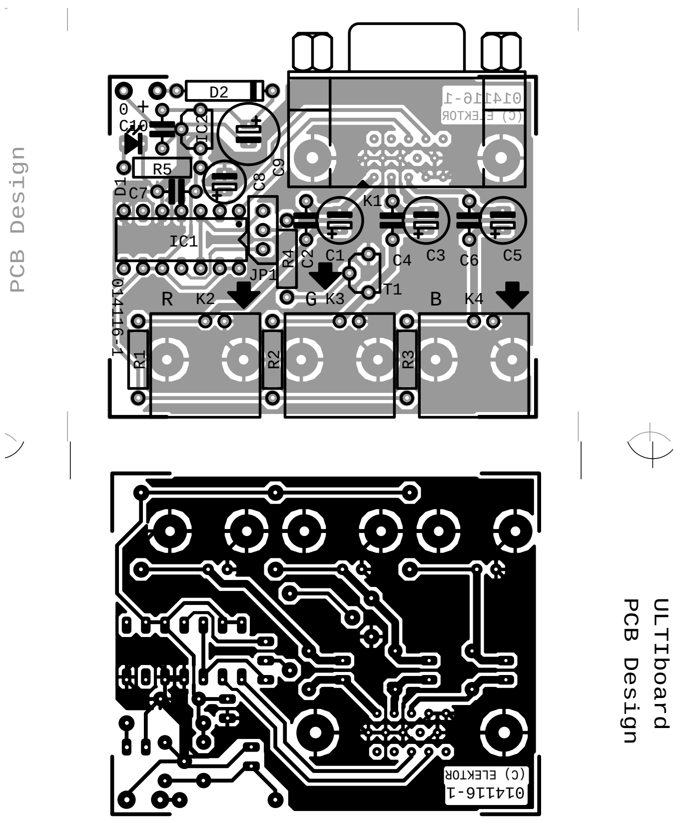


There are monitors which only have three BNC inputs and which use composite synchronisation ('sync on green'). This circuit has been designed with these types of monitor in mind. As can be seen, the circuit has been kept very simple, but it still gives a reasonable performance.

The principle of operation is very straightforward. The RGB signals from the VGA connector are fed to three BNC connectors via AC-coupling capacitors. These have been added to stop any direct current from entering the VGA card. A pull-up resistor on the green output provides a DC offset, while a transistor (a BS170 MOSFET) can switch this output to ground. It is possible to get synchronisation problems when the display is extremely bright, with a maximum green component. In this case the value of R2 should be reduced a little, but this has the side effect that the brightness noticeably decreases and the load on the graphics card increases. To keep the colour balance the same, the resistors for the other two colours (R1 en R3) have to be changed to the same value as R2.

An EXOR gate from IC1 (74HC86) combines the separate V-sync and H-sync signals into a composite sync signal. Since the sync in DOS-modes is often inverted compared to the modes commonly used by Windows, the output of IC1a is inverted by IC1b. JP1 can then by used to select the correct operating mode. This jumper can be replaced by a small two-way switch, if required. This switch should be mounted directly onto the PCB, as any connecting wires will cause a lot of interference.





The PCB has been kept as compact as possible, so the circuit can be mounted in a small metal (earthed!) enclosure. With a monitor connected the current consumption will be in the region of 30 mA. A 78L05 voltage regulator provides a stable 5 V, making it possible to use any type of mains adapter, as long as it supplies at least 9 V. Diode D2 provides protection against a reverse polarity. LED D1 indicates when the supply is present. The circuit should be powered up before connecting it to an active VGA output, as otherwise the sync signals will feed the circuit via the internal protection diodes of IC1, which can be noticed by a dimly lit LED. This is something best avoided.

(014116-1)

COMPONENTS LIST

Resistors:
R1,R2,R3 = 470Ω
R4 = 100Ω
R5 = 3kΩ3

Capacitors:
C1,C3,C5 = 47µF 25V radial
C2,C4,C6,C7,C10 = 100nF ceramic
C8 = 4µF7 63V radial
C9 = 100µF 25V radial

Semiconductors:
D1 = LED, high-efficiency
D2 = 1N4002
T1 = BS170
IC1 = 74HC86
IC2 = 78L05

Miscellaneous:
JP1 = 3-way pinheader with jumper
K1 = 15-way VGA socket (female), PCB mount (angled pins)
K2,K3,K4 = BNC socket (female), PCB mount, 75 Ω

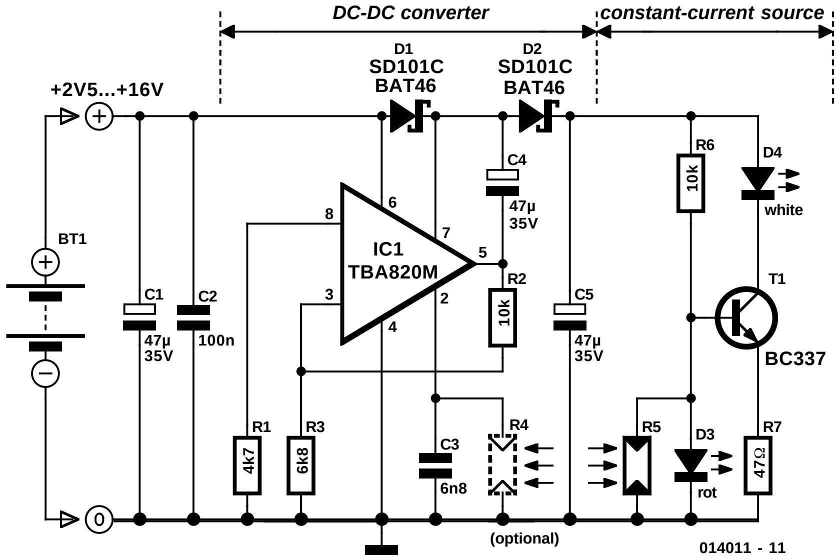
Battery Juicer

073

W. Zeiller

More and more electronic devices are portable and run off batteries. It is no surprise, then, that so many flat batteries find their way into the bin — and often far too early. When a set of batteries can no longer run some device — for example, a flashgun - the cells are not necessarily completely discharged. If you put an apparently unserviceable AA-size cell into a radio-controlled clock with an LCD display it will run for months if not years.

Of course not every partially discharged cell can be put in a clock. The circuit presented here lets you squeeze the last Watt-second out of your batteries, providing a bright ‘night light’ — for free!



The circuit features a TBA820M, a cheap audio power amplifier capable of operating from a very low supply voltage. Here it is connected as an astable multivibrator running at a frequency of around 13 kHz. Together with the two diodes and electrolytic capacitor this forms a DC-DC converter which can almost double the voltage from between four and eight series-connected AA-, C- or D-size cells, or from a PP3-style battery.

The DC-DC converter is followed by a constant current source which drives the LED. This protects the expensive white LED: the voltages obtained from old batteries can vary considerably. With the use of the DC-DC converter and 20 mA constant current source a much greater range of usable input voltages is achieved, particularly helpful at the lower end of the range when old batteries are used. With the constant current source on its own the white LED would not be adequately bright when run from low voltages.

An additional feature is the ‘automatic eye’. The LDR detects when the normal room lighting is switched on or when the room is lit by sunlight: its resistance decreases. This reduces the U_{BE} of the transistor below 0.7 V, the BC337 turns off and deactivates the LED. This prolongs further the life of the old batteries. A further LDR across capacitor C reduces the quiescent current of the circuit to just 4 mA (at 4 V). Light from the white LED must of course not fall on the LDR, or the current saving function will not work.

(014011-1)