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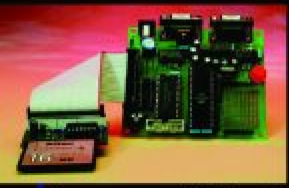

CompactFlash Interface

Dial-Out Blocking Device

USB Audio Codec
with S/PDIF input & output

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VLF Reception on the PC

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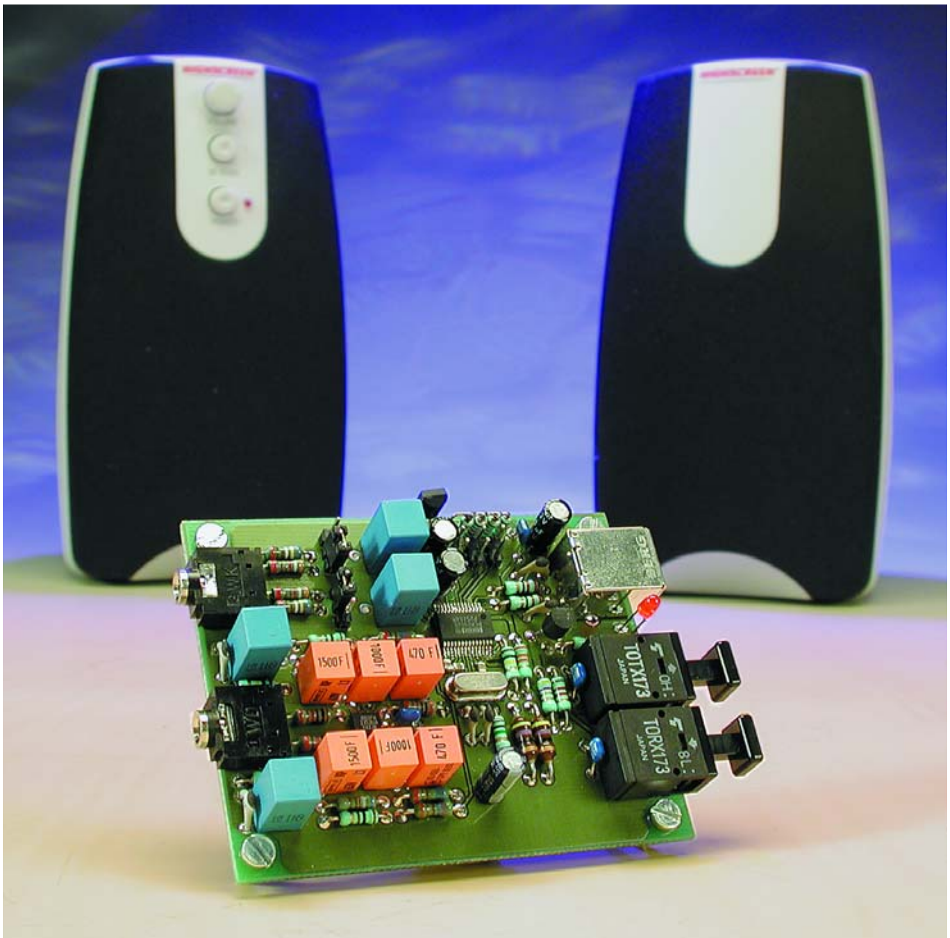
USB Audio Codec with S/PDIF

record digital audio with your PC

Design by T. Giesberts

The USB Audio-DAC described exactly two years ago received unexpected acclaim as a small external sound card. Soon after the publication we received an number of requests for a similar circuit, but then capable of recording via the USB port. The codec presented in this article does just that, and more, while not a much more elaborate circuit than the Audio-DAC.



The circuit described in this article is built around a 'stereo audio codec' IC type PCM2902 from Texas Instruments/Burr-Brown. Clearly, this chip is from the same family as the PCM2702 we used in the USB Audio-DAC. However, it is also an upgrade because besides the features of the 2702 (analogue stereo output, USB interface) it also sports an analogue stereo output and an S/PDIF input and output. The latter even allow digital recordings to be made to and from the PC. One proviso should be mentioned, however. The PCM2902 processes digital audio signals according to the Serial Copy Management System (SCMS) and will switch to the analogue input if it discovers a copied signal. If signals are simultaneously applied to the S/PDIF and analogue inputs, the digital input is automatically selected (if original data is being applied).

If you want to know all the ins and outs of this interesting IC, get the datasheet from www.ti.com. To wet your appetite the block diagram of the PCM2902 is given in **Figure 1**.

Just as with the PCM2702, the 2902 guarantees a very decent quality of the signal processing, so there's no need for audio purist to skip these pages! Those of you who insists on performance figures to be convinced of the need to build a circuit are referred to the inset which lists some measurement results obtained from our prototype.

KISS

Despite the fact that we're dealing with some pretty complex circuitry hidden away in the PCM2902, the final design meets the KISS requirement (keep it simple stupid). Besides the audio codec, IC1, the circuit has just a few more active parts — a transistor, a voltage regulator, a double opamp and an optical input and output module. Add a handful of passive parts and Bob's your uncle.

The codec card is bus powered, which means that the entire circuit is supplied from the 5-volt pin of the USB port. Components L1 and L2 are purposely located close to the USB connector to eliminate noise directly at the source. Hence, these inductors are SMDs (surface mount devices) and fitted on the pins of K3, at the underside of the board — more about this further on. Incidentally, the PCM2902 has an on-chip voltage regulator.

Input circuit

The analogue input has a fixed sensitivity, so you will not see the usual slider pot in the window containing the recorder properties. Because of this, each analogue input channel has a jumper for HI/LO (high/low) input level selection. The HI level is set to about 2 V by means of two potential dividers, R1/R2 and R3/R4. The input range of the ADC inside the PCM2902 is determined by the level of VCCCI (0.6 times VCCCI). Every user is, of course, free to replace the fixed potential dividers with a stereo potentiometer. Capacitors C2 and C3 decouple the direct voltage at the IC inputs. The voltage amounts to (approximately) VCCCI/2 (= VCOM) so will be around 1.65 V.

In order to increase the quality of the A-to-D conversion, the manufacturer recommends powering VCCCI by a separate voltage regulator. Hence the addition of IC5 to the circuit. Here, a low-drop 3.3-volt regu-

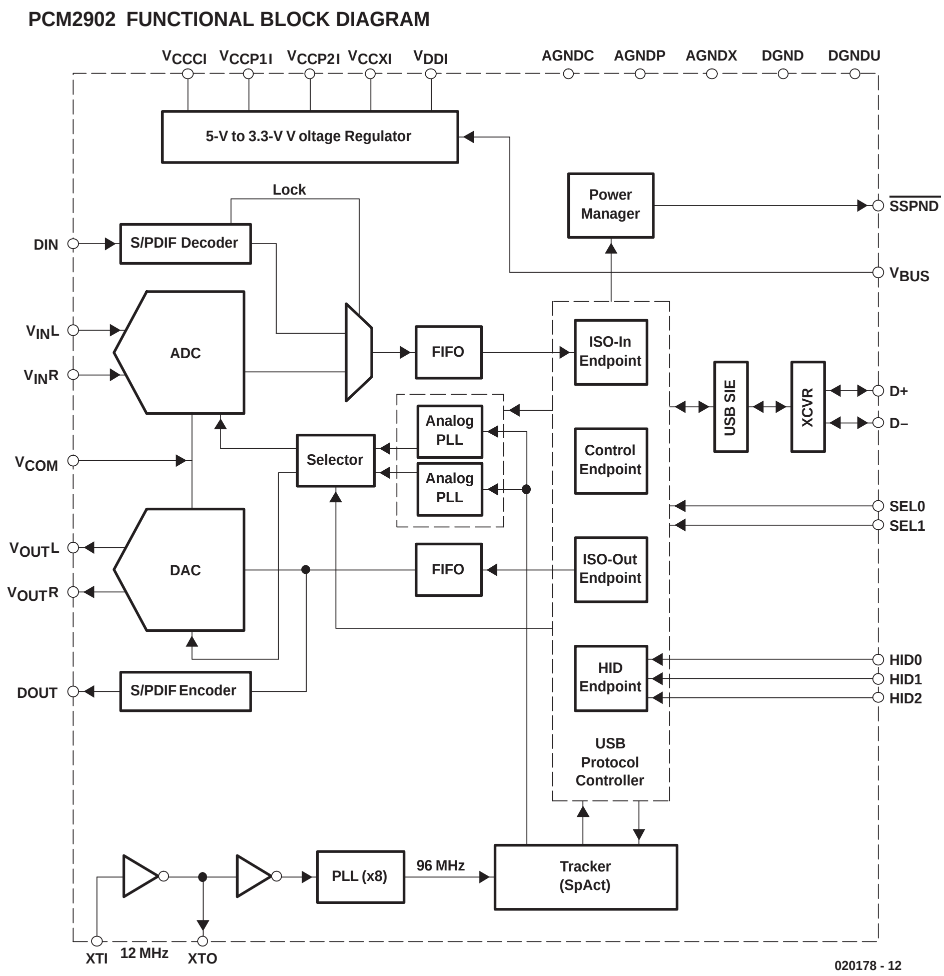


Figure 1. Internal architecture of the PCM2902 Stereo Audio Codec.

Measurement results

(VBUS= 4.84 V, VCCCI = 3.5 V)

Current consumption	approx. 90 mA
DAC	
Nominal output voltage (0 dB)	1.1 V_{rms}
Frequency range (–3 dB)	22.7 kHz (f_s = 48 kHz)
Relative amplitude at 20 kHz	–0.8 dB (f_s = 48 kHz)
Analogue filter bandwidth	28 kHz
Output impedance	100 Ω
Signal/noise ratio	> 95 dBA
THD+N (1 kHz)	0.005% (B = 22 kHz)
	0.046% (B = 80 kHz)
Channel separation	> 99 dB (1 kHz)
	> 76 dB (20 kHz)
ADC	
Input voltage range	0.75 V_{rms} (LO)
	2.1 V_{rms} (HI)
Input impedance	7.7 kΩ (LO)
	10 kΩ (HI)
THD+N (1 kHz, –0.5 dBFS)	0.01% (B = 22 kHz)
Channel separation	> 73 dB (1 kHz)
	> 47 dB (20 kHz)

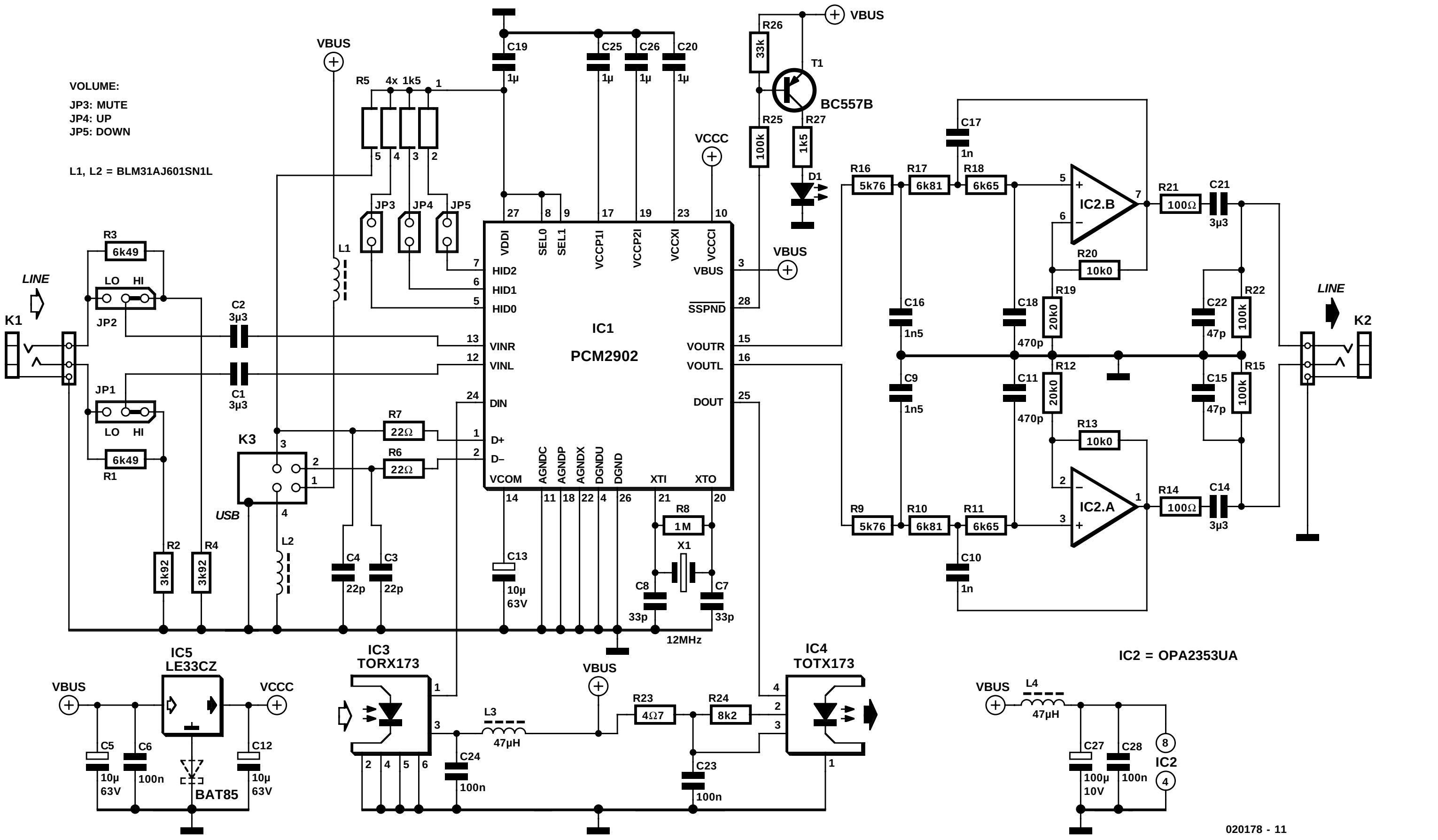


Figure 2. The circuit diagram excels in simplicity because all the complex stuff is inside IC1.

lator type LE33CZ is used. The IC is supplied by ST and comes in a TO92 case. Its presence reduces harmonic levels by more than 10 dB as compared with the internal voltage regulator. If you want to squeeze the ADC for lowest distortion, you may insert a BAT85 diode in the ground line (centre pin) of the LE33CZ. This optional addition is shown in dashed outline in the circuit diagram. The anode of the BAT85 diode goes to the regulator ground pin. The diode raises the reference voltage from 3.3 to about 3.5 V. Although a dedicated 3.5-V regulator does exist under the designation LE35CZ, this component is not easily available.

Because the ADC has an on-chip anti-aliasing filter, the input circuit is marked by delightful simplicity. However, to ensure good sonic quality, MKT (Siemens) or equivalent capacitors are specified for positions C1 and C2. Do not be tempted to use electrolytics here.

Output circuit

As regards structure and specifications, the DAC closely resembles the 'old' PCM2702. Internally there's a low-pass filter with a roll-off at 250 kHz. As with all delta-sigma DACs, the noise level rises considerably beyond 20 kHz or so due to noise shaping. To eliminate the various distortion products, a third-order Butterworth low-pass filter with f_c = 28 kHz is applied. Because the amplifier for this filter is supplied from the VBUS 5-volt line, the signal at the DAC output may be amplified a little (1.5 times). This ensures a maximum output level of more than 1 V_{rms}. The amplifier is realised by an opamp type OPA2553UA which comes in an SMD SO-8 case. The same chip was applied in the USB Audio-DAC with excellent results. It is marked by high speed, low noise, low distortion and (very important) rail-to-rail voltage swing at the input and output.

The filter outputs are equipped with the standard decoupling capacitors (again MKT types) and small series resistors to cancel the effect of capacitive loads. R15 and R22 ensure that these output capacitors remain charged (the input p.d.'s at the ADC have the same function). C15 and C22 suppress any RF noise (remember, the complete circuit s electrically connected to the PC…). In addition to these measures, the opamp is provided with its own supply decoupling network consisting of L4, C27 and C28.

Other details

We can be brief about the S/PDIF input and output. As illustrated by the circuit diagram, these consist essentially of the well-known Toslink modules — a TORX173 for the input and a TOTX173 for the output. The Toslink modules (IC3 and IC4) are directly connected to the relevant pins of IC1 and they are powered from the +5-volt rail using traditional decoupling components.

The PCM2902 has a HID volume control feature and a mute function. Jumpers JP3, JP4 and JP5 allow mute, volume-up and volume-down to be adjusted respectively. You could, for example, connect three pushbuttons to these jumper pins and so enable basic volume control without access to the PC. When connecting such pushbuttons, be careful to avoid short-circuits to ground.

Installation of this USB component under Windows 98 or higher results in two items being added to the Human Interfaces. Consequently a report is filed back to the operating system specifying the current volume, mute state, etc.

The state of the Suspend flag is reported on pin 28 and an LED is used to indicate that the IC is 'temporarily out of order'. LED is purposely connected through to ground to prevent damage to the IC when a short-circuit occurs. A small converter built around T1 converts the 0 V/3.3 V supplied by the SSPND output into a 2-mA current required for the high-efficiency LED. In this way, the LED connection may be employed to signal to other digital equipment that the signal is temporarily not available.

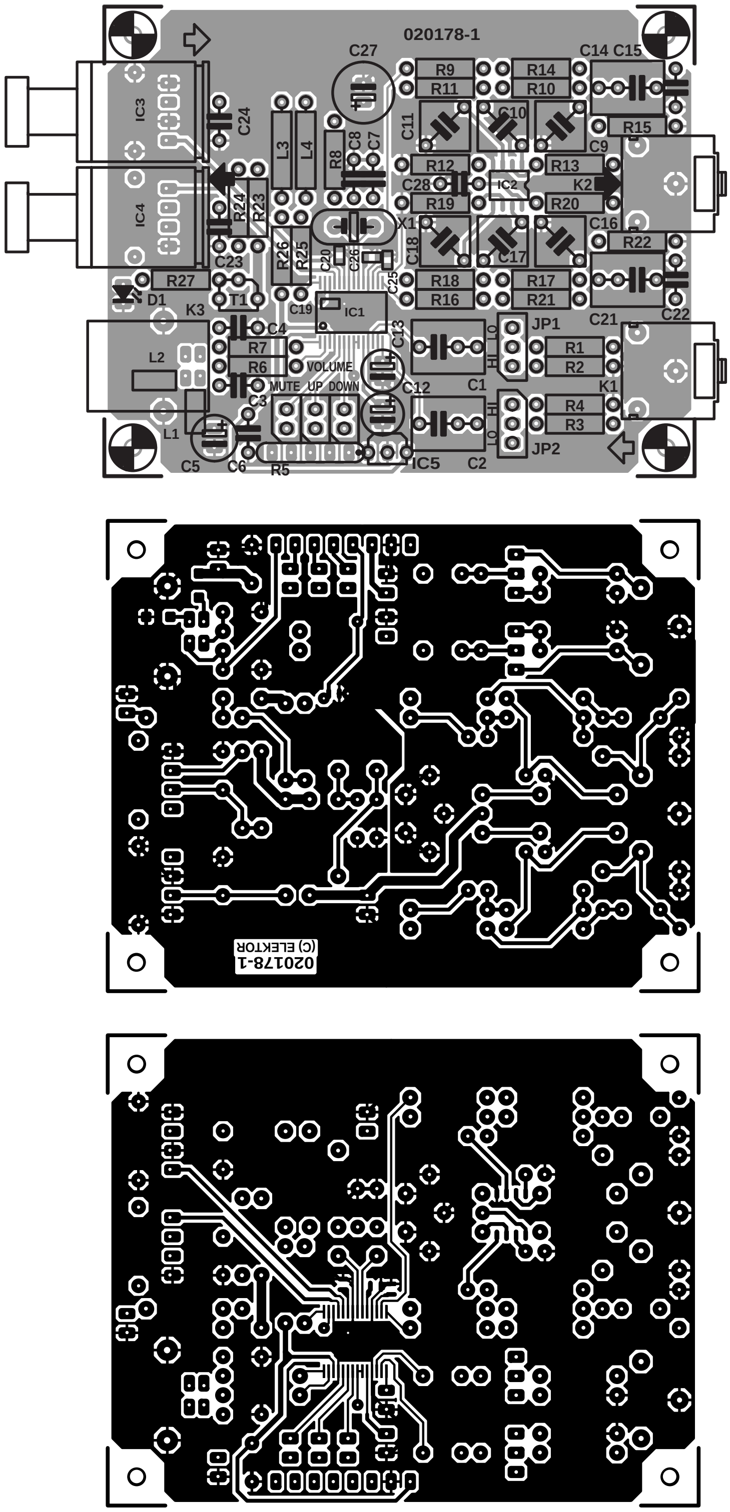


Figure 3. Copper track layout and component mounting plan of the PCB designed for the USB Audio Codec (board available ready-made).

Printed circuit board

The design of the printed circuit board developed for the USB audio codec is shown in **Figure 3**. The board is available ready-made through the Publisher's Readers Services. All connections on the board have been kept as short as possible to keep the unit as compact as possible. As you have come to expect from a high-quality Elektor board, all connectors are fitted at the edge(s).

The vast majority of components that make up the circuit are off the shelf types and their mounting is unlikely to present problems. However, working with SMDs requires some getting used to, and that is why we recommend starting with these parts. With IC2, the pin leading is such that soldering is not too difficult. IC1, however, requires a steady hand and a solder iron with a fine tip. Carefully position the IC on the board and first solder diagonally opposed pins. Then check if the IC body needs re-positioning. If not, solder the other pins quickly and not using too much solder. Use fresh desoldering braid to remove excess solder and do not forget to let the IC cool down in between solder actions.

Besides integrated circuits the PCB also contains a couple of SMDs — supply filtering chokes L1 and L2, and four decoupling capacitors for a number of supply internal to the PCM2902. Of these four miniature 1-?F capacitors, C20, C25 and C26 are mounted at the top side of the PCB, in the space between IC1 and quartz crystal X1 (see the close-up photograph in **Figure 4**). Capacitor C19 is mounted at the solder side of the board, between two through-plating spots. Chokes L1 and L2 also end up at the underside of the board (see **Figure 5**). The board allows SMDs with 06003 cases as well as the larger 0805 cases to be fitted. The latter are preferred because they are larger and therefore easier to handle.

Software installation

The installation of the board under Windows 98SE is unlikely to cause problems. First you will be notified that a 'USB Audio Codec' has

COMPONENTS LIST

Resistors:
R1,R3 = 6kΩ49
R2,R4 = 3kΩ92
R5 = 4-way 1kΩ5 SIL array
R6,R7 = 22Ω
R8 = 1MΩ
R9,R16 = 5kΩ76
R10,R17 = 6kΩ81
R11,R18 = 6kΩ65
R12,R19 = 20kΩ0
R13,R20 = 10kΩ0
R14,R21 = 100Ω
R15,R22,R25 = 100kΩ
R23 = 4Ω7
R24 = 8kΩ2
R26 = 33kΩ
R27 = 1kΩ5

Capacitors:
C1,C2,C14,C21 = 3µF3 50V, MKT (Siemens), lead pitch 5 or 7.5mm
C3,C4 = 22pF
C5,C12,C13 = 10µF 63V radial
C6,C23,C24,C28 = 100nF ceramic, lead pitch 5mm
C7,C8 = 33pF
C9,C16 = 1nF5 1% *
C10,C17 = 1nF 1% *
C11,C18 = 470pF 1% *
C15,C22 = 47pF
C19,C20,C25,C26 = 1µF 25V, SMD case 0805 (e.g., Farnell # 317-640)
C27 = 100µF 10V radial

*) polypropylene or polystyrene (EMZ)

Inductors:
L1,L2 = BLM31A601S, SMD case 1206 (e.g., Farnell #. 581-094)
L3,L4 = 47µH

Semiconductors:
D1 = LED, red, high efficiency
T1 = BC557B
IC1 = PCM2902 (Texas Instruments/Burr-Brown)
IC2 = OPA2353UA (Texas Instruments/Burr-Brown)
IC3 = TORX173 (Toshiba)
IC4 = TOTX173 (Toshiba)
IC5 = LE33CZ (ST) (e.g., Farnell # 302-4568)

Miscellaneous:
JP1,JP2 = 3-way SIL pinheader with jumper
JP3,JP4,JP5 = 2-way SIL pinheader
K1,K2 = 3.5mm stereo jack socket, PCB mount (Conrad Electronics # 73 28 93-88)
K3 = USB connector, PCB mount, type B
X1 = 12 MHz quartz crystal, parallel resonance, (Cload = 30pF)
PCB, order code **020178-1** (see Readers Service page)

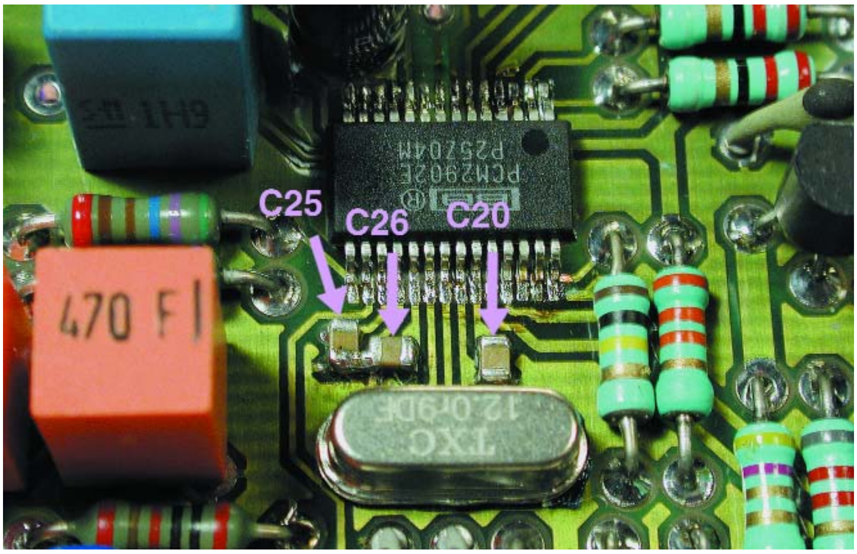


Figure 4. Mounting IC1, C20, C25 and 26 requires precision in soldering.

been found, which requires drivers to be installed. Next, three devices are found (keep the Windows CD-ROM handy): a 'USB Composite Device', a 'USB Human Interface Device' and finally a 'USB Audio Device'.

These three items may be found back under the System Properties/Device Manager tab, see the screendump in **Figure 6**. Next, with Playback properties you should see three slide controls: Desktop, Wave and SW Synth. A fourth slider called 'CD Player (for Window's own simple software player for audio CDs), will be missing and is not found back until the PC is restarted.

In Control Panel, under the Multimedia/CD Music tab, do not forget to check the 'Enable digital CD audio for this CD-ROM device'. When the USB link is briefly interrupted, the control will probably disappear. This is normal (at least, for Windows) and caused by a bug in the operating system. The problem has not been solved under Windows ME or XP, which use different names for some of the windows and controls.

For a quick test of the HID interface, open the volume control win-

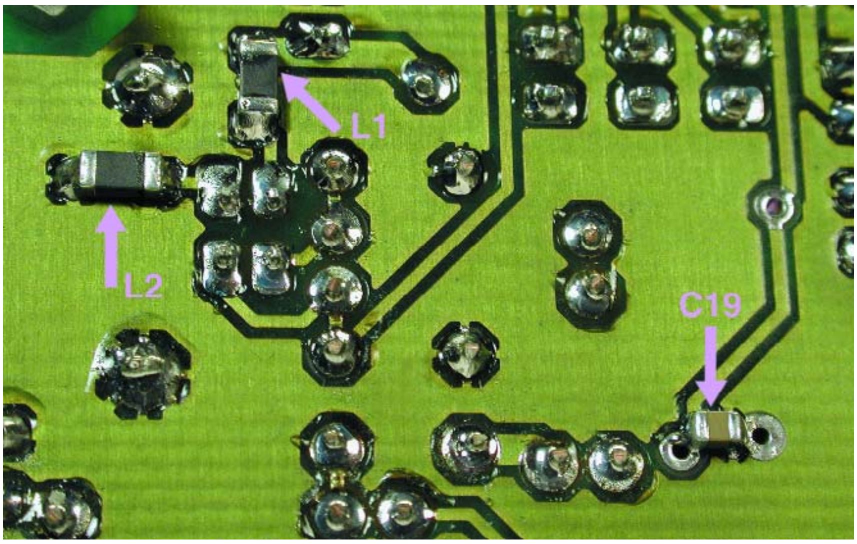


Figure 5. Just like C19, SMD chokes L1 and L2 are fitted at the solder side of the board.

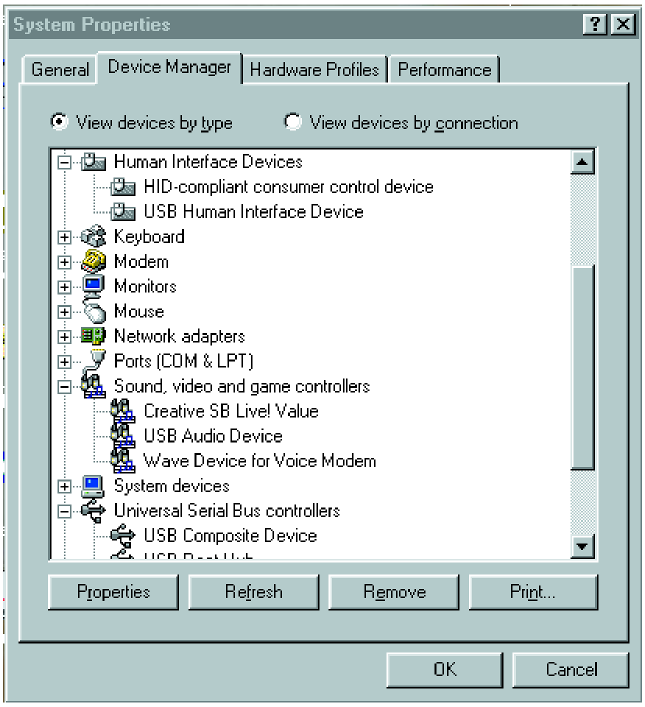


Figure 6. The software installation is quite straightforward (Windows 98SE).

dow. If you establish a contact between the pins of jumpers JP3, JP4 and JP5, you will see 'Mute' going on and off with the loudspeaker slider, while the slider itself moves up or down.

Tip

Those of you who want to test this little sound card may find freeware and shareware on the Internet. During our 'quest' we came across 'audioTester at this website:

www.sumuller.de/audiotester

This software turns your codec into an audio test system comprising a spectrum analyser, an oscilloscope and a signal generator. We tested version 1.4h which comes highly recommended.

(020178-1)

If a picture...

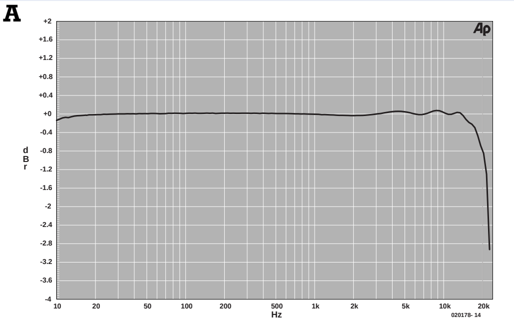
A number of test graphs were plotted that show the equivalent of two pages of text or more.

The first graph (**A**) is practically oriented showing the audio level response of the ADC and the DAC connected in series. To make this measurement we employed the ASIO Multimedia Driver from Cubase VST/32. The standard USB audio drivers in Windows do not allow full-duplex operation, hence prevent you from listing in on the recording! Oddly they do allow an audio CD or a wave file to be played at that time! At 20 kHz, the audio level has dropped by just 0.8 dB. Because the graph scale has been enlarged, the ripple caused by the digital filter of the DC is clearly visible — it is not caused by the analogue filter!

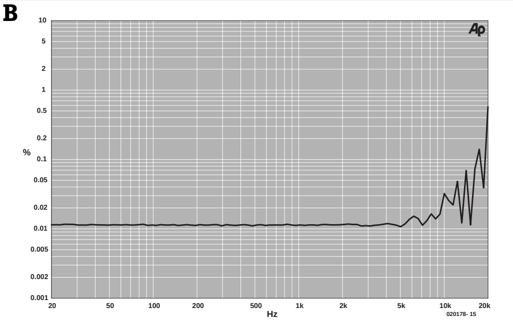
Graph **B** shows distortion and noise as a function of frequency. Here, too, the ADC and DAC are measured in series. The distortion is mainly caused by the ADC, and closer scrutiny using FFT analysis indicates the presence of other mixing products besides the expected harmonic distortion. These products are probably generated by the internal PLL and the digital filters. From 5 kHz onwards, the aliasing products contribute most to the overall distortion. However, they do not have alarming levels given the simplicity of the circuit.

Curve **C**, finally, shows the frequency spectrum of 997 Hz with full drive of the DAC (using a test CD). All harmonics are below –90 dB and account for nearly all of the 0.005% distortion measured. All noise above 20 kHz is typical for delta-sigma converters using noise sampling, and is not worrying if a measurement bandwidth of 22 kHz is used. The analogue output filter limits the larger part of the noise and aliasing products above 35 kHz to acceptable levels. If the bandwidth of the THD+N measurement is extended to 80 kHz, these products will of course cause the overall distortion to increase (to 0.046%).

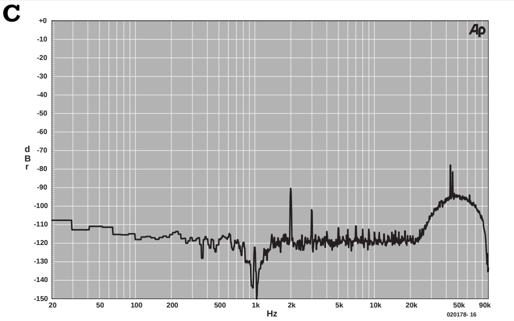
A



B



C

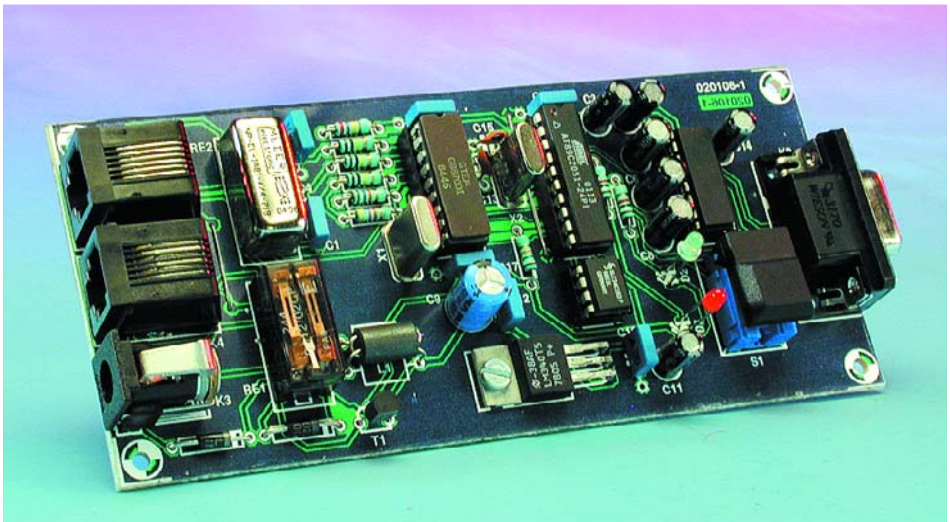


Programmable Dial-Out Blocking Device

barring premium rate numbers

Design by C. Lercher

Premium rate numbers (in the UK, generally those starting with 09) are often used as a way of extracting payments from telephone users and Internet surfers. This is however illegal if it is done covertly without the knowledge of the user. The circuit described here blocks such numbers and cannot be defeated.



Despite the best endeavours of consumer protection organisations there is still much abuse of premium rate telephone numbers. In particular, it can happen that while surfing the Internet, unbeknown to the user, a new dialler program is downloaded which terminates the call in progress and dials out again on an expensive premium rate number. Unfortunately dialler guard programs are no defence against such underhand activity, since as soon as some new piece of protection software appears it only takes the hackers a short while to develop a way to get around its security. It is of course possible to arrange for your telephone provider to bar premium rate numbers, but not generally if a carrier selection prefix is used — which if often the case with such diallers. An external device is called for, which cannot be hacked into, but which nevertheless can be updated with new numbers as required.

What are premium rate numbers?

Variable or fixed tariff premium rate numbers appear in a special separate section on the telephone bill. The charge for such calls can vary from a few pence to pounds per call or per minute. This is all perfectly legal, and provides a straightforward way to charge for services such as directory enquiries or helplines. As is so often the case, however, there is a darker side: when you use a dialler program which drops your

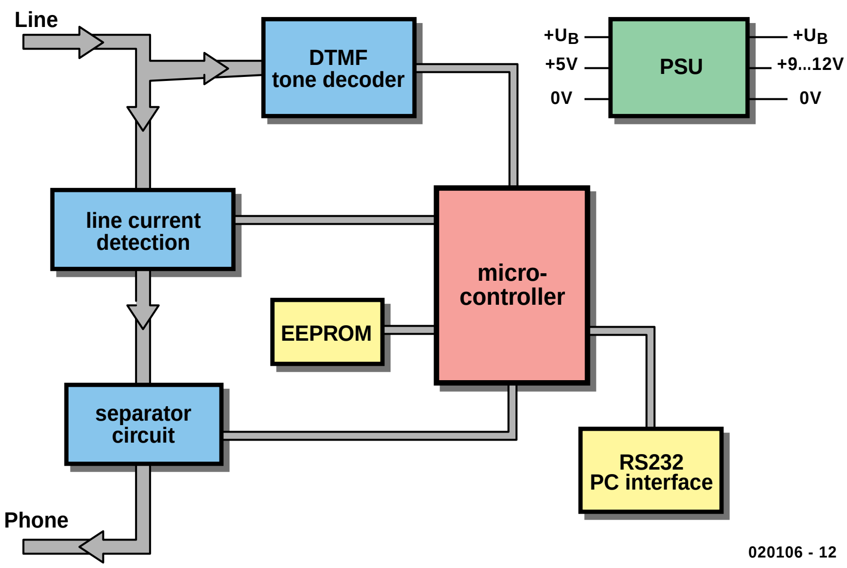


Figure 1. Block diagram of the Programmable Dial-Out Blocking Device.

modem or ISDN Internet connection and, without your knowledge, re-establishes it over an expensive premium rate number.

This Programmable Dial-out Blocking Device prevents such connections being made by barring up to ten freely-programmable numbers or number prefixes. Thus, for example, not only can 09-prefix numbers can be blocked, so can others: to allow only local calls, to bar international calls, to prevent carrier selection prefixes, and so on.

Between linebox and modem

A block diagram of the device is shown in **Figure 1**. Like an answering machine, it is connected in series with the telephone line and becomes active when the line is in use, i.e. when the receiver is picked up. It is capable of recognising the sequence of DTMF tones that correspond to a number to be barred and then breaking the connection, thus dropping the call.

To do this, two functional blocks are connected in series with the telephone line, namely a loop current monitor and a line interrupter. These two blocks are connected to a microcontroller, along with a DTMF tone decoder and an external I²C EEPROM in which the numbers to be blocked are stored. The device is programmed over an RS232 interface, which employs a MAX 232, and therefore uses standard symmetrical voltage levels. A mains power supply delivering a stable +5 V completes the circuit.

The circuit is designed so that in the event of a power cut the telephone line can be used freely. This is hardly a disadvantage — one can after all always simply pull out the plug in order to dial a barred number — but is rather a safety feature: if there is a power cut as a result of a fire, it will always still be possible to call the fire brigade!

When a piece of terminal apparatus such as an analogue modem or fax machine goes off-hook in order to make a call, the series-wired line sensing relay is energised. This is just an ordinary relay, except that its coil has an extremely low resistance. This is so that we do not insert too much additional resistance into the telephone circuit. Line sensing relays typically have a resistance of less than 10 Ω. The current through the terminal apparatus and the line sensing relay is in the region of 20 mA, which corresponds to a voltage drop of around 200 mV. When this current flows, a tiny reed contact closes in the relay: this can even be seen in the symbol shown in **Figure 2**. The relay is polarity sensitive: this means that the direction of current flow in the coils is important. If opposing currents flow in the two coils, the magnetic fields cancel one another out and the reed contact does not close.

When the line sensing relay detects a connection, it sends a signal to the microcontroller which then starts to monitor the output of the DTMF decoder.

The DTMF tone pairs are AC-coupled from the telephone line via coupling capacitors C1 and C4. The IN+, IN- and GS pins of the MT8870 are connected to an internal operational amplifier, whose gain can be set using R4. R6 and R7 form a high-impedance connection to V_{ref}. According to the datasheet, a voltage of $V_{dd}/2$, or around 2.5 V, is present on this pin. The R5-C2 RC combination effectively measures the length of the DTMF tones, and, if the length is correct, a pulse is generated on STD. The falling edge indicates that a tone has been decoded and that a valid decoded result is available on the data output pins.

The microcontroller

The main control tasks are carried out by an Atmel 89C2051 microcontroller. On reset the microcontroller first checks wither pin P3.2 is low. If this is the case, the system establishes a terminal connection with a remote PC over the RS232 interface, as the DTR input signal (pin 4 on connector K2) is asserted. Since the CD and DSR signals (pins 1 and 6 respectively) are connected to DTR, the computer (or rather a terminal program running on it) will be able to establish communication.

A serial 256 by 8 bit EEPROM memory is connected to the microcontroller. The microcontroller drives the EEPROM via an I²C two-wire bus.

Two LEDs are also connected to the microcontroller. The red LED D3 lights to indicate when the line is busy, and goes out automatically when the first DTMF tone is recognised. The green LED D3 indicates when the circuit is ready for operation. It lights continuously except when the unit has been disabled for the next call by pressing button S1, or when a connection with the host computer has

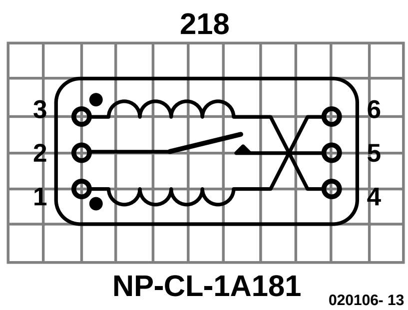


Figure 2. Line sensing relay pinout.

been established.

The device uses two six-way RJ11 sockets. RJ12 sockets can also be used, as long as the pinout is correct. Eight-way RJ45 data/ISDN sockets are sometimes also found on analogue connections, and these can also be used, although this does not conform to ETSI standards.

The line socket can be connected either directly to the master socket or in line with the modem's cable. The telephone socket is then connected to the telephone or modem respectively. Information on the pinout of RJ connectors and lineboxes can be found on the Internet, for example at www.gbnet.net/net/uk-telecom/p3-1.html.

The connection to the host computer is set up as follows:

- connect the RS232 cable (not a null-modem cable)
- start the terminal program
- briefly interrupt the power to the circuit, in order to reset it

What happens now, if the modem or other terminal device goes off-hook? Because the line sensing relay coils form a series circuit with the terminal device via K1, the reed contact in the line sensing relay will close when the line becomes busy. This information is communicated to the microcontroller in the form of a falling edge on input P1.7. The line becoming busy is also indicated by LED D3. The microcontroller has internal pull-ups, and so external resistors are not required. Contact bounce is eliminated in software.

High nibble of address	Low nibble of address																barred number
	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F	
0	30	31	39	30	0D												0190
1	30	31	39	33	0D												0193
2	30	39	30	30	0D												0900
3	30	31	30	78	78	30	31	39	0D								010xx0190
4	30	31	30	78	78	30	31	39	33	0D							010xx0900
5	30	31	30	78	78	30	39	30	30	0D							010xx0193
6	30	31	30	78	78	78	30	31	39	30	0D						010xxx0190
7	30	31	30	78	78	78	30	31	39	30	0D						010xxx0900
8	30	31	30	78	78	78	30	39	30	30	0D						010xxx0193
9	30	30	0D														00

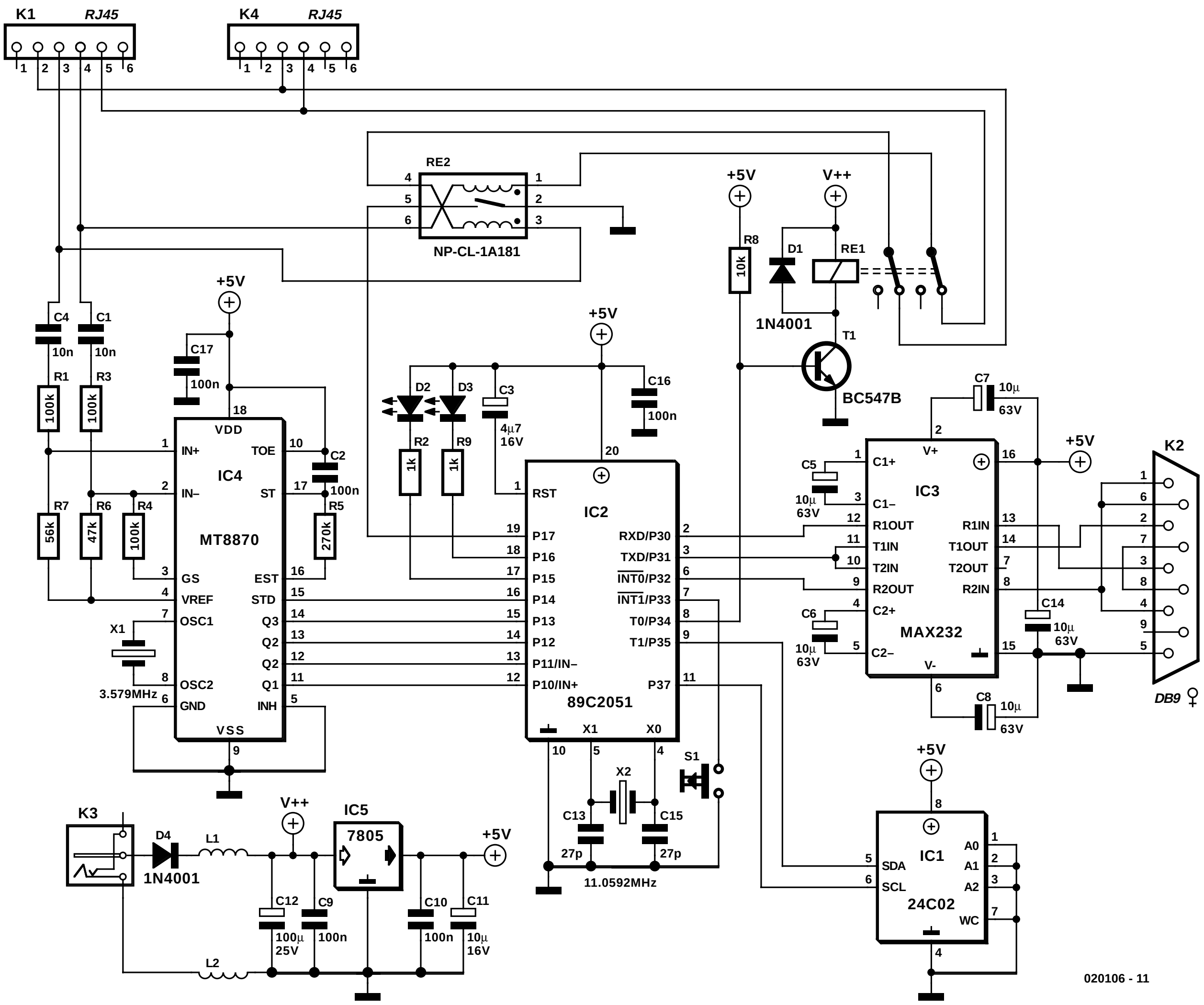


Figure 3. Detailed circuit diagram.

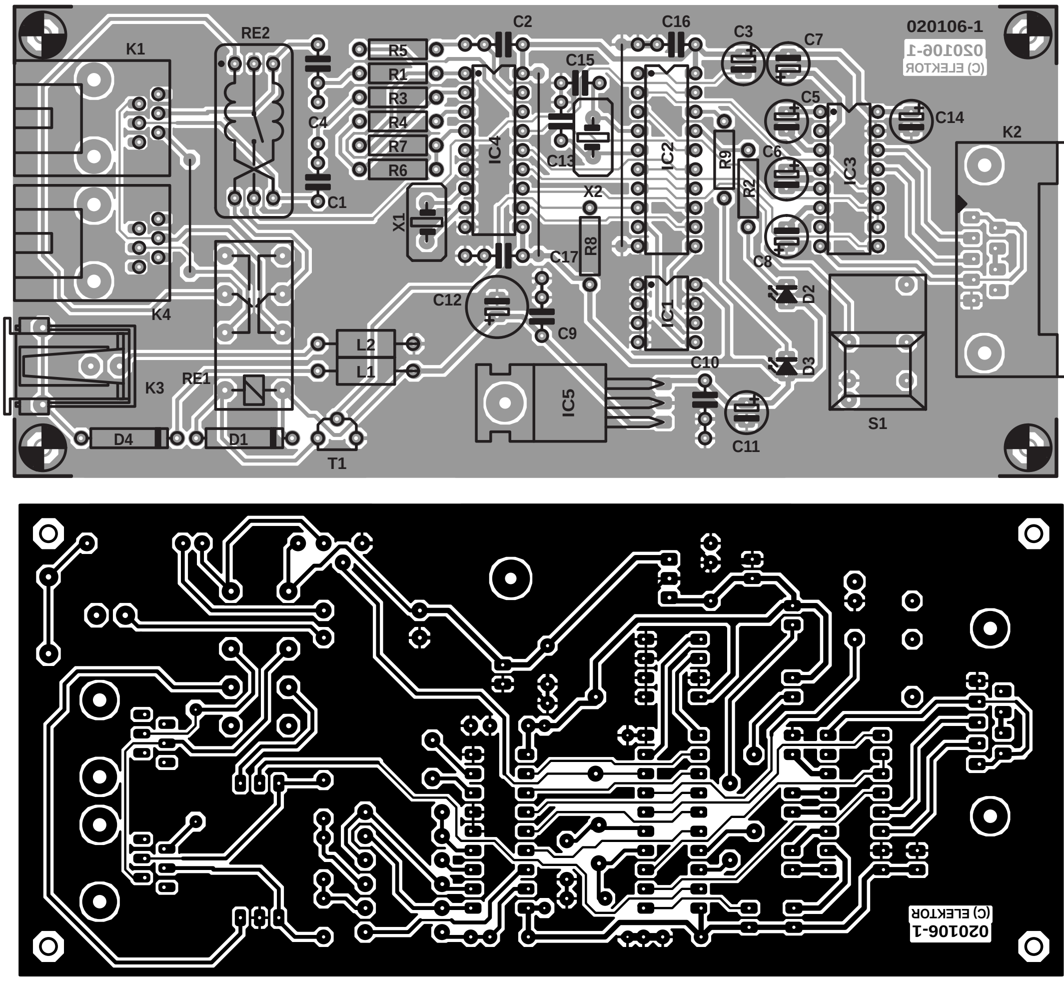


Figure 4. The single-sided printed circuit board (available ready-made).

Next, a number is dialled. Rising edges on input P1.4 indicate to the microcontroller when a new DTMF tone has been recognised. As soon as the signal goes low, the microcontroller can read the data as a 4-bit value on pins P1.0 to P1.3. This value can now be compared with the first storage location in the number table. The storage format of barred numbers in the EEPROM is illustrated in the table. At this point the microcontroller has detected a valid tone and converted the code into an ASCII value. A pointer into the table is used which starts in column zero and compares each entry with the decoded DTMF tone. For example, suppose the tone corresponds to the digit zero (30_{hex}). This matches in rows 0, 1, 2 and 9, and so in each of those rows the column pointer can be advanced to column 1. For all the other rows the column pointer is set to the value FF_{hex} to indicate that the row in question is no longer in consideration. Suppose the next

COMPONENTS LIST

Resistors:
R1,R3,R4 = 100kΩ
R2,R9 = 1kΩ
R5 = 270kΩ
R6 = 47kΩ
R7 = 56kΩ
R8 = 10kΩ

Capacitors:
C1,C4 = 10nF
C2,C9,C10,C16,C17 = 100nF
C3 = 4µF7 16V radial
C5-C8,C11,C14 = 10µF 63V radial
C12 = 100µF 25V radial
C13,C15 = 27pF

Inductors:
L1,L2 = 2-hole ferrite core, 2 x 2 turns ECW

Semiconductors:
D1,D4 = 1N4001
D2 = LED, green, high efficiency
D3 = LED, red, high efficiency
T1 = BC547B
IC1 = EEPROM, 24C02 or larger, in DIL8 case
IC2 = AT89C2051, programmed, order code **020106-41**
IC3 = MAX232CP
IC4 = MT8870 or KT3170
IC5 = 7805

Miscellaneous:
K1,K4 = 6-way RJ45- or RJ11 socket, PCB mount
K2 = 9-way sub-D socket (female), angled pins, PCB mount
K3 = mains adaptor socket
S1 = pushbutton, 1 make contact
X1 = 3.579545MHz (NTSC) quartz crystal (32pF parallel resonance)
Re1 = 12V relay, 2 changeover contacts, Fujitsu D012-02CP or Siemens V23042-A2003-B101
X2 = 11.0592MHz quartz crystal (32pF parallel resonance)
Re2 = NP-CL-1A181-4/4-218 (Meder/Finder/Omron) supplied by ELV (*www.elv.de*)
PCB, order code **020106-1**
Disk, project software, order code **020106-11**

digit is 9 (39_{hex}). This matches only in row 2; now for rows 0, 1 and 9 the column pointer is also set to the flag value FF_{hex}.

The wildcards indicated by 'x' (78_{hex}) represent blocks of digits. This function is used to allow the various network access numbers used for carrier selection to be recognised. The particular access code used does not matter; what is important is whether an expensive 09-prefix number follows or not, because this is what must be detected correctly to ensure that the connection can be broken. A table entry of $0D_{hex}$ corresponds to an 'enter' command and causes the call to be dropped.

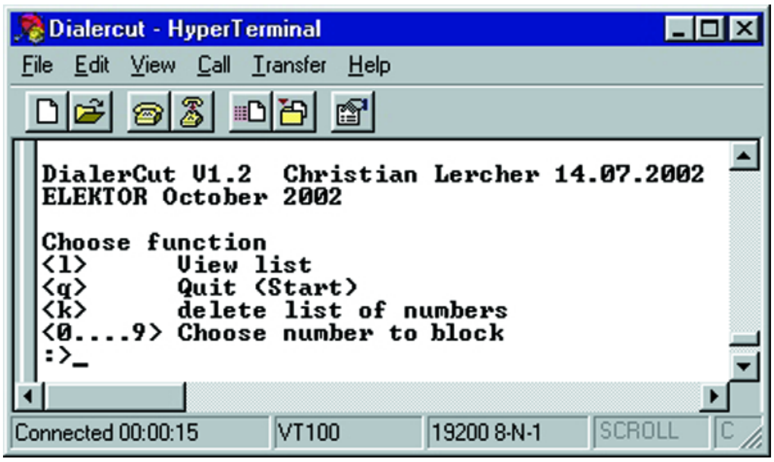


Figure 5. HyperTerminal screenshot.

Construction and test

Start as usual by populating the printed circuit board (**Figure 4**) with the smaller components such as resistors, diodes and wire links. Then fit the IC sockets, relays, connectors and capacitors.

With just voltage regulator IC5 fitted, carry out an initial test by applying 12 V to the DC power connector (positive to the central pin): 5 V should be measured on the IC sockets. Diode D4 protects against reverse polarity on the power input. Neither LED should light, but the relay should pull in since sufficient base current should flow through R8 to turn transistor T1 on. In normal operation the base of T1 is taken to ground by the microcontroller, so that the full power supply voltage appears across R8.

Now disconnect the circuit from the supply and fit the ICs in their sockets. When power is reapplied, relay Re1 should pull in and both LEDs should light until the microcontroller wakes up and all outputs become stable. The current consumption should be around 28 mA.

Disconnect the power again and connect the circuit to a computer using a 9-way RS232 cable (not a null-modem cable). On the PC, run a terminal program (HyperTerminal, for example) with communication settings 19200/8/N/1 and reapply power to the unit. As shown in **Figure 5**, the device is now in configuration mode.

There are only a few commands needed to operate the configuration program:

l list
Gives a list of all barred numbers.

0 to 9 select storage location
Here a series of digits making up a number to be barred can be entered. The character 'x' acts as a wildcard, while the 'enter' function (or CR) is used to mean 'disconnect' as well as terminating the entry.

q quit
Switches the unit automatically into active mode, to allow the telephone connection to be tested.

k kill
This function erases the entire contents of the external EEPROM.

Entering the number to be barred proceeds in a straightforward fashion. After a storage location for the number has been selected by pressing a digit from 0 to 9, either a number must be entered or 'e' (for 'exit') should be pressed. If the 'enter' key is pressed immediately, it will be stored in column 0 of the table, and every call will always be dropped immediately. A storage location selected in error should always thus be abandoned using 'exit'.

Finally we now come to the first test on the telephone network. The unit should be connected to a telephone socket and to a (DTMF-capable) telephone. A normal dial tone should be heard and we can now use the telephone to place a call: after a few moments LED D3 should have lit to indicate that the line is in use. Press a digit key on the telephone, the microcontroller should recognise the digit and LED D3 should go out again.

Assuming this has all worked correctly, replace the receiver, and now try to dial a barred number. The connection should be broken, indicated by the clicking of the relay and the lighting of the red LED.

If this also works correctly, the device is ready for use. Of course, it cannot guarantee one hundred percent safety, since one never knows what methods the hackers will find next to relieve people of their money!

The device works only with analogue systems employing DTMF, and not with older pulse-dialling systems. For ISDN or DSL a completely different digital approach would be required. Of course, the device can be used on the analogue side of an ISDN telephone installation, not just on a modem but also, for example, to bar access to particular extensions.

(020106-1)

Note:
The circuit described in this article is not approved for connection to the public switched telephone network (PSTN) in the UK.

Web links

MT8870, msan-108.pdf:
http://products.zarlink.com
AT24C02:
www.atmel.com/atmel/products/prod162.htm
AT89C2051:
www.atmel.com/atmel/products/prod71.htm
NP-CL-1A81-4/4-218:
www.meder.com/ReedRelays/npcl_se.htm
Telephone connector pinout details:
www.gbnet.net/net/uk-telecom/p3-1.html

VLF Reception on the PC

antenna on the soundcard

By H. Lutz

In the past, reception of utility stations at the low end of the radio spectrum typically required a suitable receiver or up-converter. Today, things are much simpler — just use a PC soundcard and a lot of wire.

Figure 1. A receive-only antenna for the very low end of the VLF band.

Any reasonably modern PC (Pentium 100 running Windows 95 or later) with a soundcard can be turned into a radio receiver for frequencies below 24 kHz (VLF range). This is possible without costly hardware or software additions. The only hardware you need to get your hands on is a suitable antenna. In the software department, all you need is a spectrum analysis program which is available free of charge.

Antenna

As on the medium and long wave bands, VLF (very low frequency) reception typically requires a inductive antenna. For best results, such an antenna should consist of an inductor with a large cross section and/or a large number of turns. In the case of a receive-only antenna, electrical properties like inductance and ohmic resistance are relatively unimportant factors and therefore allowed to vary over a large range. Consequently, constructing such an antenna is relatively easy. All you need is a reel of light-duty isolated wire which is connected to the LINE or MIC input of the soundcard via a piece of 2-wire cable with a length of at least 2 metres.

For best results, a minimum distance of about 2 metres should be observed between the antenna coil and the PC (and other electronic equipment). The antenna coil should be in a horizontal position. In steel-concrete buildings a position near a window is the best choice.

To improve our receiver's sensitivity, several antenna coils may be connected in series. The direction of the windings should be the same on all coils. If not, induced signals will cancel each other.

Figure 1 shows a VLF receiving antenna consisting of four series-connected wire reels of which two point in the same direction. Each wire reel has a diameter of 10.3 cm and consists of 309 turns. Paperclips allow individual wire reels to be shorted out for experiments.

Soundcard input

After connecting the antenna to the soundcard input, you will need to select the signal source on the PC. Right-click on the loudspeaker symbol in the far end of the task bar. Alternatively (in Windows 98), select Programs -> Accessories -> Entertainment -> Volume Control. If necessary, uncheck 'Mute' for the input to which the antenna is connected, and move up the 'recording volume' slider. Confirm the settings by click-

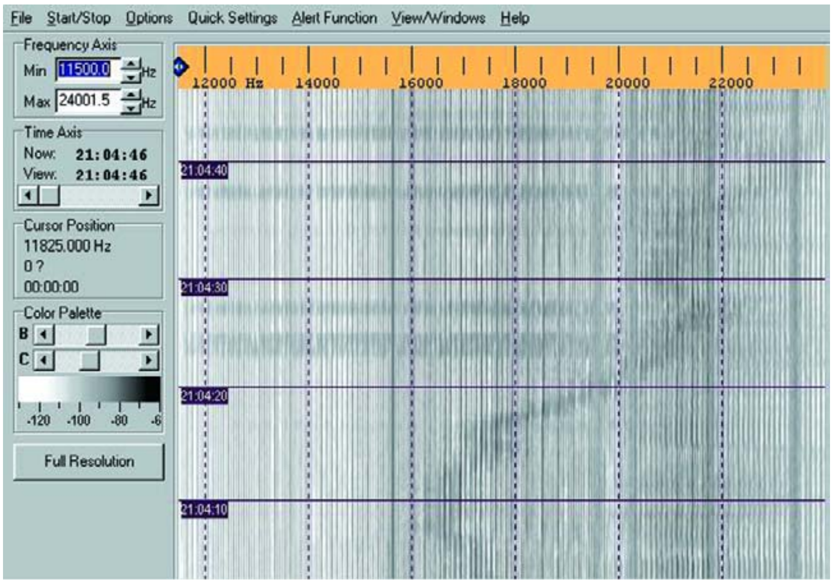


Figure 2. Main window shown by the SpecPlus software.

ing on 'OK'. The volume control slider for VLF reception should be set to maximum, and the balance control to the centre position. Naturally, these settings may be changed later, for example, if a spectral analysis of a different signal is required.

Analysis software

Several programs are available for spectral analysis of low-frequency signals applied to the PC via the soundcard (see www.vlf.it/harald/strangerec.htm).

The author only uses the extremely powerful software called **SpecPlus**, mainly because it is capable of storing received signals in the form of jpeg files containing frequency/time/intensity diagrams (also known as 'spectrograms'). The main window presented by SpecPlus is shown in **Figure 2**. This filter is marked by excellent stability under Windows 95, Windows 98 and Windows ME. No information is available about the performance of SpecPlus under Windows NT or later Windows versions. We know for sure, however, that the program will not run under Windows 3.x.

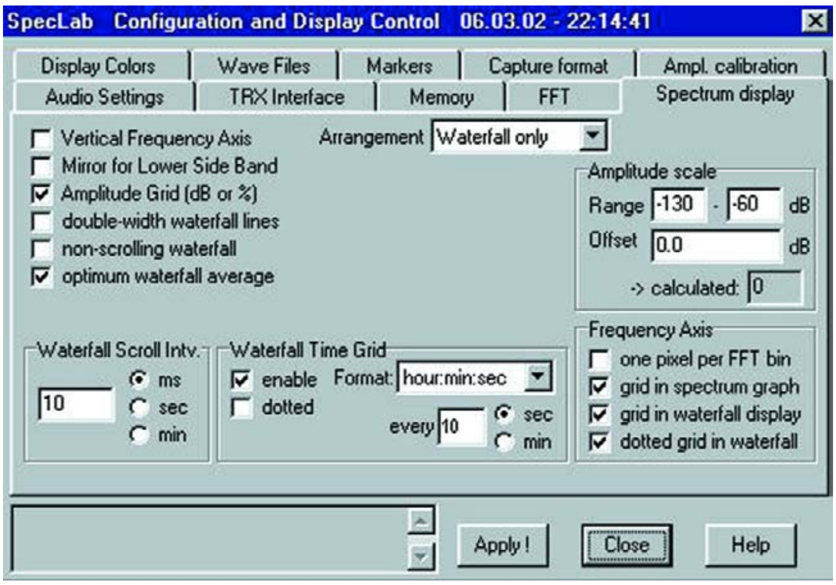


Figure 3. Configuration screen for the spectrum analyser.

SpecPlus is available as a free download from www.qsl.net/dl4yhf/spectra1.html Having downloaded the .zip file, you first unpack it in an installation directory using WinZip. Next, the software may be installed. In line with results obtained from practical experience, the software should run without problems.

With the program up and running, you need to look at some settings. First, determine the colour palette. Although many simulated colour settings are a sight for sore eyes, the preferred colour setting for the readout is black for the signals and white for the background. After all, this combination is easily understood even without knowledge of the colour palette. Besides, the resultant jpeg files may be compressed further using other programs, without losing information or creating room for errors or confusion due to wrong or badly combining colours appearing in the end result.

To define the colour palette, a file with certain settings may be loaded via the Configuration menu (**Figure 3**), using 'Option' and then 'Load Colour Palette'.

Next, set the sampling rate using 'Option' and then 'Audio Settings'. The sampling rate determines the highest frequency that can be received, as follows:

f = sampling rate / (2-input Sample Rate Divisor).

For a maximum input frequency of 24 kHz (most inexpensive soundcards are unable to process higher frequencies) the sampling rate should be set to 48 kHz and the 'Input Sampling Rate Divisor' to 1.

Next, it's time to have a look at the FFT characteristics. Go to 'Options' then 'FFT Settings'. For reception of VLF signals, 'FFT Output' should be set to 'Logarithmic', and 'FFT type' to 'Real number FFT starting at 0'.

The next setting concerns the readout mode. Go to 'Options', 'Display', 'Spectrum Display Settings', and select a display range of –60 to –130 dB.

In practice this range was found to be the most useful for meaningful displaying of VLF signals. Stronger signals should not be expected while the noise level of the average sound card is typically at –120 to –130 dB. In the same window, further settings may be defined for the way results are displayed on your monitor (see illustration).

Finally, in the main window, you need to set the two sliders B (Brightness) and C (Contrast) for optimum sensitivity. This is done by disconnecting or short-circuiting the antenna and moving the B slider so that a white background just remains visible. The Contrast slider C is then moved so that small intensity variations can be seen. For fine adjustment, reconnect the antenna. Because the B and C adjustments affect one another it may be necessary to repeat the above procedure several times until you are satisfied with the resulting display.

At this point your PC is ready to be used as a VLF band receiver.

Because PC monitors generate strong interference in the VLF range, it is recommended to record a spectrum with the monitor switched off, save the file and view it later. Time controlled automatic operation with the monitor switched off is therefore the best mode to use. Practical experience has established the hours between 00.00 h and 06.00 h to be the best for VLF reception, not so much with propagation conditions in mind, but because interference levels due to electrical appliances are then at their lowest.

Automatic operation is possible by selecting 'File' and then 'Periodic Actions' (**Figure 4**). The settings shown here cause one spectrogram graphic to be stored every 40 seconds under the file designation

ns + consecutive number + .jpg

between 00:00:02 h and 12:00:02 h and written into the directory g:\vlf07032002.

The two letters at the start of each file name indicate the axis of reception; '*ns*' meaning north-south, '*ew*' , east-west. This is useful because the antenna used is directive. Make sure the desired directory exists

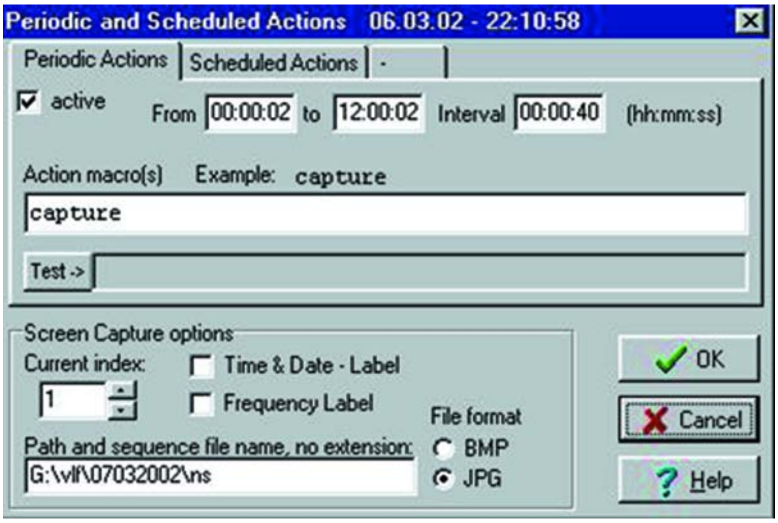


Figure 4. Automatic operation of SpecLab.

and that 'Active' is checked (enabled) because otherwise no recordings are made.

Received signals

The VLF range contains dozens of signals from various origins. Many signals that can be picked up originate from colossal transmitter sites and have travelled a long way to your antenna. Other signals are from nearby sources in and around your own home. A number of stations that can be received at reasonable quality in west and central Europe are listed in **Table 1**. In the frequency range 10 to 24 kHz, you'll find military operated VLF stations transmitting surfacing commands and other simple messages to submarines. The penetration depth of VLF radio signals in sea water is of the order of 10-30 metres, depending on the frequency used, receiver sensitivity, distance travelled over land, water temperature and salinity.

The same frequency range also contains navigation and time standard signals. Despite its favourable

Callsign	Frequency	Location	Note(s)
-	11.905 kHz	Russia (various locations)	ALPHA Navigation
-	12.649 kHz	Russia (various locations)	ALPHA Navigation
-	14.881 kHz	Russia (various locations)	ALPHA- Navigation
?	15.8 kHz	?	
GBR	16.0 kHz	Rugby	
JXN	16.4 kHz	Helgeland (Norway)	
SAQ	17.2 kHz	GGrimeton (Sweden	Special occasions only
?	17.8 kHz	Cutler, ME? (USA)	
RDL/UPD/UFQE/UPP/UPD8	18.1 kHz	Russia (various locations)	
HWU	18.3 kHz	Le Blanc (France)	Often off the air for long periods
RKS	18.9 kHz	Russia	Rare and brief activity
GBZ	19.6 kHz	Criggion	Several different modes
ICV	20.27 kHz	Tavolara (Italien)	
RJH63/RJH77/RJH99 u.a.	20.5 kHz	Russia (various locations)	Time signals
ICV	20.76 kHz	Tavolara (Italy)	
HWU	20.9 kHz	Le Blanc (France)	
RDL	21.1 kHz	Russia (various locations)	Rare and brief activity
HWU	21.75 kHz	Le Blanc (France)	
RJH63/RJH77/RJH99,u.a.	23.0 kHz	Russia (various locations)	Time signals
DHO38	23.4 kHz	West-Rhauderfehn (Germany)	
NAA	24.0 kHz	Cutler (USA)	

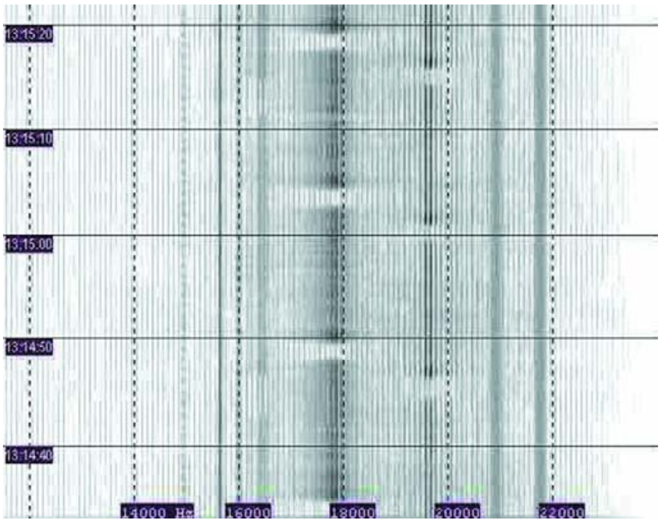


Figure 5. Example of a VLF spectrum showing some signals and interference.

propagation characteristics (enabling permanent worldwide communication) the 10-24 kHz section of the VLF band is not used for broadcast or other 'civil' applications, mainly because of the enormous size of the antennas (whose footprint are larger than the state of Monaco) and the extremely limited bandwidth of just 100-300 Hz. Most transmissions from the military are encoded using high-level encryption methods and will be impossible to decipher.

That leaves you with the challenge of investigating and recording the transmission times of the various stations (no VLF station except ALPHA Navigation is on the air around the clock), examine the intensity and the shape of the received signals, or determine their approximate direction. Directional finding involves performing a 'minimum' signal strength measurement using a ferrite or a window antenna.

The best noticeable signals in the VLF range originate from Navy transmitters. Most of these employ an encoded MSK mode and bandwidths between 100 Hz and 200 Hz.

In the spectrograms, MSK signals are identified as solid lines whose thickness is a measure of the bandwidth. **Figure 5** shows frequency-modulated burst signals from JXN, GBZ and an unidentified station at 17.8 kHz (possibly Cutler, ME, a US Navy station, *Ed.*). You will also notice MSK signals from HWU at 20.9 kHz and 21.7 kHz, as well as GBR (Rugby) at 16 kHz.

The line at 15.625 kHz indicates radiation of the horizontal line frequency component from a nearby TV set. The signal at 14.8 kHz is cheerfully generated by the PC itself.

Sometimes, different modulation types are employed. For example, continuous carriers and transmissions in F1B mode may be picked up from Russian transmitters, while the stations JXN a 16.4 kHz and GBZ at 19.6 kHz transmit frequency modulated burst signals from time to time. The unidentified stations at 15.8 kHz and 17.8 kHz appear to transmit that type of signal only. GBZ undoubtedly has the largest repertoire of modes: apart from MSK and frequency modulated burst signals it also transmits the odd pulse patterns that look like tiny fish or garlands.

In the GUS states, time signals are transmitted at fixed times on frequencies between 20 kHz and 26 kHz. These transmissions follow a fairly complex schedule for several stations, of which RJH69, RJH77 and RJH63 are the easiest to receive. At the frequencies that can be still be received with an ordinary soundcard (20.5 kHz and 23 kHz) only continuous carriers are transmitted (with the exception of RJH63).

Since the dismantling of OMEGA the Russian ALPHA is the only active navigation system left. ALPHA uses 11.905 kHz, 12.649 kHz and 14.881 kHz. Its signals consist of empty carriers with a duration of 3.6 seconds, which are far less conspicuous on the spectrograms than the white bands caused by MSK signals.

Interference

The VLF range is infested with interference from electrical appliances like switch-mode power supplies, computer monitors, TV sets, electromotors, gas discharge lamps and PCs. The best known 'headache' is the 15.625 kHz electron beam deflection frequency used in TV sets. Electromotors generate interference with a load and speed dependent frequency. Configuration commands for the high-voltage grid (electricity distribution system) are probably the cause of burst-like pulses between 17 and 18 kHz observed at the author's location. These bursts occur with different intensities and always last 20 seconds.

The PC used for the receiver system will also add a fair amount of interference. The frequencies will, of course, depend on the model and make of the PC, and they can be pinpointed by short-circuiting or disconnecting the antenna and then looking at the spectrum. It is safe to assume that all signals remaining in the spectrogram originate from the PC.

(020111-1)

More on VLF reception:
www.lwca.org

Corrections & Updates

Audio Combiner
A 4.7-µF electrolytic capacitor should be connected between R17 and ground. The + terminal of the capacitor is connected to R17. The same applies to R18, R19 and R20.

60-dB LED VU Meter
Due to a scaling error, the lower part of the circuit diagram is not visible. Components C5 and R7 should be connected to ground. The connections for S1 and S3 are on 3-way headers. The pole connection is at pin 3, not 2 as expected. Junction D21-C6-IC3 is erroneously labelled '+5V'. A suggested label is 'V+'.

Light Mixer Panel
The parts list on page 48 should be modified to read IC23,IC24 = CNY74-4.

Digital Radio Mondiale (DRM)

digital long-, medium- and shortwave radio

by H. Weber

Even shortwave is now going digital! This year, field trials of a new transmission method got under way, involving shortwave listeners and radio amateurs from all over the world. A 'concept' receiver was demonstrated at this year's International Broadcasting Conference (IBC) in Amsterdam, and transmissions are officially scheduled to start in June 2003.

The use of radio frequency bands below 30 MHz — long-, medium- and shortwave — has been in continuous decline over recent years. The main reason for this is poor sound quality. The channels used for programme transmission are very narrow: 9 kHz on medium- and longwave, 10 kHz on shortwave. Amplitude modulation, as used to date, is certainly technically very straightforward, but not very efficient. In particular, shortwave is very prone to interference. However, by using more sophisticated modulation schemes and modern data compression techniques it is possible to transmit 'near-CD' quality radio in this frequency band. Then the advantages of shortwave, its long range and lack of dependence on satellite operators or Internet service providers, come into their own.

Development

After pioneering systems designed and tested as part of the German T2M project (**Figure 1**), the French company Thomcast (now known as Thales) developed the 'Skywave 2000' system which uses a large number of carriers (at least 47) with a separation of 66.666 Hz. This gives a relatively long data symbol time. The technique is also known as 'slimmed-down DAB'. The technique is indeed reminiscent of DAB, using COFDM (coded orthogonal frequency division multiplex), but is however limited to a much narrower bandwidth. Skywave 2000 allows for a transition period where analogue and digital signals are broadcast simultaneously.

The individual carriers are modulated using QAM (quadrature amplitude modulation), a form of APSK (amplitude and phase shift keying) where two signals at a 90-degree phase offset are amplitude modulated at various set levels and then added together. With four such levels a total of sixteen modulation states (or data symbols) are possible (16-QAM); with eight levels there are sixty-four (64-QAM).

In March 1998 the Digital Radio Mondiale (DRM) consortium was founded, consisting of over seventy companies and other organisations, to set up a framework for international standardisation. The consortium included big foreign service broadcasters such as the BBC, Deutsche Welle and Radio Netherlands, as well as transmitter manufacturers (such as Thales, Telefunken and Harris) and receiver manufacturers (such as Sony and Sangean).

The participants in the consortium took over a year to come to an agreed plan. COFDM was chosen as the transmission technique, being the method favoured by the French participants. Some elements from other systems, in particular regarding error detection and correction, also influenced the final standard. The main modulation scheme selected was 64-QAM, with 16-QAM, offering improved resistance to interference at the cost of lower quality, also available.

The conversion of audio signals into a digital data stream, or 'source coding', employs Advanced Audio Coding (AAC), for which dedicated integrated circuit implementations are available. AAC should not be confused with MP3, despite the fact that they were developed at the same institution. As far as data compression is concerned, AAC is superior to MP3, and it is especially suitable for the low bit-rate data stream demanded by narrow-bandwidth transmission over shortwave.

A technique called SBR (spectral band replication) is employed to improve the audio bandwidth still further. Broadly speaking, the frequencies above 6 kHz are regenerated by synthesising harmonics. This extends the audio bandwidth to 15 kHz, without having to transmit the information in the higher frequency range.

The idea of simultaneous transmission of analogue and digital signals on the same frequency seems to have been abandoned. Instead, set frequency bands will be reserved

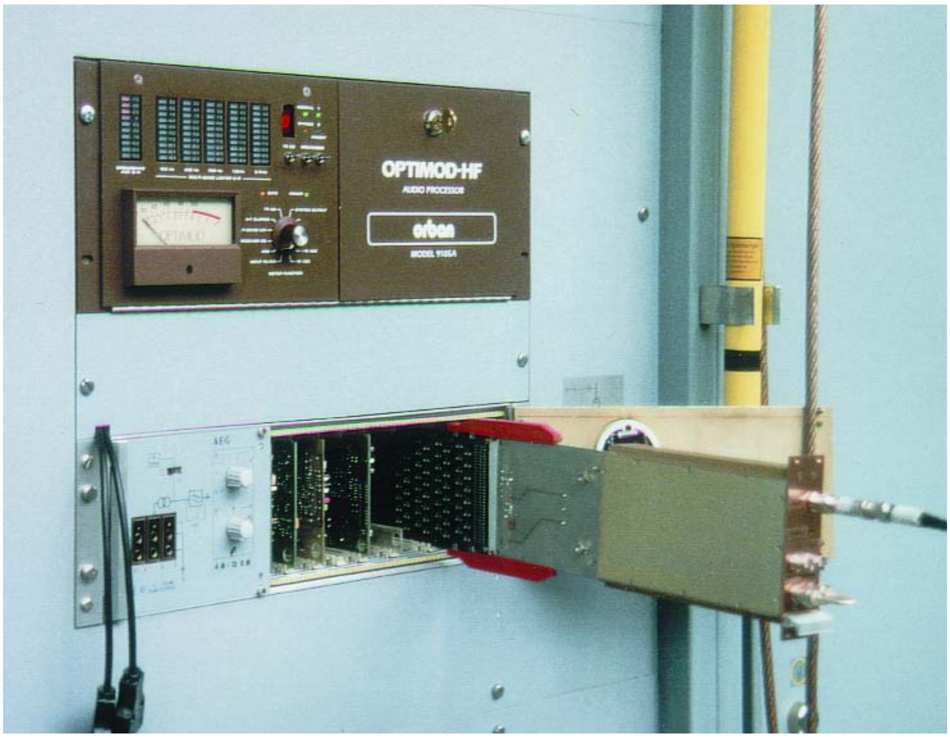


Figure 1. Early trials of digital transmissions over shortwave were carried out in April 1996 at the Jülich transmitter near Cologne using this plug-in card (photo: H. Weber).

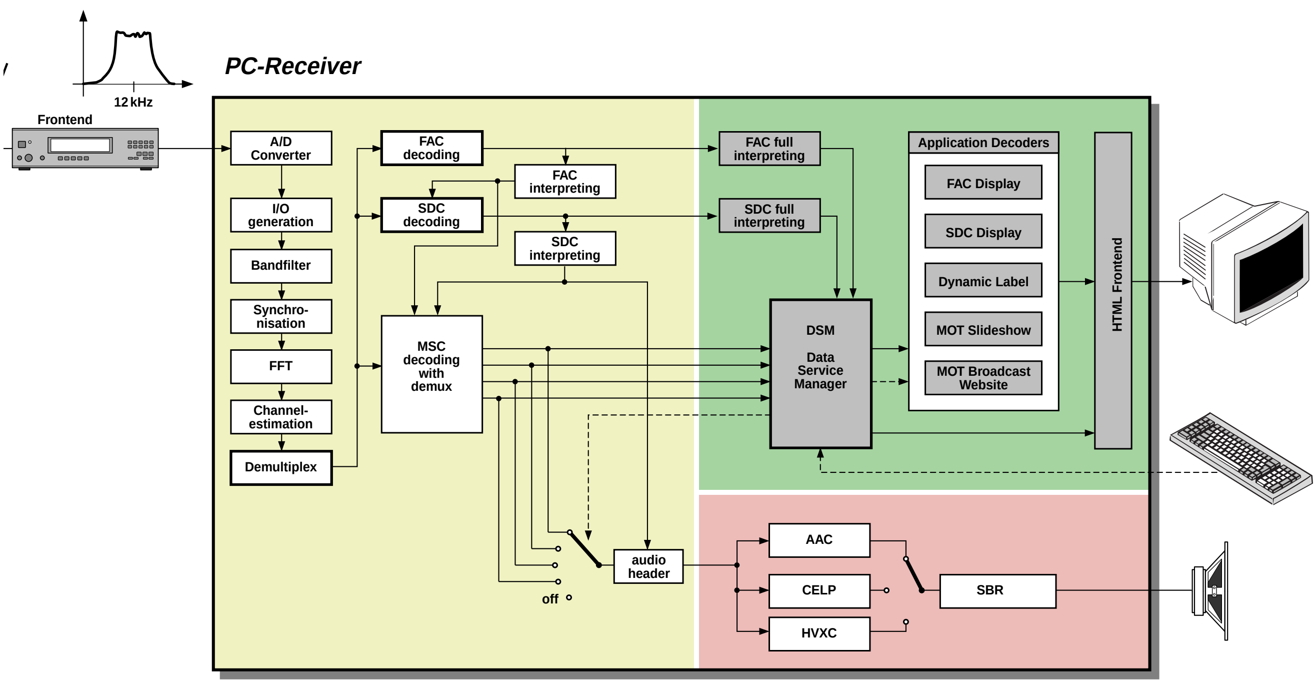


Figure 2. Block diagram of a DRM software receiver (courtesy Fraunhofer Institute for Integrated Circuits).

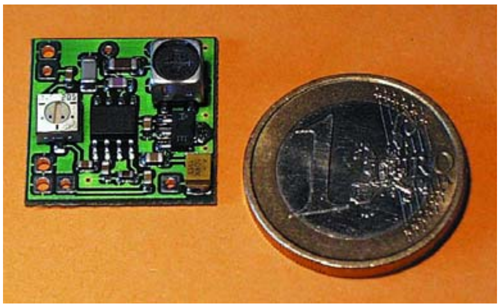


Figure 3. The 'mixer chip' circuit board used for modifying a world receiver for DRM reception (courtesy Sat-Service Schneider).

for DRM in order to prevent mutual interference. In April 2001, the DRM standard was adopted by the ITU (International Telecommunications Union) as a recommendation to its member countries. The way is now clear for the technology to be used worldwide.

Field trials

The next step is a trial period planned for two years in which radio amateurs and shortwave listeners from all over the world can (and should) take part. Trials start at the end of this year. A 'light' version of the professional receiver software (see **Figure 2**) is being made available to participants, which has already been used over the last year to receive test transmissions for evaluation. The software not only decodes the transmission, but also checks the reception quality and reports back to DRM.

To take part, a high-end PC and a shortwave receiver in the middle-to-high price bracket is needed (for example, the AOR 7030 or Yaesu FRG 100). This is modified using a 20 mm square add-in circuit board (or 'mixer chip' — see **Figure 3**), which generates a 12 kHz intermediate frequency. This is required to drive the soundcard of the PC. The receiver must also be adapted for a bandwidth of 10 kHz, since the filter normally used (which typically has a bandwidth of 6 kHz) will not let the whole DRM signal through.

The printed circuit board required for the modifications can, for example, be obtained from Sat-Service Schneider in Germany. The LC version (**Figure 4**) does the conversion job for under 40 euros; the quartz crystal version is almost twice as expensive. If you are not prepared to modify your equipment yourself, a professional fitting service is available. A complete, modified receiver is available for around £ 500 (799 euros); the receiver software costs a further £ 38 (60 euros).

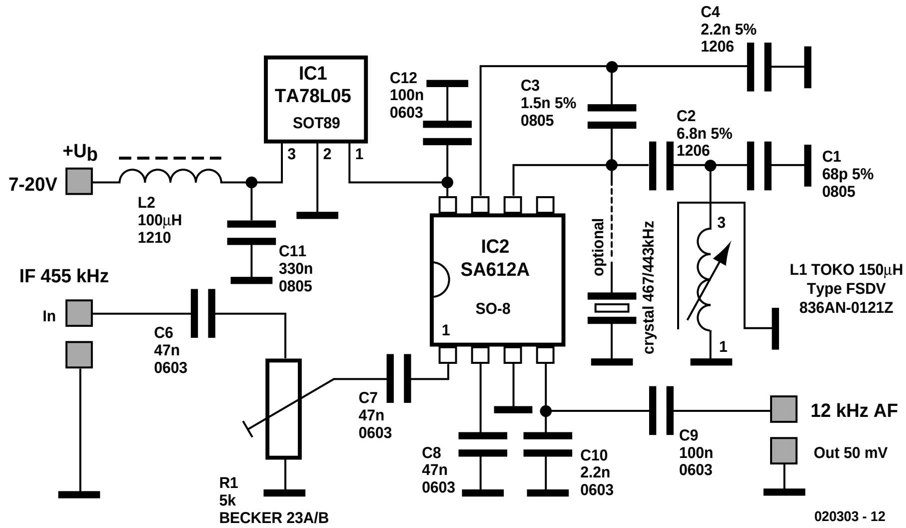


Figure 4. Circuit of the LC-mixer (courtesy Sat-Service Schneider).

Receivers

Of course, only being able to receive DRM transmissions with a PC is no long-term solution. A 'concept' DRM world receiver (**Figure 5**) was demonstrated at the IBC in September in Amsterdam. This was developed by Coding Technologies, a Swedish-German company, in conjunction with the BBC and AFG, a terminal equipment manufacturer. In this receiver the functions which would have been performed in the PC software are realised in an add-in module (the 'TriMedia DSP' in the block diagram of **Figure 6**).

Figure 5. First 'concept' DRM receiver (courtesy Coding Technologies).

Other companies are also working on DRM receivers. Sat-Service Schneider also intends to bring to

DRM websites:

www.drm.org
(general DRM information)

www.drmrx.org
(includes registration to participate in the DRM trials)

www.rnw.nl/realradio/html/drm.html
(Radio Netherlands World Service DRM pages)

www.CodingTechnologies.com
(DRM receivers)

www.iis.fraunhofer.de/dab/products/drmreceiver/index.html
(FhG software radio)

www.sat-schneider.de
(DRM receivers and components for modifying receivers)

market its own mini-receiver (whose block diagram is shown in **Figure 7**).

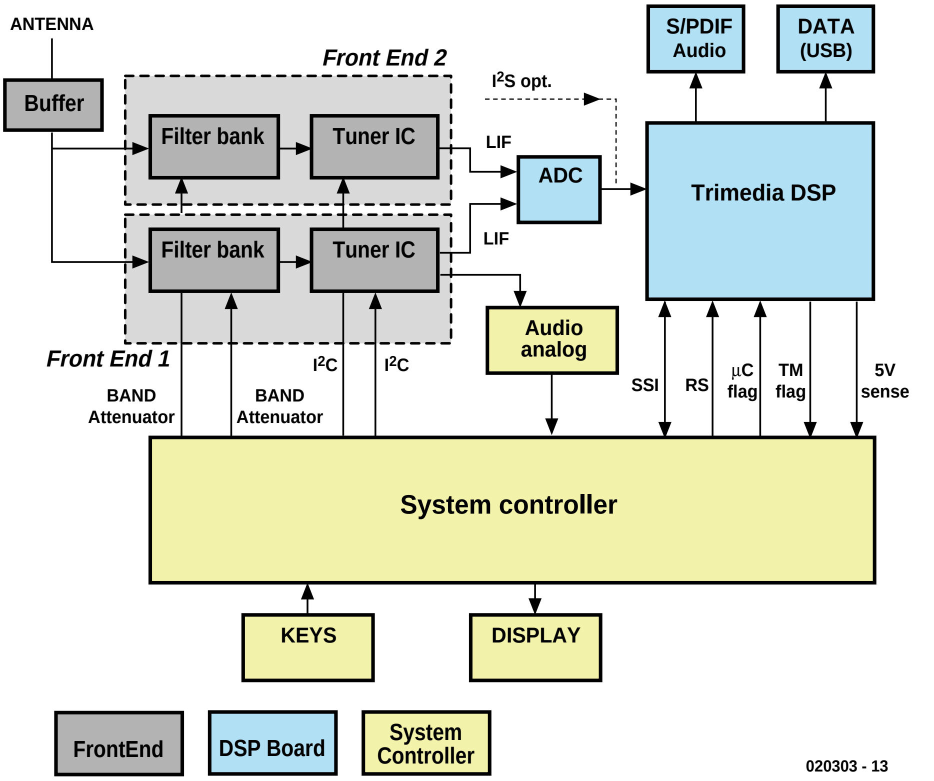


Figure 6. Block diagram of a DRM receiver (courtesy Coding Technologies).

Starting in June

DRM transmissions will officially start after the World Radio Conference, which takes place in June next year. By then the first receiver models will be in production and available in the shops. At first the receivers are expected to be rather expensive; but after the initial period, when mass production begins, the equipment is expected to be 'only a little more expensive' than existing sets. They must support both analogue and digital transmission modes, since the transition will necessarily be gradual. At the earliest analogue transmissions will stop in fifteen years time; in poorer countries somewhat later still.

Most of the big and many of the small shortwave broadcasters have expressed an interest in DRM. Modern transmitters can be modified relatively easily to allow DRM transmissions to be made.

Mediumwave could also experience a Renaissance through improved sound quality; in some cases broadcasters are already using mediumwave for digital transmissions.

(020303-1)

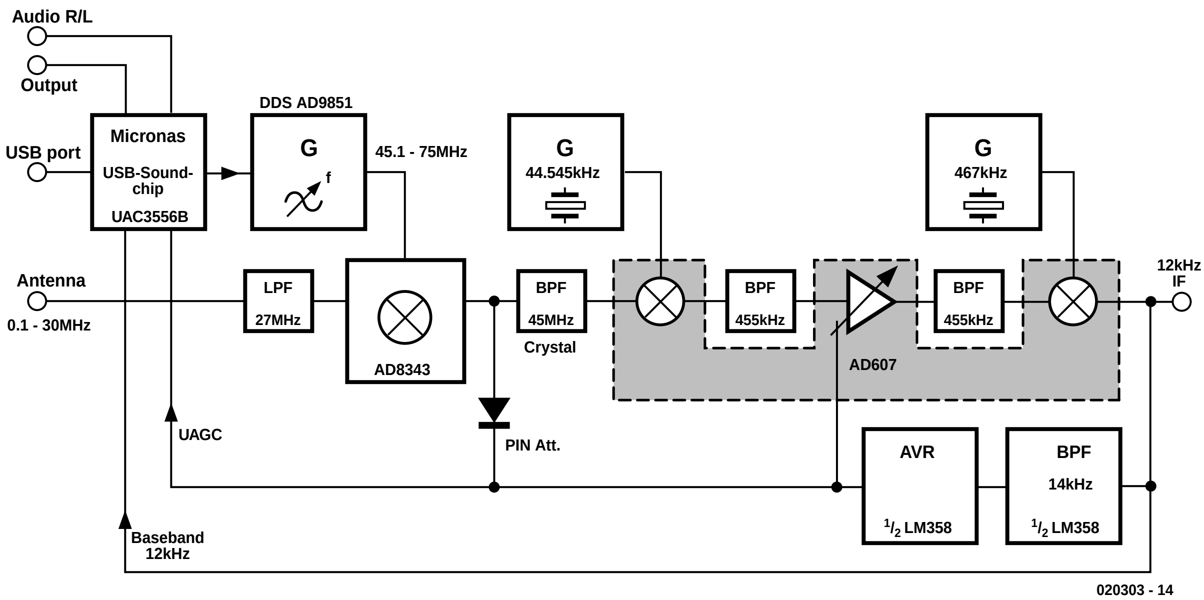


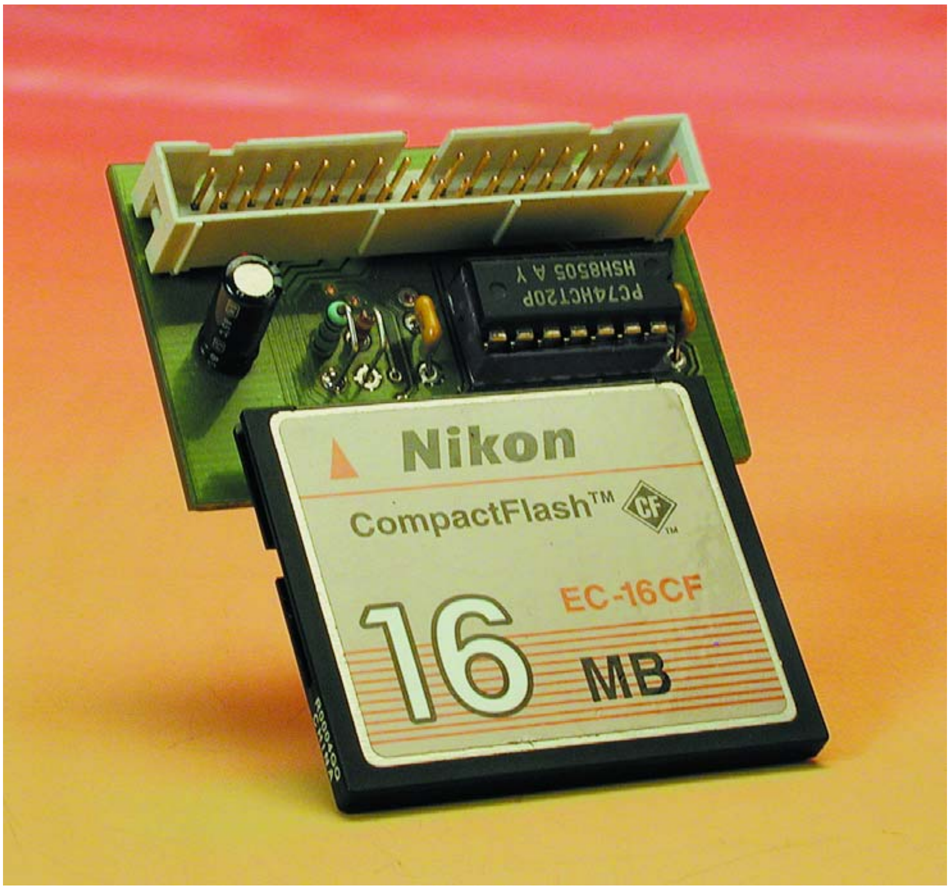
Figure 7. Block diagram of a DRM mini-receiver (courtesy Sat-Service Schneider).

CompactFlash Interface for Microcontroller Systems

including our 89S8252 Flash board

Design by P. Goossens

CompactFlash (CF) cards are ideal for storage of large amounts of data, which is retained for years without the need for a backup supply voltage.



In the wake of our CompactFlash Drive on IDE Bus (April 2002), we now present a similar circuit for microcontroller boards. Specific attention is given to the popular 89S8252 Flash Micro board which forms the hardware basis of our Microcontroller Basics course.

The present CF interface was initially designed as an extension for the 89S8252 Flash Micro board published in the December 2001 issue of *Elektor Electronics*. The circuit may also be used in combination with other microcontroller systems provided you are able to make a suitable adapter between the CF interface and the extension connector on the system you have available.

The CF interface enables the processor to read and write data from/to a CompactFlash card. In this way, the memory capacity of the microcontroller circuit is considerably extended. CompactFlash cards are widely available these days at very competitive prices and the latest ones have a capacity of 1 GByte! Apart from their ease of use, the greatest thing about these cards is their ability to retain data without a backup supply voltage.

Applications of this interface are only limited by your imagination and could include a data logger, voice recording/playback, and so on.

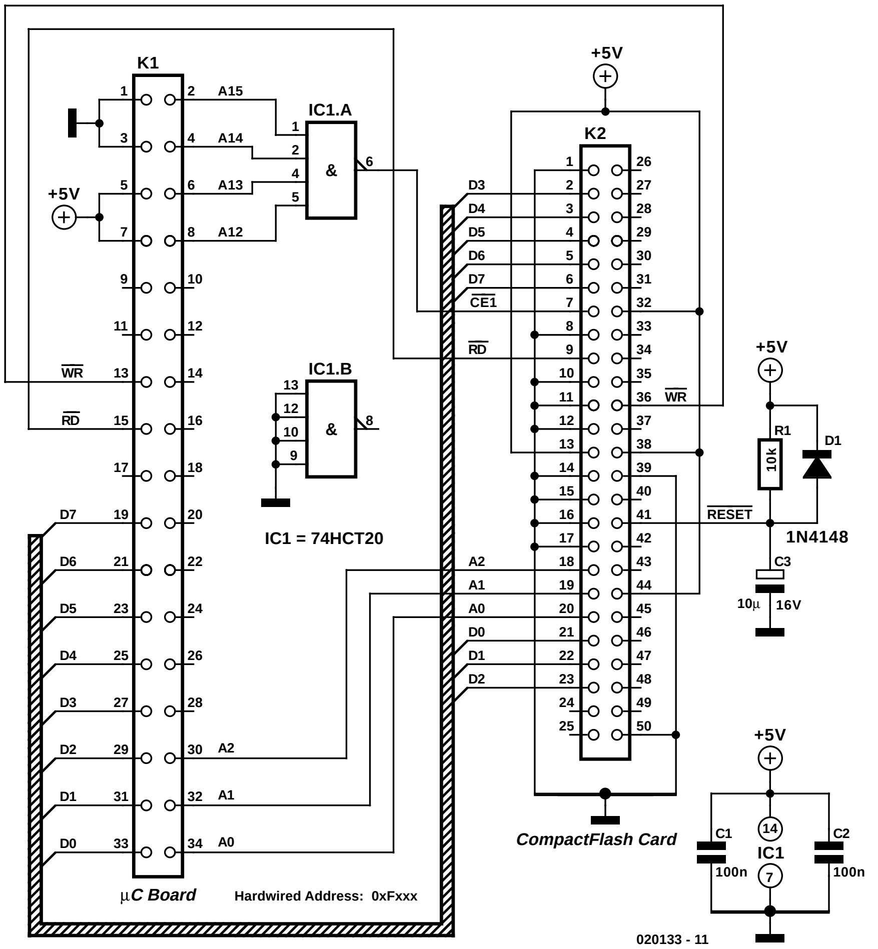


Figure 1. The circuit diagram of the CompactFlash interface consists of little more than two connectors.

Circuit diagram

The circuit diagram of the CF interface is very simple indeed, see **Figure 1**. The ‘electronics’ is down to an address decoder made from 1 (yes one) logic gate (IC1a). This will decode A12-A15 and select the CompactFlash card if all of these address lines are at logic High. Consequently the CompactFlash card will occupy the address range $F000_H$ – $FFFF_H$.

The rest of the circuit connects the relevant CF card terminals to those of the processor and provides a supply voltage for the CF card.

Capacitors C1 and C2 provide the necessary supply decoupling. C3, R1 and D1 produce a reset signal when the supply is switched on.

That concludes our discussion of the circuit. For more information on the size and connection data of the CF you are referred to the article on the CompactFlash Drive in the April 2002 issue.

The artwork for the double-sided PCB is shown in **Figure 2**. Most board space is taken up by the 50-way connector for the CF card and the 34-way boxheader for the CF-to-micro links.

Although the circuit is not difficult to build, care should be taken in the soldering of the pinheader for the CF card. The reason is obvious — the pins are very close together!

The connection between the interface (K1) and the Flash Micro board (K8) consists of a short length of 24-way flatcable with two IDCs (insulation displacement connectors). The introductory photograph shows how the interface board may be placed next to the Flash Micro board. The CF card is fitted onto K2 in such a way that the side with the print on it is at the top (see photograph). Note that this extension does not work if an LCD is connected to the Flash Micro board.

Software

Without appropriate software, a processor will ignore the presence of a CompactFlash card within the memory range. It is the programmer’s task to instruct the processor to read from, or write to, this memory area, **and** tell the processor how to do just that!

The full specification of a CompactFlash card is of a hefty size and could deter you from writing your own software. To remove this ‘CF fear’ to some extent we developed a small demonstration program intended to demonstrate the essential and useful functions of the interface. The functions actually used are listed in **Table 1**. This little program, or pieces of it, may be used as a template for

Tabel 1.

Main functions of CompactFlash interface

Command Name	Command code
READ SECTORS(S)	0x20
WRITE SECTOR(S)	0x30
IDENTIFY DRIVE	0xEC

your own programs, and should avoid recourse to the 'indigestible' documentation describing all the intricacies of a CF card. The not so faint hearted will find these at the CompactFlash Association website: www.compactflash.org

The source code files for the CF interface demo program, as well as the program itself, may be obtained free of charge from the Free Downloads page on Publishers' website at www.elektor-electronics.co.uk. For

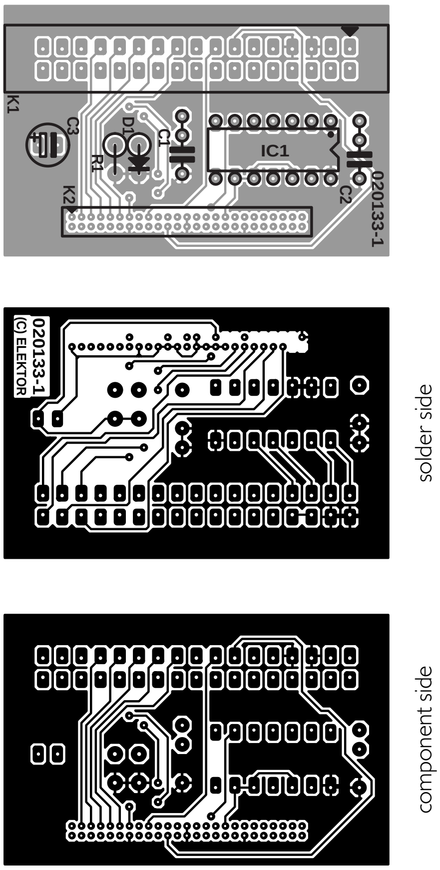
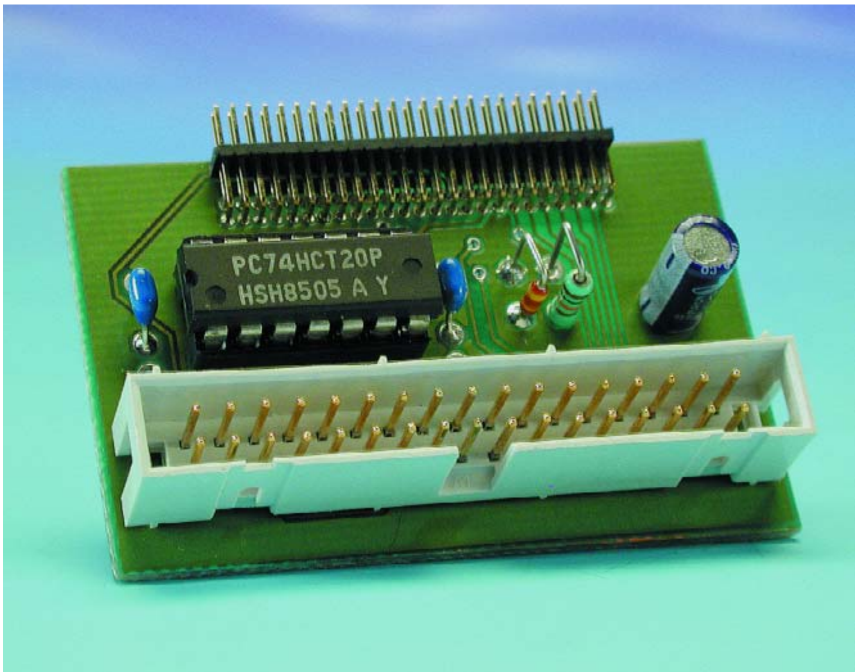


Figure 2. Double-sided printed circuit board for the CompactFlash interface board (board available ready-made).



COMPONENTS LIST

Resistors:
R1 = 10kΩ

Capacitors:
C1,C2 = 100nF
C3 = 10µF 16V radial

Semiconductors:
D1 = 1N4148
IC1 = 74HCT20

Miscellaneous:
K1 = 34-way boxheader
K2 = 50-way 0.05"-grid pinheader, angled (e.g., Farnell # 307-8127)
PCB, order code **020133-1** (see Readers Services page)
Disk, source code file of demo program order code **020133-11** or Free Download

Table 2.
CompactFlash Interface registers

Address	**Read**	**Write**
F000h (atrDATMSB)	D8 - D15	D8 - D15
F006h (atrALTERN) (atrDEVCTRL)	Alternate Status	Device control
F007h (atrDRIVEAD)	Drive Address	
F008h (atrDATLSB)	Data	Data
F009h (atrERROR) (atrFEATURE)	Error	Feature
F00Ah (atrSECCNT)	Sector Count	Sector Count
F00Bh (atrSECNR)	Sector Number	Sector Number
F00Ch (atrCYLLOW)	Cylinder Low	Cylinder Low
F00Dh (atrCYLHIG)	Cylinder High	Cylinder High
F00Eh (atrDRHEAD)	Drive/Head	Drive/Head
F00Fh (atrSTATUS) (atrCOMMAND)	Status	Command

Table 3.
Commands in example program

?	Help	Supply brief descriptions of all program functions
D	Display	Display buffer contents in hexadecimal as well as ASCII notation
I	Info	Display main data of CompactFlash card
R	Read	Read sector on CompactFlash card and copy contents into buffer
W	Write	Write buffer contents to sector on CompactFlash card
C	Cylinder	Modify currently selected cylinder
H	Head	Modify currently selected head
S	Sector	Modify currently selected sector

those without access to the Internet, there's floppy disk number **020133-11** which may be ordered through our Readers Services. The program was written using the Tasking 'C' compiler, and some details may need patching to run it on other compilers. This may include the declarations of the CF registers. Using the well-known 'MicroFlash' utility, the program may be downloaded directly into the 89C8252 chip. Next, you may use HyperTerminal or a similar terminal emulation program to test the different functions of the interface. Use these communications settings: 9,600 bits/s, 1 start bit, 8 data bits and no parity (9600N81).

When the program is started, the CF card is first reset and some salient data is retrieved from it. This includes the sector at address CYL 1, HEAD 1, SECTOR 1, whose data is copied into the buffer. Next, the program expects the user to supply a command.

Finally

Before using a CompactFlash card, it is recommended to make a backup of its contents.

It should be noted that reformatting for a specific system (digital camera, PC) may be required once a microcontroller has performed a write action on a CompactFlash card. This is caused by PCs and digital cameras employing a filing system to enable data on the CF card to be organised in folders and files. This filing system employs a part of the CF card's memory to keep track of the start of individual folders and files. File fragments may be 'scattered' all over the memory area, hence the filing system holds data that indicates the order in which certain sectors have to be read to 'assemble' a file from the fragments stored on the CF.

A full description of the structure of the various filing systems employed for CF cards would easily fill this entire magazine so it is well beyond the scope of this article. The demo program purposely avoids the use of a filing system so it can remain simple while getting the point across: demonstrate how sectors on a CF card can be read and written.

If you want to know all the ins and outs of the filing system used in Windows, you should know that Microsoft have published the full specification at www.microsoft.com/hwdev/download/hardware/FATGEN103.doc

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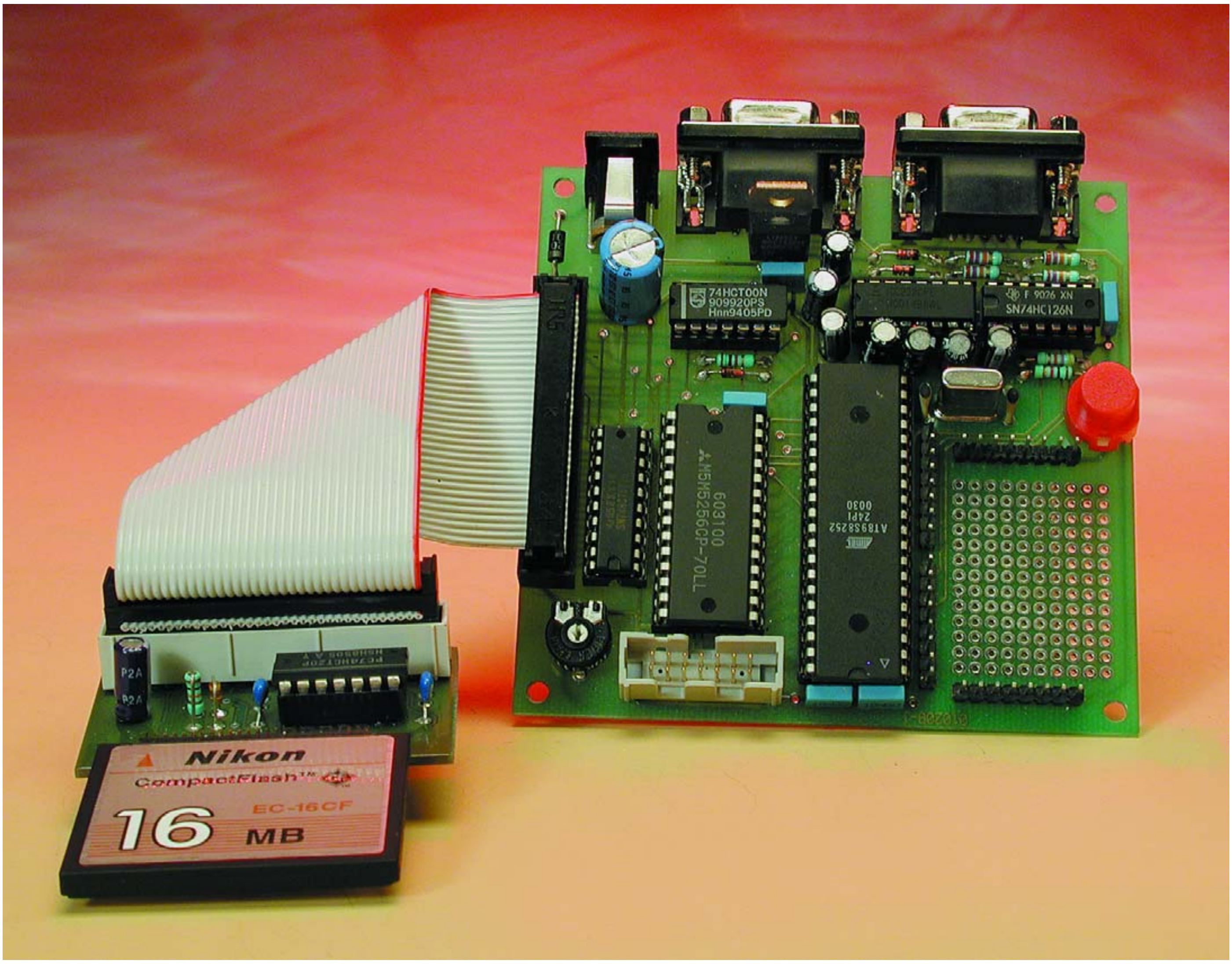


Figure 3. Connecting-up the CF interface to the Flash Micro board.

Vehicle Diagnostics Adapter (2)

Windows software for the OBD-2 interface

Design by G. Müller

In the previous article we described the hardware necessary to enable a vehicle OBD system to communicate through the serial port of a PC. As we mentioned you can use a terminal emulator program to read this ASCII coded data or better still try this free Windows program, it not only allows you to talk with the vehicle in a more user-friendly fashion, it also interprets the 'trouble codes'.

Vehicle OBD systems only understand and speak using hexadecimal characters. If you are not equipped with a reference book detailing the OBD protocols it is difficult to make any meaningful communication with an OBD system with just a terminal emulator program to help you. What we need is a user-interface program that converts OBD-2 data into a readable format and likewise converts user commands into OBD-2 messages. It would also be helpful if the program could output a description of the detected fault and suggest possible causes of the problem without the user needing to refer back to a list of codes or the vehicle handbook.

The ELM interpreter chip described in detail in the previous article is a dedicated pre-programmed microcontroller designed to perform low-level communications with the vehicle OBD system. It handles the OBD initialisation by sending hex value 0x33 at 5 baud via the L pin on the connector (pin 15). More recent vehicles use the K pin (pin 7). When the ELM chip receives the response (hex value 0x55 at 10400 baud) it will know that initialisation was successful. After initialisation it continually sends dummy characters every five seconds to keep the communication link active. The chip also performs calculations necessary to check the Cyclic Redundancy Check (CRC) checksum appended to the OBD data, thereby reducing the possibility of data being corrupted.

Figure 1. Main menu of the Scantool.net OBD-2 diagnostic program.

As we detailed in the first article in this series, faults or failures found by the diagnostic system are given an identifying code number. In the OBD-2 literature these are referred to as 'trouble codes'. Using the information given describing the OBD-2

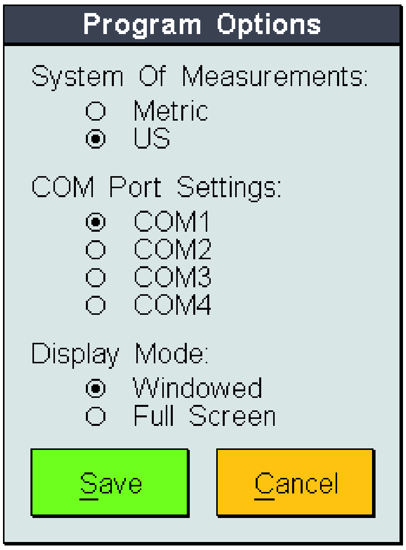


Figure 2. The settings available under 'options'.

protocol together with the communications of the ELM interpreter chip covered in previous articles (see 'Literature' at the end of this article) it is now possible to outline some basic functional blocks of a PC based program that will usefully interface with the OBD system:

– Read out and clear 'trouble codes'.
– Read out and display sensor readings in real time.
– Read out freeze-frame data.
– Read out test results produced by the vehicle on-board electronics system.
– Read out vehicle manufacturer specific information. This is only available on vehicles manufactured more recently and includes information such as the Vehicle Identification Number (VIN).

Free Windows Software

A Windows program fulfilling these requirements has been developed by ScanTool.net (www.scantool.net). The program is called ScanTool (**Figure 1**) and is currently available as release 1.04 (beta). The program is available as 'open source' software so that all the necessary source code is freely available to ensure that porting to operating systems other than Windows is a relatively painless process. Earlier releases of ScanTool operate in a DOS environment and can be run in a DOS window in Windows but the more recent releases of Windows (2000, NT and XP) do not support this feature and do not allow low-level access to the ports and display hardware. Running the DOS version of ScanTool under these operating systems means that it is necessary to power-up or reset the PC with a DOS boot disk in the floppy drive and then start the program using DOS commands. The latest release of ScanTool (version 1.04) however works in a Windows environment. All software and source code can be downloaded from this month's Free Downloads page of the *Elektor Electronics* website at www.elektor-electronics.co.uk — go to Free Downloads and click on the information for December 2002.

In the spirit of open-source software, the source code includes a readme file containing information of the compilation process together with details of the open-source compiler program and Allegro user-interface libraries so that you can experiment by adding your own features and develop the software (and your programming skills) further. The software team at ScanTools have invested much time and effort in producing this useful program.

Those of you who do not feel confident enough to tackle the software can periodically check the web site for forthcoming updates to the ScanTool software.

Program functions

Version 1.4 of the ScanTool program can read and reset OBD trouble codes and also display up to 11 sensor readings in real time. Additional features such as displaying freeze-frame data (sensor values stored at the time the trouble occurred) and support for various test modes appear in the main menu of the user interface but are not yet implemented in this beta version of the software. Also not yet implemented is a method of storing data output from the system. In the DOS version of the program the key sequence of Ctrl + Alt + Print will generate a file in the current directory with the name `screenshotX.pcx` containing a screenshot where 'X' is a integer incremented each time the screenshot is taken. In the Windows version pressing 'print screen' will copy the screen to a buffer so that it can be pasted to a document later.

Reading either the codes or sensor data will only work if the connections between the PC, interface adapter and OBD-2 connector are correctly made and the vehicle ignition is switched to 'ON'. If these conditions are not met you will see a message asking you to check the serial port settings. The 'option' button (**Figure 2**) allows the measurement system to be switched between metric or US (imperial) units. This setting is stored in the `scantool.cfg` file along with the on/off setting for each of the 11 sensor inputs. Fault messages including software failures are logged in the `log.txt` file.

The two data files `codes.dat` and `scantool.dat` must be in the same directory as the `scantool.exe` program so that they can be used when the program starts. The file `codes.dat` contains a description for the 3107 trouble codes including all the standard codes together with many additional manufacturer specific codes. In the 'Read Codes' page there is an option to simulate troubles (**Figure 3**) and produce the corresponding comments related to the type of trouble. To read the actual trouble codes, press the 'Read' button, a fail indicator will be associated with each trouble code. The 'Clear' button will erase all the trouble codes but only after answering yes to the 'are you sure?' dialog box. The key for the alphanumeric trouble codes are given in the previous article and can also be found on many Internet sites, some of which are mentioned at the end of this article. The description corresponding to each code is mainly self-explanatory like the description of the sensors in the sensor data screen (**Figure 4**). One exception to this is the 'injector status' that actually refers to the catalyst control loop and the status can be OPEN LOOP or CLOSED LOOP along with some error conditions. One task of the engine ECU is to ensure that the catalyst in the catalytic converter is operating at optimal efficiency. An oxygen (lambda) sensor is used to measure the amount of O_2 in the exhaust and the engine ECU uses this measurement to adjust the fuel/air mix. When the engine is first started the temperature of the lambda sensor is too low to give any meaningful output so the control loop is said to be in an open-loop condition. The loop becomes closed once the lambda sensor has reached its working temperature. An increasing number of lambda sensors are fitted with heaters to reduce the warm-up time.

The file `scantool.dat` contains bitmaps for the program graphics, buttons, colour pallet and fonts. It is anticipated that a separate file will eventually be generated to contain the text strings (currently in the main program) used in the program. This will make it easier to change the text so that the program can be used in other countries. Both of the files with the `.dat` extension are in a packed format and allow the Allegro 'Grabber' tool to be used. With this system it will, for example, be possible to alter the text and add new tips in the 'Possible causes and known solutions' box without re-compiling the software.

Further advice on modifying the program — or indeed writing a completely new program — is beyond the scope of this article. The ScanTool program is well designed with good modularity and appropriate comments so that even a weekend programmer should find it easy to make successful modifications to the source code. A quick trawl of the Internet will produce many sites with information supporting the OBD-2 standard.

The development of the ScanTool program is an ongoing process so that we can expect to see the missing features implemented soon and possibly even a version running under Linux. Any modifications that you make to the source code must be carried out in accordance with the rules of the GNU general public licence for free software if you intend the modified program to be publicly distributed.

Putting it into practice

You would probably expect that vehicle repairs would be greatly simplified with an OBD system but this is not always the case. The more components that a system contains, the greater the chance of a single item failing. It is probably fair to say that the average garage mechanic has little time to investigate causes of a reported sensor failure and would always choose to replace a 'faulty' sensor. This expense can often be avoided by following systematic troubleshooting procedures at home; simple checks on the wiring and connections to the sensor may uncover the real culprit. Many of the causes and solutions suggested for the reported trouble codes indicate either a loose cable connection or a short circuit either to ground or to the vehicle battery (Vbatt) as a possible cause of the trouble. Maybe the failure is a result of a problem with another component in the vehicle (e.g., a faulty air flow sensor would cause the fuel/air mixture to be incorrectly set resulting in a bad exhaust gas lambda reading). Very often the cost of a workshop manual for your vehicle will be repaid many times over in saved time and trouble. These manuals approach faultfinding using a logical, step-by-step procedure and interpret error codes reported via the diagnostics connector.

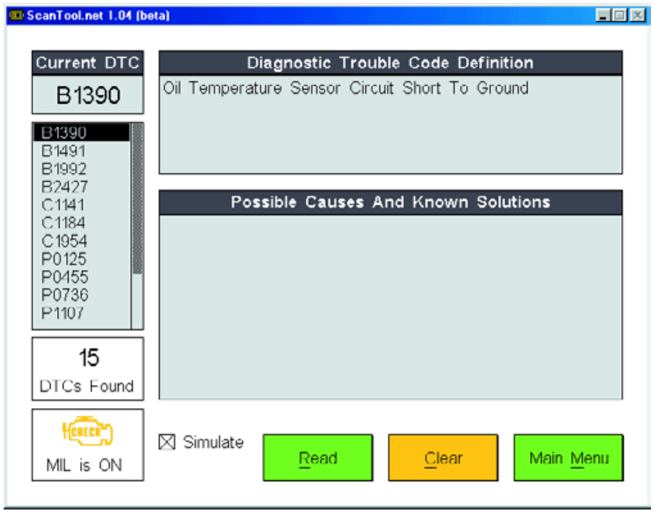


Figure 3. Trouble code display along with the description.

Even if you don't enjoy the prospect of getting your hands dirty and prefer to entrust repairs to your local garage, information gleaned from the OBD can be very useful in determining the state of health of your vehicle and can help you decide any fault priority and whether it will harm the engine if you continue to use the car for work for a few days. Some faults such as incorrect ignition timing or too lean fuel/air mixture however, require immediate attention otherwise serious damage will ensue relatively quickly. In any case, the engine ECU will switch to an emergency mode to help prevent engine damage but this settings is not particularly fuel-efficient.

As the motorcar becomes more sophisticated we notice that repair bills are also inevitably rising. Armed with a PC we can now plug into the vehicle OBD and use this increased sophistication to actually help reduce vehicle maintenance costs.

(020138-3)

Literature:

1. Car Diagnostic Systems, Elektor Electronics October 2002, p. 50.
2. Vehicle Diagnostics Adapter: Interface between the OBD-2 vehicle connector and the serial PC port, Elektor Electronics November 2002, p. 24.

Weblinks:

www.scantool.net

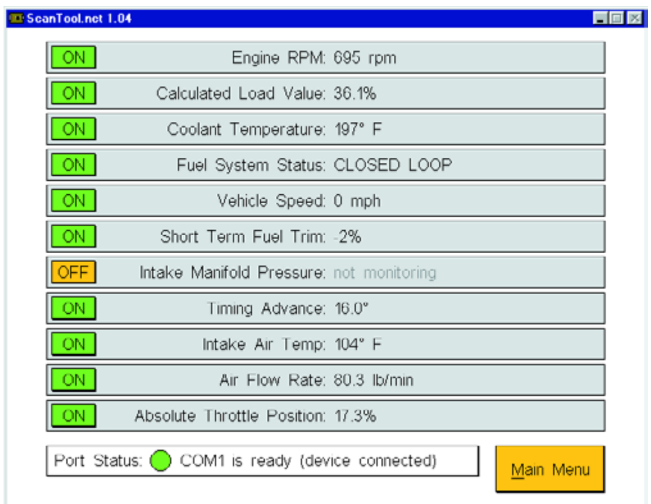


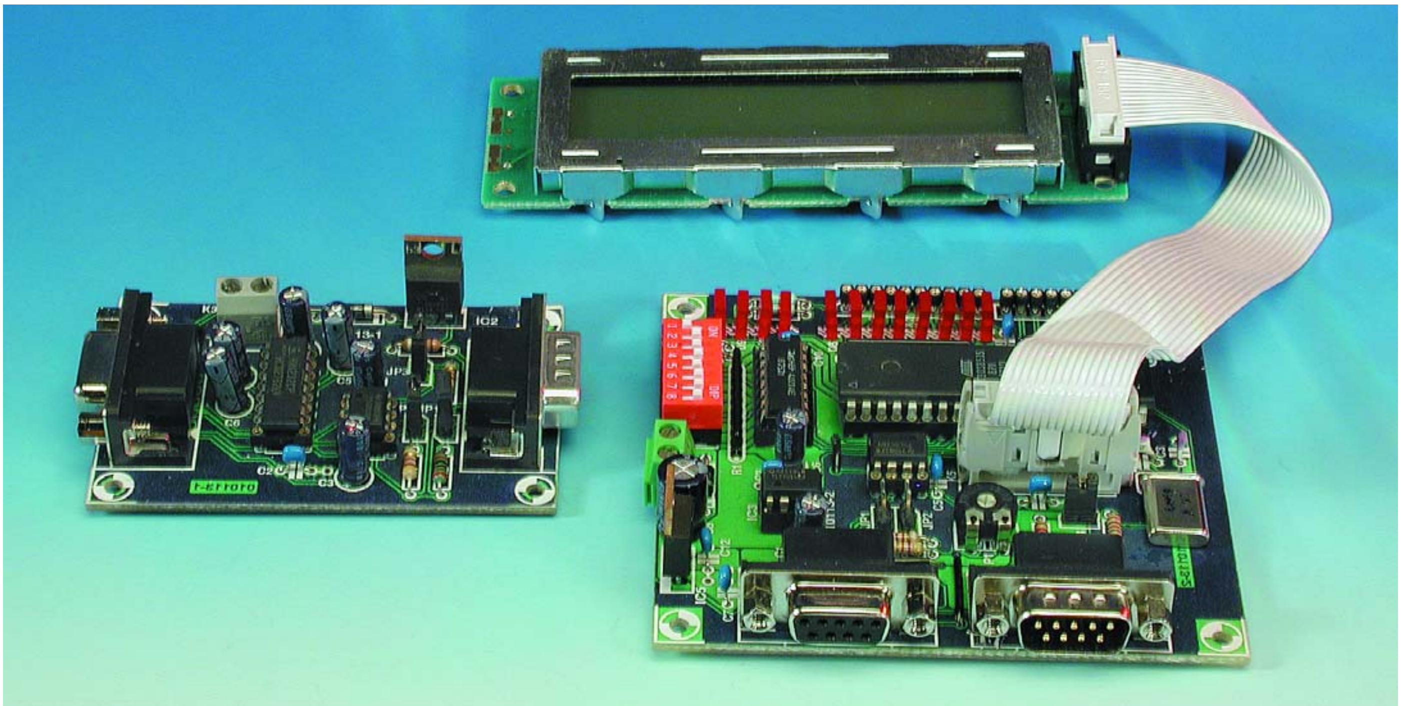
Figure 4. Sensor data page of the Scantool.net program.

DCI Bus

RS485 home network with a maximum of 64 terminals

Design by I. de Coninck

This universal bus has many applications. With a PC as a master, information can be exchanged with up to 64 slave terminals. Because each terminal contains eight selectable inputs and outputs as well as an LCD, this home network is not only suitable for use in the home, but it would also be perfect as a combined alarm/communication system for schools and small firms.



Before we delve into the technical details, we will first give a brief description of the system.

The backbone of the system is a complete serial bus that uses its own protocol. Data is sent to and received from a maximum of 64 terminals over long distances using an RS485 interface.

The hardware of the system consists of a simple RS232 to RS485 converter and a microprocessor driven terminal. Of the latter you will obviously need to build as many as are required. The software consists of a program for the PC and one for the 'terminal processor'. Both files can be downloaded from this month's Free Downloads on our website (www.elektor-electronics.co.uk). The terminal processor is also sold ready programmed. The PC software runs under Windows 95, 98 and ME and comes with an example program that controls the inputs and outputs of every terminal, as well as send the 2 x 20 characters that are displayed on the terminals.

Overview of the system

The starting point of the system is a program that controls the serial port of the PC (baud rate = 115,200 bits/s). At the other end of the serial port sits an RS232 to RS485 converter. This is done with a fairly simple circuit, which has a MAX232 and a SN75LBC184 as the most important components. Then there is an RS485 bus (peer-to-peer) that can have 64 terminals connected to it.

Each terminal contains a compact circuit, using an AT90S8515 processor, a 4021 and again a SN75LBC184. Next there is an eight-bit input port, an eight-bit output port and a connector for a two-line LCD module. Each terminal can be given an address in the range 0 to 63. The 'terminal processor' runs a program that takes care of a number of tasks: communicating with the PC, driving the outputs, reading the inputs, sending text to the display and reading its address that has been set with its jumpers.

So how have the communications been implemented?

The program in the PC (master) can select a terminal (slave) with a certain address, then set the state of its eight outputs, followed by the transmission of data for the display, and finally request the state of its eight inputs. The total time taken for these three functions is approximately 25 ms.

The same procedure is then used for the next terminal. If the same terminal has to be selected again, then this takes an extra 0.8 s, because the data on the display needs to be refreshed first.

RS485

The transmission of data in this system takes place over shielded twisted-pair cable, using the RS485 protocol. A description of this is first in order.

When small quantities of data have to be transmitted over larger distances, the RS485 interface is a good choice. This interface is an electrical specification for a multi-drop bus that uses differential data transmission. RS485 permits the use of several transmitters and receivers in one network (bus).

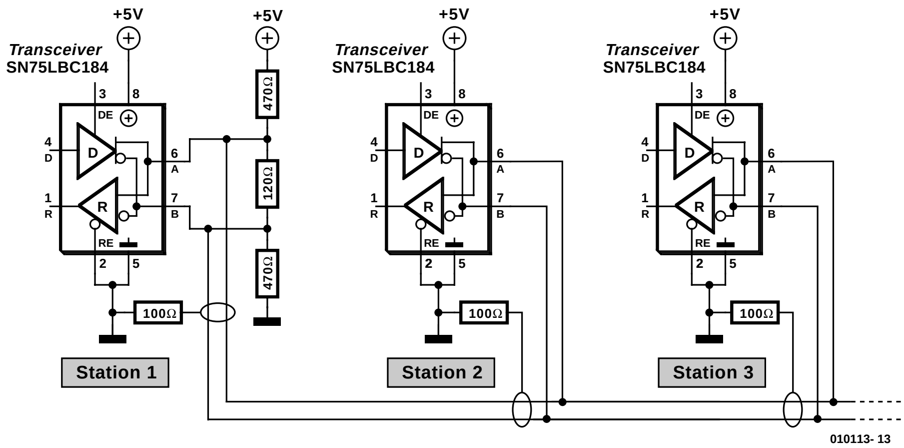


Figure 1. An example of an RS485 network.

The RS485 specification (TIA/EIA-485-A) defines the electrical characteristics of the bus and of the transmitters and receivers. There are also suggestions for the wiring and termination of the network, but the choice of connectors is left open, as is the software protocol that is used.

An RS485 network can have up to 256 terminals when use is made of receivers that have a higher input impedance. The length of the network can be up to 1200 metres at speeds up to 10 Mbps. For longer distances use is made of repeaters that restore the signal and start a new RS485 network. When this system was tested we didn't use extreme lengths of cable; when tested with a cable length of 75 meters everything was still working perfectly.

As mentioned earlier, the RS485 specification doesn't refer to the protocol that is used. In practice much use is made of a protocol that is compatible with that used by the UART in the PC. Several types of RS485 converters are available in the trade and a RS485 transceiver can be connected directly to the serial port of the microcontroller. Most networks use an extra signal to control the transceiver. On the PC side we can use the RTS signal for this purpose.

The reason why RS485 networks can communicate over such a large distance is that the receivers measure the difference in potential between the two conductors in the cable. Most of the interference that occurs in the conductors will be the same for both; therefore the potential difference between the conductors doesn't change. A common-mode voltage (as in RS232) won't appear either since the signal return is via the second conductor.

The transmitter should provide a voltage difference of at least 1.5 V, giving the signal sufficient tolerance against noise and attenuation. At a node the wiring should be kept as short as possible. As a rule a twisted-pair shielded cable is used for this, because this has characteristics that prevent noise.

The datasheets of the interface chips refer to the non-inverting signal as 'Line A' and the inverting signal as 'Line B'. When the voltage at Line A is at least 200 mV more than at B, the output of the receiver will be 'high'. In the opposite case the output of the receiver will be 'low'. When the difference between Line A and Line B is less than 200 mV, the output state is undefined.

Figure 1 shows an example of an RS485 network. At the start of the network we can see three resistors: two of 470 Ω and one of 120 Ω. These resistors keep the voltage stable on the bus when no drivers are active.

There should be a terminating resistor at the ends of an RS485 network in order to reduce signal reflections in the cable. The value for the terminating resistor in an RS485 network should be between 100 and 150 Ω. For a baud rate of 115,200, as is used here, a value of 120 Ω is a good choice. The terminating resistors should only be connected to the start and end points of the network. More resistors don't have any use and could cause a virtual short circuit on the network, overloading the transmitters. The RS485 specification also recommends that a 100 Ω resistor (0.5 W) is connected in series with the ground at each node in the network. Should there be a potential difference between the

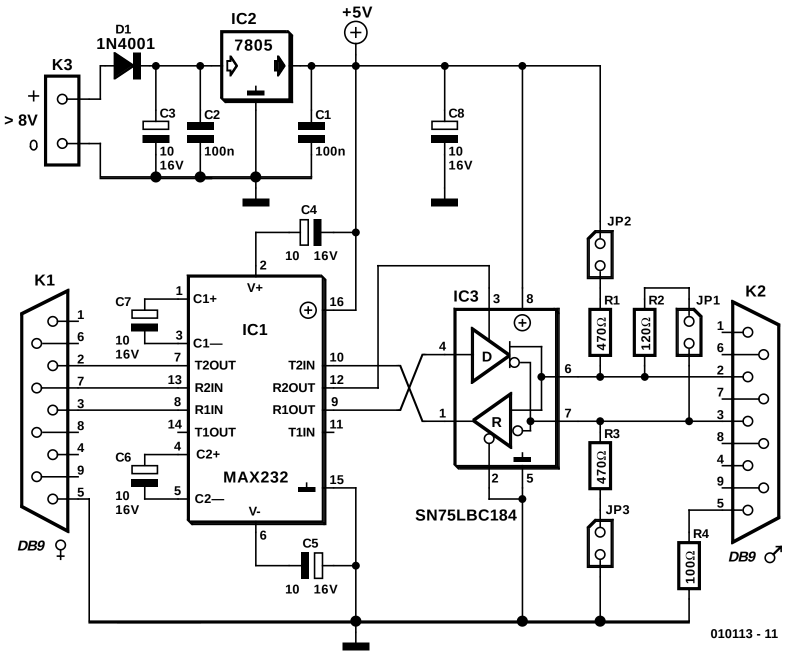


Figure 2. The RS232 to RS485 converter built round the SN75LBC184 transceiver is superbly simple.

grounds at two nodes then the resistors will limit the current flow.

The RS232/485 converter

The circuit that converts the signals from RS232 to RS485 follows a very simple design, as shown in. **Figure 2**. The voltage levels of the serial port first have to be adapted for use with the SN75LBC184 and for this we use a MAX232 (IC1). Electrolytic capacitors C4 to C7 are required by the internal DC/DC converter of the MAX232. The specially designed transceiver IC SN75LBC184 (IC3) takes care of the transmission and reception of data. A 75176 may also be used for this transceiver; but this part does not have ESD protection.

Because pin 2 of this IC is connected to ground, any data on the bus is always received. Pin 3 is connected to pin 7 of the serial port (RTS), via the MAX232. The RTS signal of the serial port will be used via the software to enable and disable the transmitter. Jumper 1 is used to connect the terminating resistor. Resistors R1 and R3 that can be connected via jumpers 2 and 3 to the positive supply and ground respectively, make sure that the voltage on the bus is stable when no drivers are active. Since the converter is at the start of the bus we need to use all three jumpers.

A standard 9 V mains adapter can be connected to K3 for the supply. No special demands are made of the mains adapter, because IC3 (7805) provides a properly stabilised voltage of 5 V.

The terminal circuit

The complete circuit diagram for the terminal is shown in **Figure 3**. Nearly all the work is performed by the AT90S8515 from Atmel (IC2). This microcontroller contains the software that controls the proper functioning of the terminal. The clock frequency is set to 3.6864 MHz by crystal X1. At this frequency the baud rate generated by the microcontroller is exactly the same as that used in the PC. The transceiver (IC4) sits between the RXD/TXD lines of the microcontroller and the sub-D connectors (K3 and K4) that are provided for the connection to the bus.

The setting of DIP-switch S1 is read with the help of a shift register (IC1). Switches 1 to 6 determine the address of the terminal. When all six are in an open position, the terminal address will be 63. When all six switches are closed, the terminal address is 0. In total there are therefore 64 terminals that can be connected to the bus. Take care never to put two terminals with the same address on the bus, because both terminals would try to respond at the same time, thereby corrupting the data on the bus!

Switches 7 and 8 in S1 are not used at this stage and can be used to provide extra functions to the terminal. The software for the microcontroller has to be modified for this, of course.

LED D9 indicates that the AT90S8515 is ready to receive data. During the time the terminal is active (receiving or transmitting data), LED D12 is lit. LED D10 and LED D11 are not used, but are provided for any future developments.

Pins 32 to 39 of the microcontroller function as outputs and drive LEDs D1 to D8. The outputs are also connected to a header (K2), to provide an interface with the outside world. The inputs go to pins 21 to 28; these have pull-up resistors (array R6) and header K1 provides an external interface.

The reset pulse is generated by a TL7705 (IC3). Electrolytic capacitor C1 determines the timing of the pulse. As can be seen, the reset pulse for the microcontroller is taken from the inverting output of IC3.

That leaves only the connection of a 2 by 20 character LCD display. This is what header K5 is for. The contrast can be adjusted via P1. Display control lines RS and E are driven by INT1 and INT0 respectively. Pin 5 of the display (R/W) is connected to ground, so it is only possible to send data to the LCD.

A simple 9-V mains adapter, as used for the transceiver board, can again provide the supply for the circuit. This adapter is connected to K6.

The PCBs

Figure 4 and **Figure 5** show the track and component layouts of the converter and terminal boards respectively. The first one especially is very compact and due to the small number of components it shouldn't take more than an hour to populate.

The terminal board contains a few more ICs and the population will take a bit longer. But populating this board shouldn't give those with average soldering skills any problems either. The connectors and headers have been placed along the edge of the board as much as possible, to make subsequent connections as easy as possible. The only exception to this is K5 for the LCD.

Because of the relatively small current consumption there is no need to fit heatsinks to the 5 V regulators on either board.

Connections to the bus

Figure 6 shows how three terminals should be connected to the bus and where the terminating resistors are to be placed.

As mentioned earlier, the address of the terminal is set using the first six switches of DIP-switch S1. The example in **Figure 7** shows an address of 12 (binary value 4 + 8 = 12). Jumpers JP1 and JP2 in the terminal circuit are for use at the start of the bus (parallel resistors of 470 Ω to 5 V and GND respectively). Jumper JP3 is used to connect the 120 Ω terminating resistor; in **Figure 6** terminal 12 is at the end of the bus, so it has this jumper closed.

When the supply (a standard 9 V mains adapter) is connected, LED D9 will light up after a short period. This indicates that the IC is ready to receive or transmit data. If a liquid crystal display has been connected to the terminal, the following text will appear:

'DCI-BUS Addr: 12'

'waiting for data.U'

The number 12 is the value of the address that has been set for that terminal. The 'U' at the end of the second line is the version number of the software in the microcontroller.

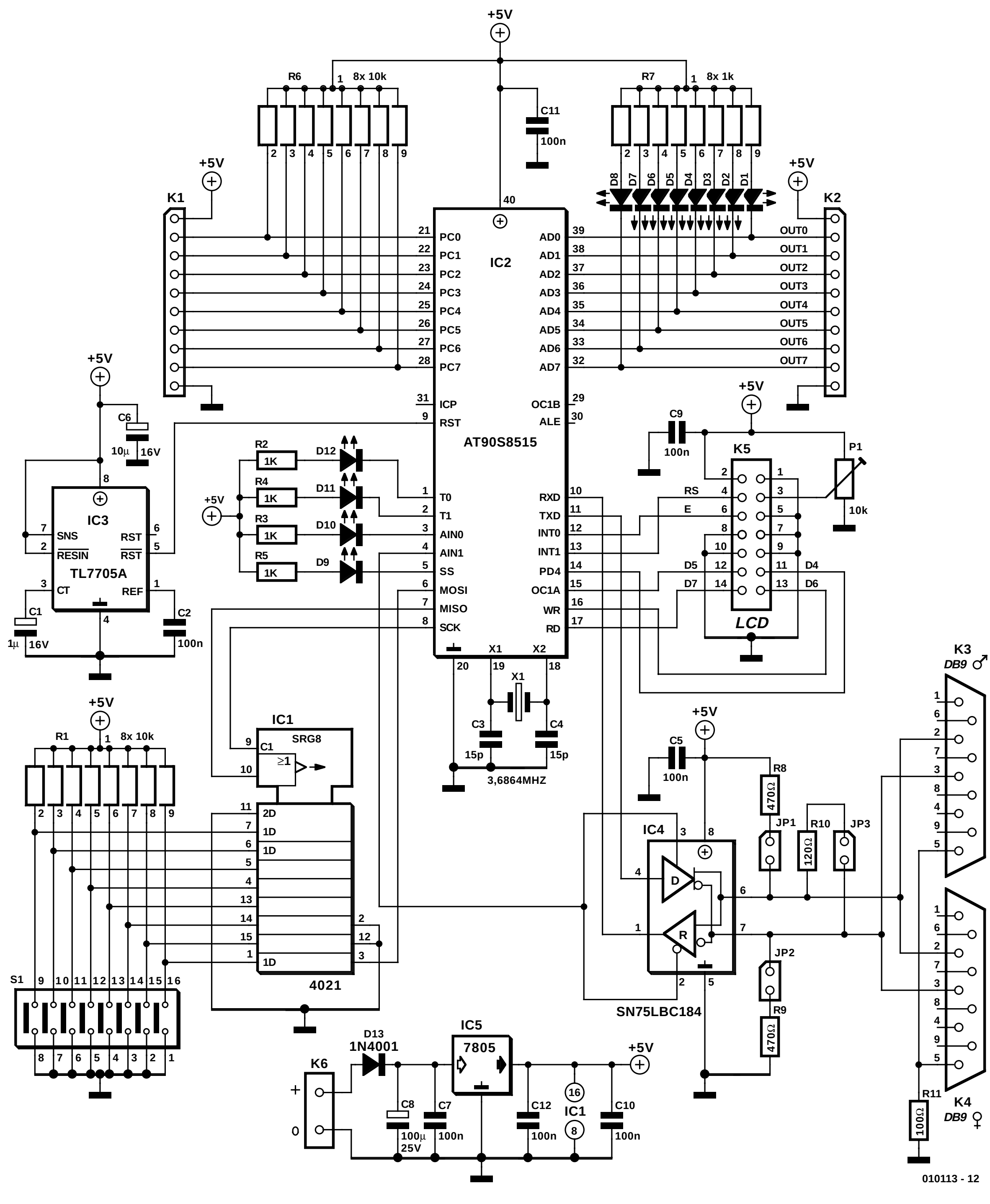


Figure 3. The complete diagram of a terminal circuit. The AT90S8515 controller plays a major part.

COMPONENTS LIST

Converter

Resistors:
R1,R3 = 470Ω
R2 = 120Ω
R4 = 100Ω

Capacitors:
C1,C2 = 100nF
C3-C8 = 10µF 50V radial

Semiconductors:
D1 = 1N4001
IC1 = MAX232
IC2 = 7805
IC3 = SN75LBC184 (or 75176)

Miscellaneous:
JP1,JP2,JP3 = 2-way pinheader w. jumper
K1 = 9-way sub-D socket (female), PCB mount, angled pins
K2 = 9-way sub-D plug (male), PCB mount, angled pins
PCB, order code **010113-1** (see Readers Services page)

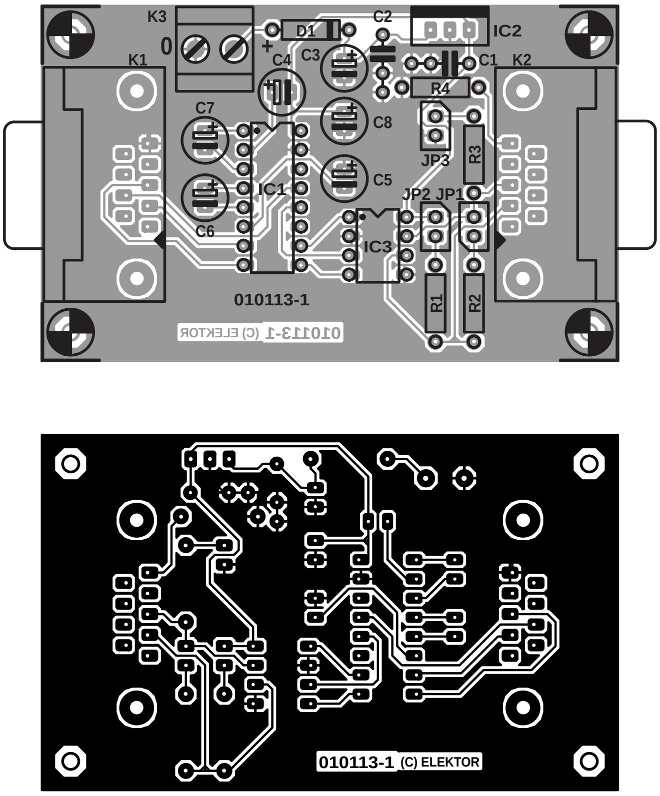


Figure 4. PCB of the RS232 to RS485 converter.

COMPONENTS LIST

Terminal

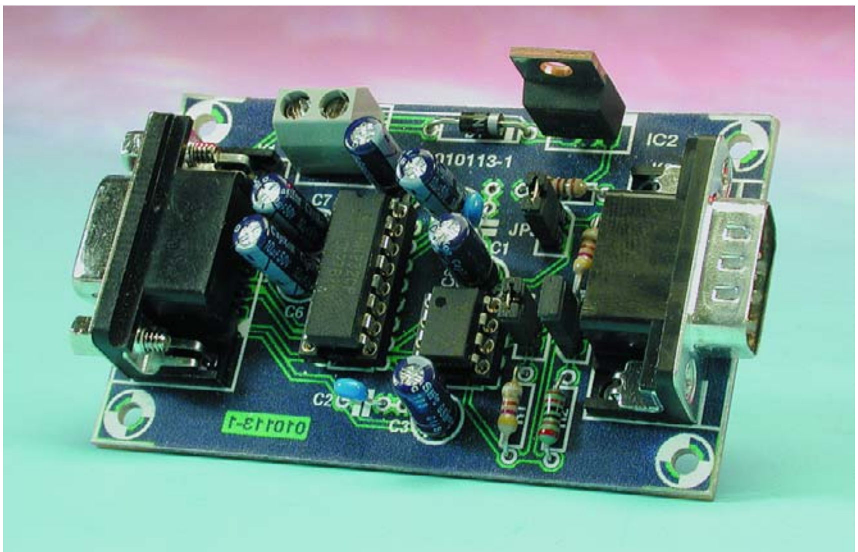
Resistors:
R1,R6 = 8-way SIL resistor array, 10kΩ
R2-R5 = 1kΩ
R7 = 8-way SIL resistor array, 1kΩ
R8,R9 = 470Ω
R10 = 120Ω
R11 = 100Ω
P1 = 10kΩ preset H

Capacitors:
C1 = 1µF 16V radial
C2,C5,C7,C9-C12 = 100nF
C3,C4 = 15pF
C6 = 10µF 16V
C8 = 100µF 25V

Semiconductors:
D1-D12 = LED, red, rectangular, high efficiency
D13 = 1N4001
IC1 = 4021
IC2 = AT90S8515-8PC programmed, order code **010113-41**
IC3 = TL7705-ACP
IC4 = SN75LBC184 (or 75176)
IC5 = 7805

Miscellaneous:
JP1,JP2,JP3 = 2-way pinheader w. jumper
K1, K2 = 10way pinheader
K3 = 9-way sub-D plug (male), PCB mount, angled pins
K4 = 9-way sub-D socket (female), PCB mount, angled pins
K5 = 14-way boxheader
K6 = 2-way PCB terminal block, lead pitch 5mm
S1 = 8-way DIP switch
X1 = 3.6864MHz quartz crystal
LCD module: 2 x 20 characters
PCB, order code **010113-2** (see Readers Services page)
Disk, contains PC en controller software (incl. source code files), order code **010113-11**

PCB layouts and project software also available from ‘Free Downloads’ page at
www.elektor-electronics.co.uk



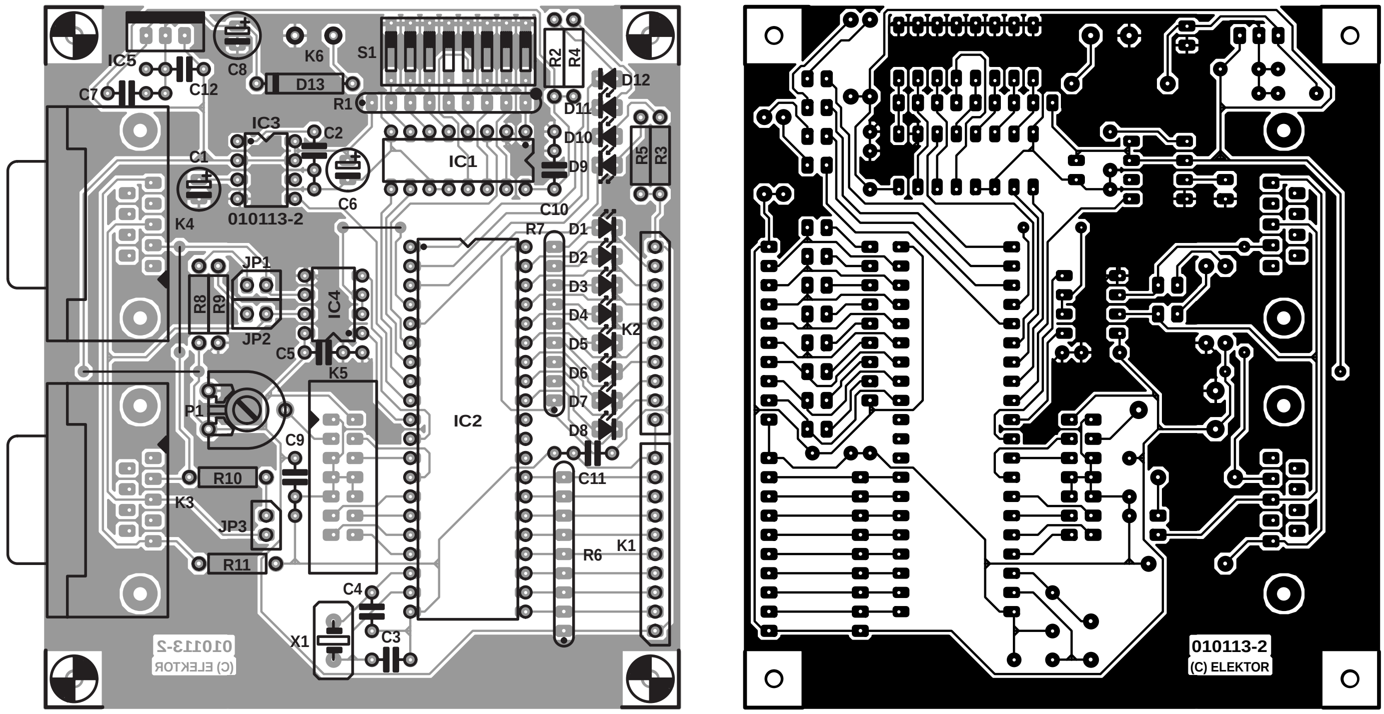
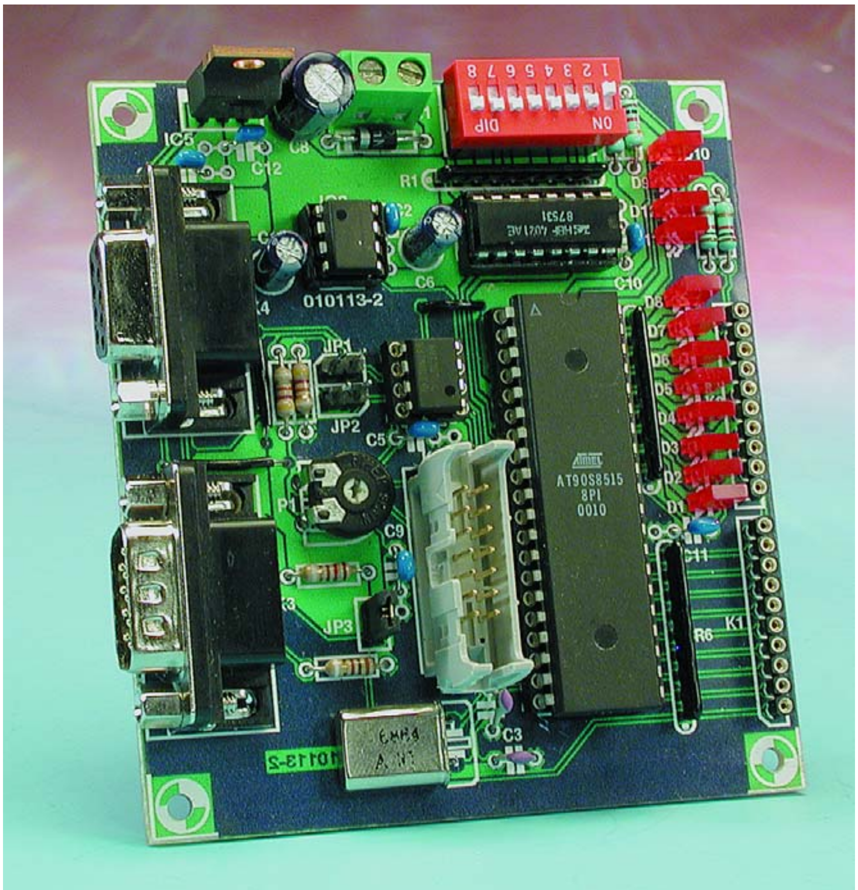


Figure 5. PCB of a terminal circuit. All connectors are at the edge of the board apart from K5.

The software for the PC

After the hardware has been connected and the software started, the correct port has to be set up. Click on 'Select port' from the 'Ports' menu and choose the required serial port.



Now click on 'Open port' from the 'Ports' menu and a dialogue box should appear stating that the port has been opened successfully. When a port has been selected that doesn't exist then the message 'The system cannot find the file specified' appears. Next click on 'Run' from the 'Bus' menu and the program will be in RUN-mode (see **Figure 8**).

Next to each 'SetStation' button is an up/down component that can be used to select a terminal number. Then click on the 'SetStation' button and the terminal will be on-line; to the left of the button the number of the selected terminal will appear. From now on the text that is in the two text boxes will appear on the display of the selected terminal and the outputs that have been ticked will be set. At the same time the state of the inputs is also shown. The software can be used to control up to four terminals simultaneously.

The 'adjust bus' up/down button is used to set the so-called 'critical section' to a time between 0 and 20 ms. A value between 3 and 6 works well on a Pentium 400 and 475. This option is probably more useful with the current generation of PCs, which are much faster. Because a program running under Windows doesn't work in real-time, there is a possibility that errors can occur on the bus. This can be seen clearly in the diagram in **Figure 9**. If the RTS signal at the serial port is not 'low' before a terminal returns data, then this data will be lost. This can happen

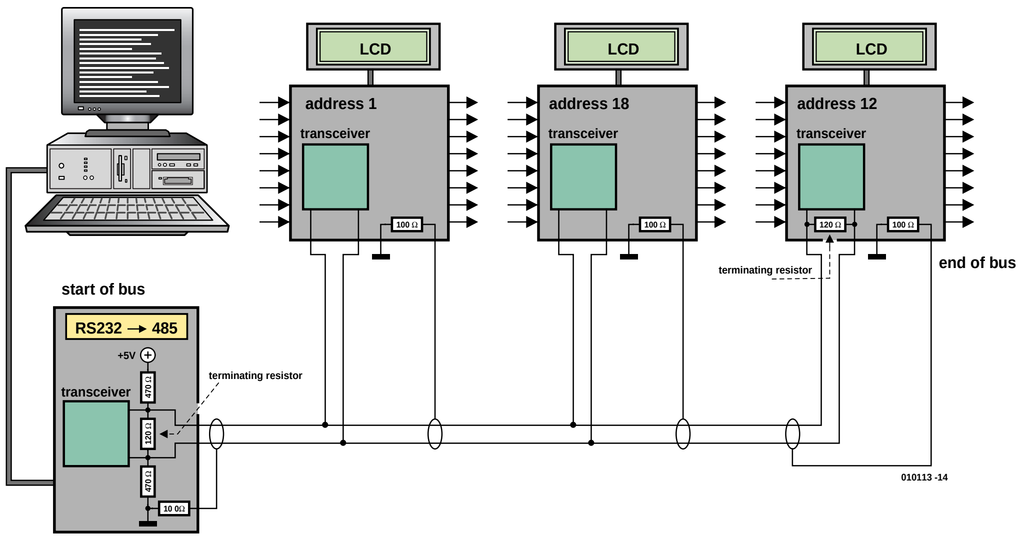


Figure 6. A practical example of a bus with three terminals.

when the operating system (Windows) deems it necessary to use all processing time for a different process, such as starting other software, dealing with a newly inserted CD, screen saver, anti-virus software, etc. Because of this, the RTS signal will sometimes not go 'low' in time.

This can be avoided by adding an error-checking routine to the software that prevents erroneous readings of the terminal inputs. This has been implemented as follows:

0. The transmit-enable output of all terminals will be 'low'.
1. The PC sets its RTS signal to 'low'.
2. The PC transmits 2 x ASCII-code 10 on the bus.
3. The PC puts the address of the terminal to be accessed on the bus.
4. The PC puts the value for the outputs of the terminal on the bus.
5. The PC sets its RTS signal to 'high'.
6. The terminal with the correct address sets its transmit-enable to 'high'.
7. The terminal puts its address on the bus.
8. The terminal puts the status of its inputs on the bus.
9. The terminal puts its address on the bus again.
10. The terminal with the correct address sets its transmit-enable to 'low'.
11. The PC software checks that the first byte received is equal to the address that has been transmitted.
12. The PC software stores the value of the second byte (state of the inputs).
13. The PC software checks that the third byte received is equal to the address that has been transmitted.
14. If checkpoints 11 and 13 return the correct result, the PC uses the value returned in step 12 as the new state of the inputs. If either check failed then the software will wait for a cycle that has no errors.

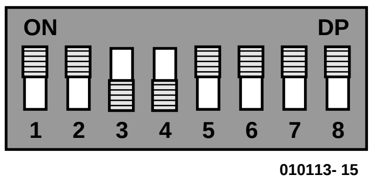


Figure 7. The terminal address has been set to 12 using DIP switch S1.

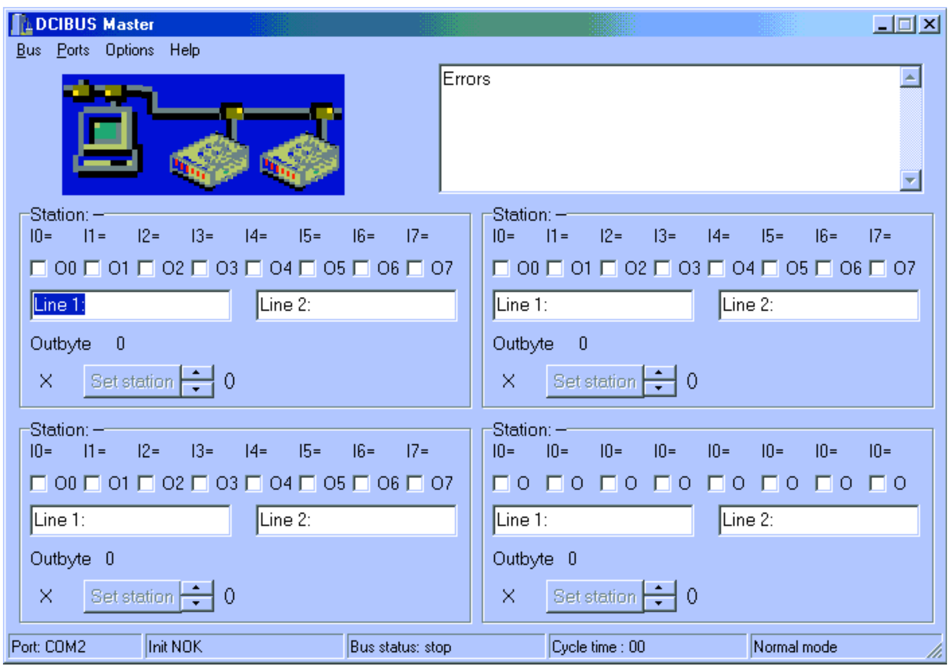


Figure 8. A screenshot of the program in RUN mode.

In this way we can be certain that the inputs will always be read correctly. Every time an error occurs, a message is shown with the number of the terminal that caused the error. When we use the software to enable a terminal that is not present on the bus then this error message will also appear.

When our simple RS232 to RS485 converter is replaced by a microcontroller version with a data buffer, the whole communication problem will no longer be an issue. Such a converter is therefore a likely candidate for a future project.

Now for some general information about the software:

The accompanying software for this project comes on a disk (EPS010113-11), which can also be downloaded from the Elektor website. Apart from the PC program it also comes with the source code, written in C++ (Builder 4). The source code and HEX listing for the microcontroller are also on this disk. With these the system can be adapted as much as the user requires.

When modifying the software you should take into account that the terminal requires about a second to refresh the data on its display. Consequently there has to be a delay of one second before the same terminal can be selected again. This delay has to be programmed into the software of the PC!

Furthermore, it is not permitted to include the character with ASCII-code 10 in the text for the LCD, since this character is used to initiate the selection of a terminal!

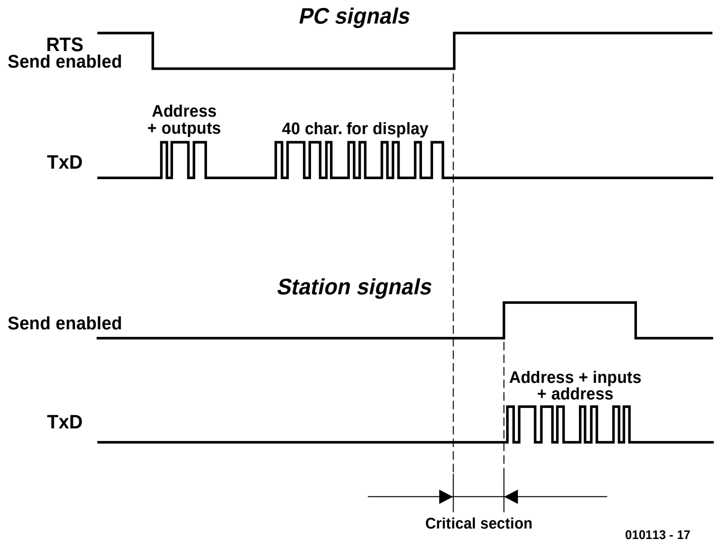


Figure 9. The RTS signal has to be 'low' when a terminal transmits data back, otherwise the data will be lost.

Control via an external program

The **Busmstr.exe** program contains a simple COM (Component Object Model) server interface. This allows an external program, such as Excel or Visual Basic, to start the Busmstr.exe program and use it to drive the hardware.

As an example:

- First start the Busmstr.exe program and then close it.
- Start Excel, open the file 'Client.xls' and start the 'Visual Basic Editor' (Alt + F11).
- From the 'View' menu select the 'Object Browser' (F2).
- Place the mouse pointer over the 'Object Browser' pane and click on it with the right-hand mouse button.
- Click on 'References' in the pop-up menu.
- Choose 'Browse' from the 'References' dialogue and choose as file type 'Executable Files ("*.exe,*.dll")'.
- Navigate to the folder where Busmstr.exe is and choose Busmstr.exe and click on 'Open'.
- In the 'Classes' window there should now be an object with the name 'TBusServer'. Click on this and the members of the TBusServer object appear in the right-hand window. These should be 'About', 'InputGet', 'LCDTxt' and 'OutputSet'.
- Return to Excel and click on the 'INFO' button.
- The Busmstr.exe program is then started automatically. Choose the correct serial port, open it and start the bus.
- Click on 'Server mode' in the 'Options' menu.
- Set a terminal to number 4 and start it using the 'SetStation' button.
- Go back to Excel and close the dialogue box containing Info about the Busmstr.exe program.
- Now click on the 'Refresh' button. The number in box C4 represents the state of the inputs to terminal 4. The text in box C8 appears on the LCD of terminal 4 and the number entered in box C6 is copied to the outputs of terminal 4. The text in box C8 must not exceed 40 characters in length.
- Now go back to the 'Visual Basic Editor' window and select 'Design Mode' from the 'Run' menu.
- Return to Excel and click with the right-hand mouse button on the 'Refresh' button and choose the option 'View Code'.
- Now the code can be edited. This should be studied with a view of possibly automating the Excel worksheet further.

Observations:

1. If the Busmstr.exe program has been started via Excel, it will be closed every time 'Design Mode' is entered.
2. Never close the server program (Busmstr.exe) while the client program (Excel in this case) is still running!

(010113-1)

Further information

may be found on the website of the author:
http://home.planetinternet.be/~dc11cd/index.html
Comments and suggestions are welcome and should be sent via his email address:
ivo.deconinck@planetinternet.be

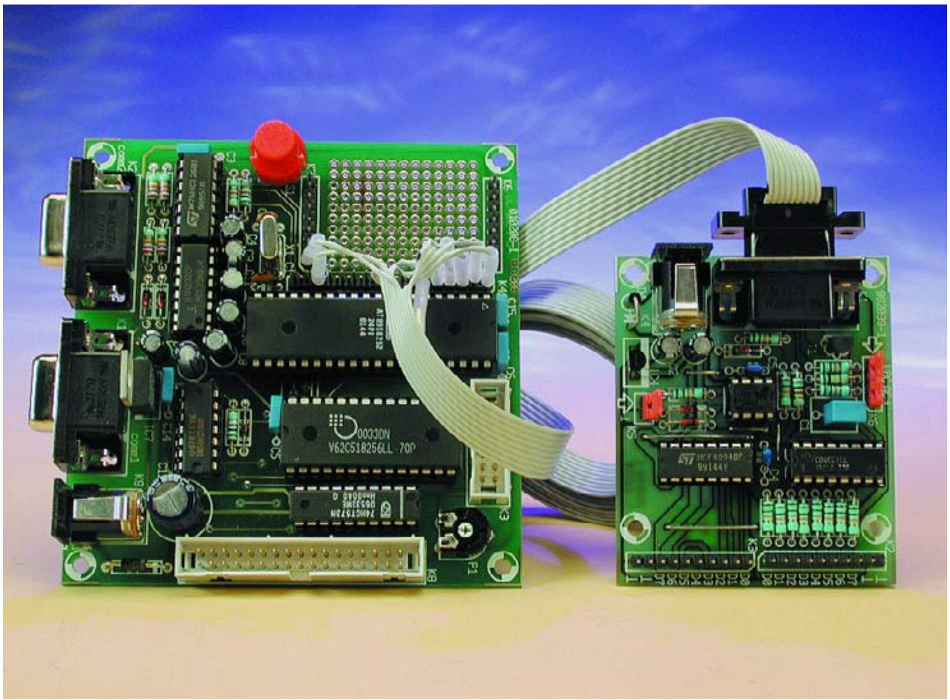
Port Line and ADC Extension

for 89S8252 Flash Micro Board

using our Universal Interface for Windows

Design by B. Kainka

External components have to be used whenever the number of port lines on a microcontroller is insufficient. And when you need to process analogue signals instead of digital ones, it's time to look at adding an ADC.



If it is essential to keep the cost of a microcontroller extension circuit as low as possible, there's nothing to beat standard CMOS integrated circuits from the 4000 series. Only three port lines are required to drive a shift register that creates additional output lines: data, clock and a control line via an output latch. The 'input' direction is equally simple because many A-D converters operate on the same principle of clocked serial data transmission.

The basis for extending the extremely popular **89S8252 Flash Micro Board** (December 2001) is the **Universal Interface for Windows** described in the December 1999 *PC Topics Supplement*. The circuit diagram of the Universal Interface is shown in **Figure 1**. This unit is connected directly to the RS232 port and employs a type 4094 shift register for eight output lines, another shift register type 4021 for eight input lines and an inexpensive ADC type TLC549 to create an 8-bit analogue input with a measurement range up to +5 volts.

The extension circuit should be designed for minimum use of port line 'resources' because with RS232 there are only three output lines and four inputs available. Consequently, a common clock line is used for all three ICs, and they also share a chip select line. Only the data lines are available three times. When an extension circuit is hooked up to a microcontroller circuit, the same principle applies as when it is connected to a PC: the fewer lines are used up, the more ports remain available for other functions. With this in mind the author aimed at using the Universal Interface 'as is' with the 89S8252 Flash Micro Board.

The Universal Interface has a couple of zener diodes that serve to adapt the bipolar voltage swing on the RS232 lines to 0-5 V needed by the CMOS ICs. Level conversion is not required when a microcontroller is connected to the Universal Interface, and even has a small disadvantage in that fast pulse transients are 'rounded' to a certain extent by the stray diode capacitances. Fortunately, if you already have a built up Universal Interface, there is no need to remove the diodes as long as you do not run the microcontroller at maximum speed. Using moderate I/O and clock speeds will allow you to use one and the same Universal Interface both as a port line extender with your PC (connected via RS232) and your 89S8252 Flash Micro board. This may be very useful with experiments or educational use — depending on the assignment given to you, a proposed solution may be tested using PC software first and then evolve into a microcontroller project.

The Universal Interface is connected to Port1 of the controller, **not** to the Sub-D connector on the 89S8252 Flash Micro board. Port1 pin connections are available on pinheader K4 on the board. P3.5 is routed via K5, ground via K7 (see **Figure 2**). In addition to ground, a total of five signal lines are connected-up. Clock line 'Clk' and chip select line 'CS' are common to all three ICs. Next, there are individual data lines for digital output (Dout), digital input (Din), the A-D converter (Adin) and the counter input (Fin).

The extension is controlled in software using BASCOM-51. The modern BASIC offered by this compiler guarantees programs that are easily read and understood. If necessary, programs for other comopilers or programming languages may be translated into BASCOM-51. Further advantages of BASCOM include direct control over port lines (impossible in BASIC-52) ready-made routines for an LCD and the possibility for assembler code to be embedded and so optimise your programs for speed.

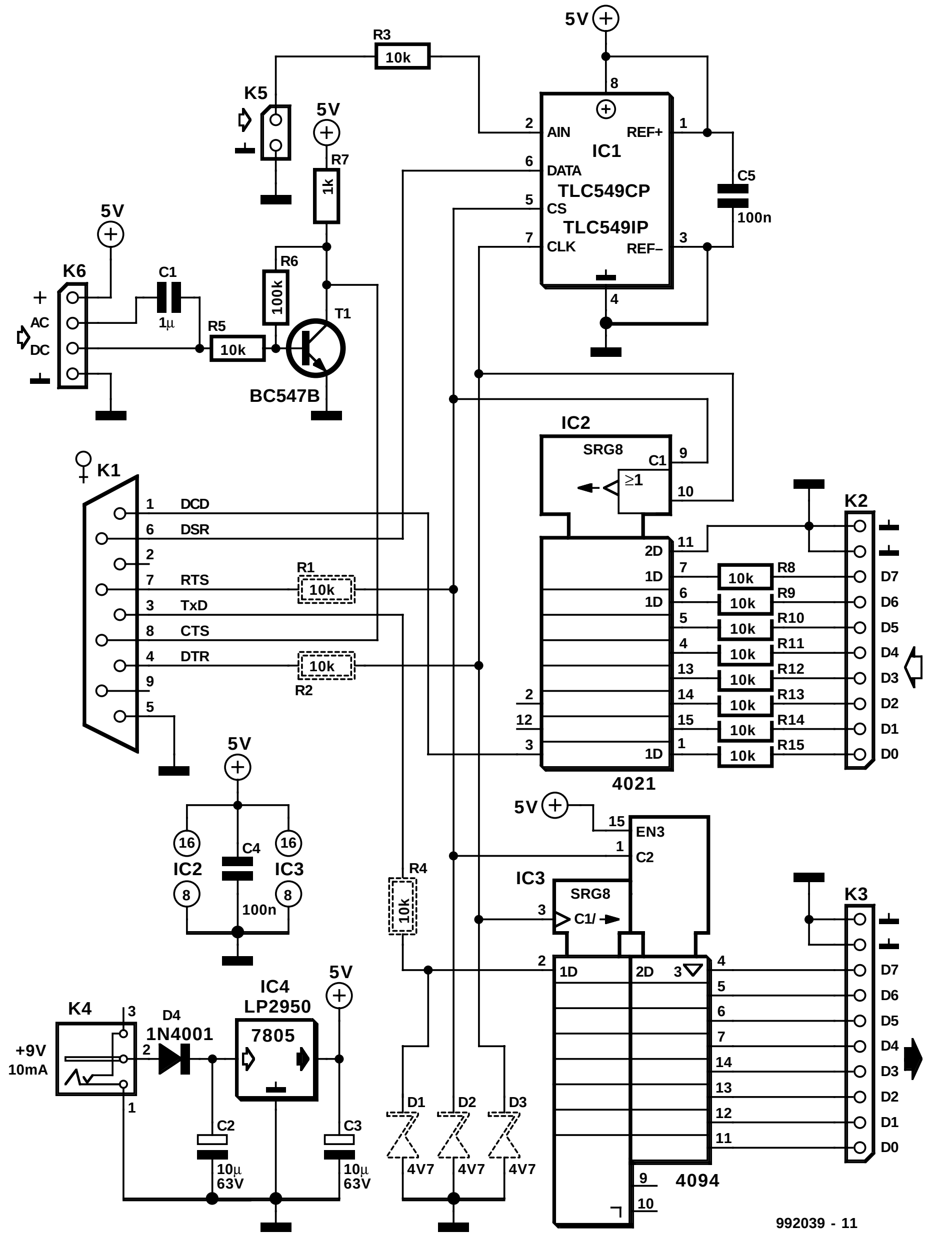


Figure 1. The Universal Interface for Windows may be connected to the 89S8252 Flash Micro board without modifications.

Shift register 4094

Below we'll discuss the way the individual components are controlled. Each component is directly connected to the processor port and individually tested with the aid of a program. If you require just one component, you may want to fit it in the prototyping area on the Flash Micro board. We'll begin by tackling the 4094 shift register. **Figure 3** shows its connection to the processor port.

The actual control is not difficult. The processor supplies the first bit to dataline D and then generates a clock pulse at the CLK input. The databit is copied into the shift register on the positive edge of the CLK signal. The other seven bits are 'clocked in' in the same way. After the last bit, a transfer pulse at the strobe input STR causes all data to be copied simultaneously into the output latch. Next, they appear as logic High and Low levels at the pins.

The datasheet of the 4094 will indicate that the order of the D0-D7 outputs has been reversed here. However, the names assigned to the output lines are arbitrary because we are free to begin with bit 0 or bit 7. Here, the bit order was used as found in the Windows software and the associated programming examples in Delphi [1] and Visual BASIC [2]. The advantage is that an experimental circuit may be tested using a Windows program before diving into the intricacies of microcontroller programming.

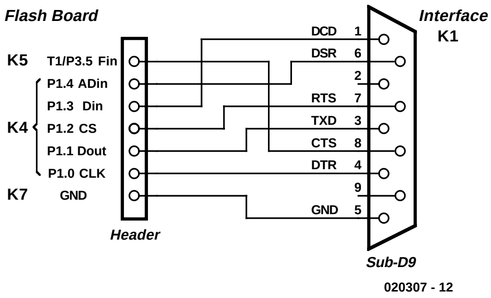


Figure 2. Cable link between Universal Interface and Flash Board.

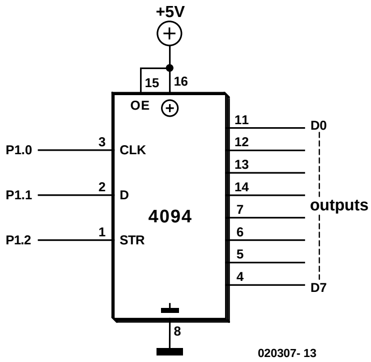


Figure 3. Connection of a 4094 shift register.

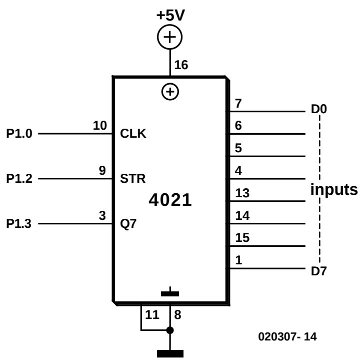


Figure 4. Creating eight inputs with the aid of a 4021.

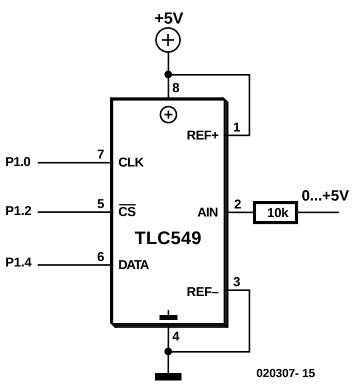


Figure 5. Connection of a TLC549 ADC.

The program in **Listing 1** was written to control the shift registers in BASCOM-51. The main program generates number sequences fed into the subroutine `Out4094`. A global variable called `Outdat` arranges the transfer.

Port lines P1.0, P1.1 and P1.2 are given names that reflect their function. This is done to keep the source code text legible. When using freely chose names, you may need to look carefully at the spelling to avoid confusion with reserved BASIC expressions — see, for example, 'Str/Strb'. The program editor will assist the user in this respect by highlighting all reserved words.

Data outputting employs a shift clock pulse in a loop with eight iterations. A variable `Bitval` copies bit 0 from the data transferred, and is then used to control the dataline. At the end of the loop the input data byte is shifted to the right by one bit. In this way, each successive bit in the word is placed onto the dataline, up to and including bit 7. Each successive Clock pulse is slightly delayed using the BASCOM-51 'Delay' command loaded with value 51 here for a delay of about 100 μs. After the output loop, another 100-μs long Strobe pulse arranges for the data to be copied into the output register.

You will now see repeating bit patterns at the shift register outputs. Each individual output operation takes 1.4 ms of wich 0.9 ms can be traced back to the delays used here. When the circuit is connected directly to the controller, all delays may be removed resulting in a three-fold increase in outputting speed. The delays are however essential if the Universal Interface is applied.

Shift register 4021

Our next assignment is to control an input shift register type 4021 (**Figure 4**). As before, data inputs are labelled in accordance with the requirements of the Windows software. A strobe pulse at pin 9 causes parallel data to be copied in. Next, data bits are shifted at each clock pulse and appear sequentially at output Q7.

The BASCOM-51 program shown in **Listing 2** reads the extended port inputs and shows them on a 2-line LCD. From version 2.0.10 onwards, the new compiler directive `$lcdrs = &H8002` ensures correct control of the Flash Micro Board. With older versions, it used to be difficult to actually employ the parallel LCD connection. The main program demonstrates the simplicity of dealing with LCD outputs. The top line shows the input states in decimal notation, the lower line, in hexadecimal notation. A wait command `waitms 250` provides a sufficiently long delay and thus a legible readout.

The real read routine starts with a 100-μs long Strobe pulse for the intake of parallel data. Next, using a loop each bit is read from the Din line and copied into bit 7 of the variable `Indat`. By means of a right-shift operation, the first bit finally lands at position 0, while the last bit remains at position 7, representing the value 128. After each bit a 100-μs clock pulse moves the data by one position.

A/D converter TLC549

The TLC549 from Texas Instruments is a cheap and widely used A-D converters (**Figure 5**). At a resolution of 8 bits (256 steps), a voltage range of 0 to +5 V is divided into 20-mV increments. The TLC549 requires just two outputs and one input for its connection to a microcontroller. After a positive-going CS pulse of at least 20 μs, eight databits may be clocked out of the IC. The transmission is similar to that of a shift regeister at a low level at CS. The shift clock is also the conversion clock for a successive approximation operation. Consequently, each read access produces the data of the last conversion.

The program shown in **Listing 3** illustrates the basic control method for the converter and the way data are sent to the LCD. The converter supplies data with values between 0 and 255, and multiplication by 20 yields the measured voltage in millivolts. This result is shown on the top line of the LCD. To make a 'volts' readout, a data type known as 'Real' would be required. Unfortunately that is not available in BASCOM-51, so as a recourse the lower line alternately shows the values before and after the decimal point. Fr example, 2300 mV is displayed as '2.300' V.

The A-D conversion routine Adtlc549 bears great resemblance to the reading of a 4021 shift register, although the order of the data is reversed — the higher value bit is read first, making it necessary for a shift-left command to be included in the read loop.

Comprehensive

As far as their control is concerned, the individual modules discussed above differ only marginally. Hence it makes sense to write a common subroutine. One clock signal is sufficient for both shift registers and the A-D converter. The chip select signal for the ADC doubles as the Strobe for the shift register, while the additional frequency input is read at the same time. Frequency measurements rely on Timer 1 of the controller. Input signals are conditioned by a small preamplifier as shown in **Figure 6**. Depending on the signal source, you can either use DC or AC coupling. The frequency meter created in this way has a range of up to about 400 kHz.

The program shown in **Listing 4** first initialises Timer 1 as a 16-bit counter with P3.5 as its external input. The actual measurement at a gate time of 100 ms is carried out at the end of the universal hardware routine called Shiftall. Counter 1 is first reset to 0 and then started. After 100 ms, the counter is halted and read out. A resolution of 10 Hz is obtained by reading pulses within a gate of 100 ms. Multiplication by 10 then yields the frequency in Hertz.

The main program employs all inputs and outputs. The input voltage presented to the ADC, the digital input states and the current frequency of the signal applied to the counter input are all displayed. Furthermore, the results of the ADC are copied to the digital outputs and may be 'viewed' there by means of a set of LEDs.

The subroutine Shiftall caters for the common driving of all peripheral modules. The shared clock signal can make do without a dedicated delay routine because program parts that are necessary in any case provide the necessary delays of a few microseconds. The clocked data transmission takes less than a millisecond. This allows time-critical tasks to be handled, although it must be said that the frequency measurement has an additional time requirement of 100 ms.

(020307-1)

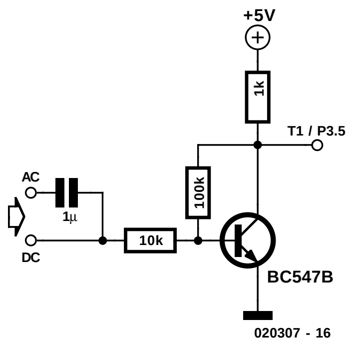


Figure 6. A small preamplifier for the frequency meter.

Note:

The BASCOM-51 programs discussed in this article are available from the Free Downloads page at www.elektor-electronics.co.uk.
Item number **020307-11**, under month of publication.

For further reading

PC Interfaces under Windows, Elektor Electronics (Publishing), ISBN 0 905705 65 1.

Listing 1.

Output via a 4094 shift register

```
'______________
'    Shift4094.BAS
' Elektor 89S8252 board
'______________
$regfile = "89s8252.dat"
Dim N As Byte
Dim Outdat As Byte
Declare Sub Out4094

While 1 = 1
 For N = 0 To 255
  Outdat = N
  Out4094
 Next N
Wend
End

Sub Out4094
 Clk Alias P1.0
 Dat Alias P1.1
 Strb Alias P1.2
 Dim Count As Byte
 Dim Bitval As Byte
 Strb = 0
 Clk = 0
 For Count = 1 To 8
  Bitval = Outdat And 1
  If Bitval > 0 Then Dat = 1
Else Dat = 0
  Clk = 1
  Delay
  Clk = 0
  Shift Outdat , Right , 1
 Next Count
 Strb = 1
 Delay
 Strb = 0
End Sub
```

Listing 2.

Data input via a 4021 shift register.

```
'______________
'    Shift4021.BAS
' Elektor 89S8252 board
'______________
$regfile = "89s8252.dat"
Dim N As Byte
Dim Indat As Byte
Declare Sub In4021

Config Lcd = 16 * 2
$lcd = &H8000
$lcdrs = &H8002

Cls
While 1 = 1
 In4021
 Locate 1 , 1

 Lcd "Inputs=" ; Indat ; "     "
 Lowerline
 Lcd "hex    "
 Lcdhex Indat
 Waitms 250
Wend
End

Sub In4021
 Clk Alias P1.0
 Strb Alias P1.2
 Din Alias P1.3
 Dim Count As Byte
 Strb = 0
```

```
Clk = 0
Strb = 1
Delay
Strb = 0
Indat = 0
For Count = 1 To 8
 Shift Indat , Right , 1
 If Din > 0 Then Indat = Indat
+ 128
 Clk = 1
 Delay
 Clk = 0
Next Count
End Sub
```

Listing 3. Reading an ADC type TLC549.

```
'____________
'    Adtlc549.BAS
' Elektor 89S8252 board
'____________

$regfile = "89s8252.dat"
Dim N As Byte
Dim Addat As Byte
Dim Voltage As Integer
Dim Millivolts As Integer
Dim Volts As Integer
Declare Sub Adtlc549

Config Lcd = 16 * 2
$lcd = &H8000
$lcdrs = &H8002

Cls
While 1 = 1
 Adtlc549
 Voltage = Addat * 20
 Locate 1 , 1
 Lcd "AD= " ; Voltage ; " mV  "
 Lowerline
 Volts = Voltage / 1000
 Millivolts = Voltage Mod 1000
 Lcd "AD= " ; Volts ; "." ; Millivolts ; "" V "
 Waitms 250
Wend
End

Sub Adtlc549
 Clk Alias P1.0
 Cs Alias P1.2
 Adin Alias P1.4
 Dim Count As Byte
 Addat = 0
 Cs = 0
 Clk = 0
 Cs = 1
 Delay
 Cs = 0
 For Count = 1 To 8
  Shift Addat , Left , 1
  If Adin > 0 Then Addat = Addat + 1
  Clk = 1
  Delay
  Clk = 0
 Next Count
End Sub
```

Listing 4. A suggested program to control it all.

```
'____________
'    Interface.BAS
' Elektor 89S8252 board
'____________

$regfile = "89s8252.dat"
Dim N As Byte
Dim Outdat As Byte
Dim Indat As Byte
Dim Addat As Byte
Dim Voltage As Integer
Dim Freq As Long
Declare Sub Shiftall

Config Lcd = 16 * 2
Config Timer1 = Counter , Gate = Internal , Mode = 1

$lcd = &H8000
$lcdrs = &H8002

Cls
While 1 = 1
 Shiftall
 Outdat = Addat
 Voltage = Addat * 20
 Locate 1 , 1
 Lcd Voltage ; " mV  "
 Locate 1 , 12
 Lcdhex Indat ; "   "
 Lowerline
 Lcd Freq ; " Hz    "
 Waitms 250
Wend
End

Sub Shiftall
 Clk Alias P1.0
 Dout Alias P1.1
 Cs Alias P1.2
 Din Alias P1.3
 Adin Alias P1.4
 Dim Count As Byte
 Dim Bitval As Byte
 Clk = 0
 Indat = 0
 Addat = 0
 Cs = 1
 Delay
 Cs = 0
 For Count = 1 To 8
  Shift Addat , Left , 1
  If Adin > 0 Then Addat = Addat + 1
  Shift Indat , Right , 1
  If Din > 0 Then Indat = Indat + 128
  Bitval = Outdat And 1
  If Bitval > 0 Then Dout = 1 Else Dout = 0
  Clk = 1
  Shift Outdat , Right , 1
  Clk = 0
 Next Count
 Cs = 1
 Delay
 Cs = 0
 Tl1 = 0
 Th1 = 0
 Start Counter1
 Waitms 100
 Stop Counter1
 Freq = Th1 * 256
 Freq = Freq + Tl1
 Freq = Freq * 10
End Sub
```

Capacitance Meter

using a CMOS timer

Design by M. A. Lange

As demonstrated in this article, a simple test instrument is sufficient to unravel the mysteries of the cryptic and impossibly small print often found on capacitors.

Besides the obvious advantages of space savings, the miniaturisation of electronic components has a couple of dark sides too. Until about ten years ago, there used to be plenty of room on capacitor bodies to print the capacitance value, the tolerance, operating voltage, manufacturer code and other salient information. Today's capacitors, being much smaller in size, have illegible, incredibly small and cryptic print on them and before fitting such a capacitor you are well advised to measure the actual capacitance! Rocket science? Well, no. The good news is that this article describes a low-cost and extremely simple instrument to do just that.

Two timers

The circuit diagram shown in **Figure 1** indicates that two ICs type 555C are used. These are standard timer ICs that are largely pin and functionally compatible with the good old NE555 or LM555. The truth table of the IC is given in **Table 1**. These essential difference is the suffix 'C' — the current consumption of the inputs labels THRESHOLD, RESET and $\overline{\text{TRIGGER}}$ is just a few pico-amperes and so low that it has no noticeable effect on the capacitor's charging process.

The two timer ICs — internal architecture shown in **Figure 2** — operate in different 'modes'. IC1 is configured as an astable multivibrator; IC2, as a monostable one. IC1 generates short negative pulses of about 25 µs and spaced 65 ms apart at its output (pin 3). These pulses serve to trigger the second timer, IC2, in order to start a measurement cycle.

Timer IC2 handles the actual measurement of the unknown capacitor. Initially, the Discharge pin, number 7, can be considered as having ground potential, hence discharges the capacitor under examination. The measurement starts when the trigger signal arrives at the Trigger input pin 2. The internal Discharge FET is then switched off and the unknown capacitor is charged via resistors R2-R7 connected into the circuit by rotary switch S1 (see Table 2). The end of the trigger pulse has no effect since the states of the output and the Discharge FET remain unchanged as long as the voltage on the capacitor stays under 2/3rd of the supply voltage. This voltage is monitored at the Threshold input.

However, after a time

$$T_H = 1.1\ R\ C_x$$

that condition is ended and the IC output toggles to Low. Consequently, the Discharge output goes low again, discharging the capacitor. No more changes occur until the next trigger pulse arrives. This cycle is repeated until you switch off the instrument. The mark/space (= on/off) ratio of the output signal is a measure of the capacitance between the test inputs.

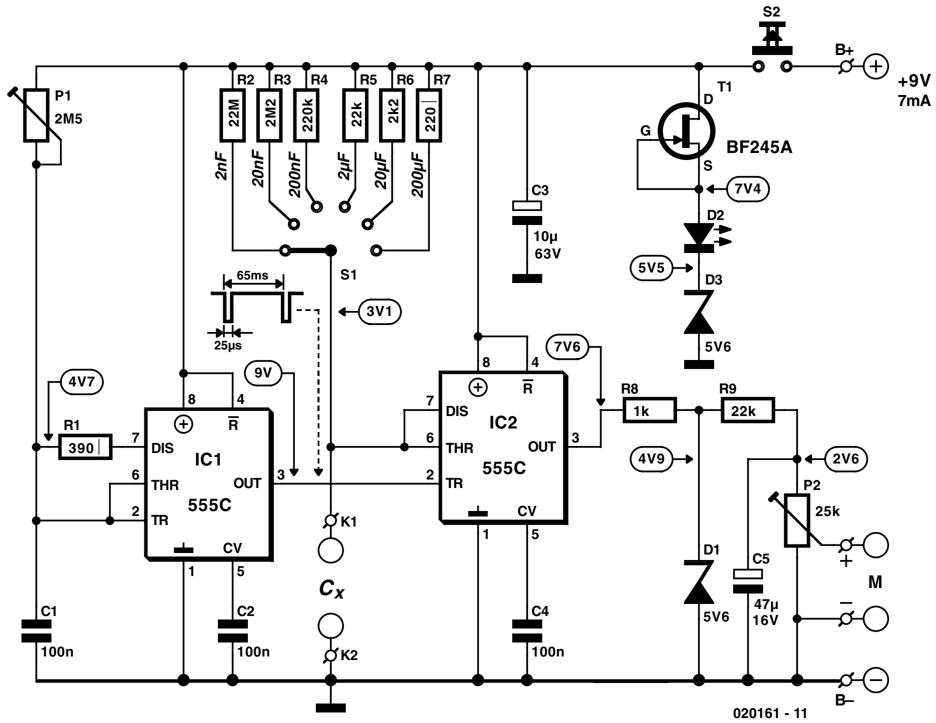


Figure 1. Circuit diagram of the capacitance meter based on the 555 — it's a classic!

Table 1. 555 Truth Table

THRESHOLD (Pin 6)	TRIGGER (Pin 2)	RESET (Pin 4)	OUTPUT (Pin 3)	DISCHARGE SWITCH (Pin 7)
don´t care	don´t care	Low	Low	On
>2/3·V+	>1/3·V+	High	Low	On
<2/3·V+	<1/3·V+	High	Stable	Stable
don´t care	<1/3·V+	High	High	Off

The rest of the circuit will require a less elaborate explanation. For simplicity's sake, a 100-μA moving-coil meter is used for the readout. Alternatively, you may want to use a DVM set to the 2-volts range. Resistor R9 ad capacitor C5 smooth the output signal to prevent an unsteady meter indication caused by the mark/space ratio of the output signal. A direct voltage proportional to the mark/space ratio is taken from the wiper of potentiometer P2. Diode D1 stabilizes the voltage to make it independent (within limits) of the battery voltage. That concludes our discussion of the measurement principle. To arrive at capacitance readings that are reliable as well as sensible, some conditions need to be fulfilled.

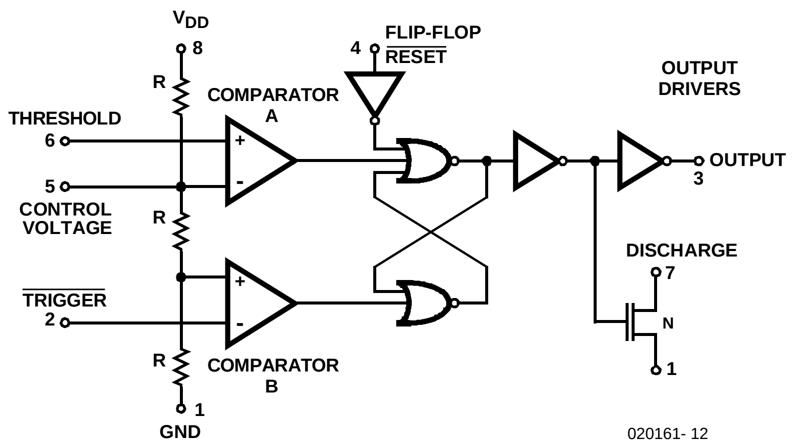


Figure 2. What's inside the 555 timer IC.

The period time of the measurement (here, 65 ms) may not be too long because the average output voltage and consequently the meter deflection would become too small.

Much worse results are obtained, however, by a too short period time because then a new trigger pulse arrives before the measurement is finished. This causes pulse loss and erroneous measurement results. You can actually see this happening by turning P1 and so raising the oscillator frequency — the readout will suddenly drop by half the value.

Table 2. Measurement Ranges

S1	R_{Meas}	Range*
1	22 MΩ	1 nF
2	2,2 MΩ	10 nF
3	220 kΩ	100 nF
4	22 kΩ	1μF
5	2.2 kΩ	10 μF
6	220 Ω	100 μF

* Double value on DVM readout

With period time and measurement time at the right ratio, but too long (for example, of the order of tens of seconds), the smoothing action of R9 and C5 will no longer suffice to keep the needle from quivering.

A simple battery indicator is built around T1, D2 and D3. The 'on' voltage of the LED has been 'raised' to about 7.4 V by zener diode D3. When the battery voltage drops below that level, the LED will go out. FET T1 acts as a simple current source.

Construction, adjustment and practical use

The PCB designed for this month's Mini Project is shown in **Figure 3**. Unfortunately, it is not available

COMPONENTS LIST

Resistors:
R1 = 390Ω
R2 = 22MΩ
R3 = 2MΩ2
R4 = 220kΩ
R5,R9 = 22kΩ
R6 = 2kΩ2
R7 = 220Ω
R8 = 1kΩ
P1 = 2MΩ5 preset
P2 = 25kΩ preset

Capacitors:
C1,C2,C4 = 100nF
C3 = 10µF 63V radial
C5 = 47µF 16V radial

Semiconductors:
D1,D3 = zener diode 5V6, 500mW
D2 = LED, red, high-efficiency (2mA)
T1 = BF245A or BF256A
IC1,IC2 = 555C or TLC555 (CMOS 555)

Miscellaneous:
S1 = rotary switch, 2 poles, 6 positions
S2 = pushbutton, 1 make contact
K1,K2 = 4-way SIL socket for IC pins, turned pins
Case, 60 x 10 x 126 mm with battery compartment
Knob
Moving coil meter, f.s.d.100 µA

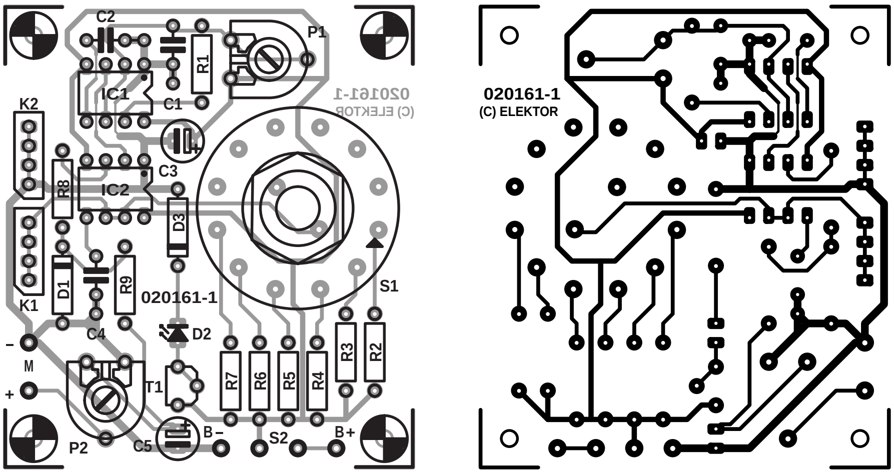
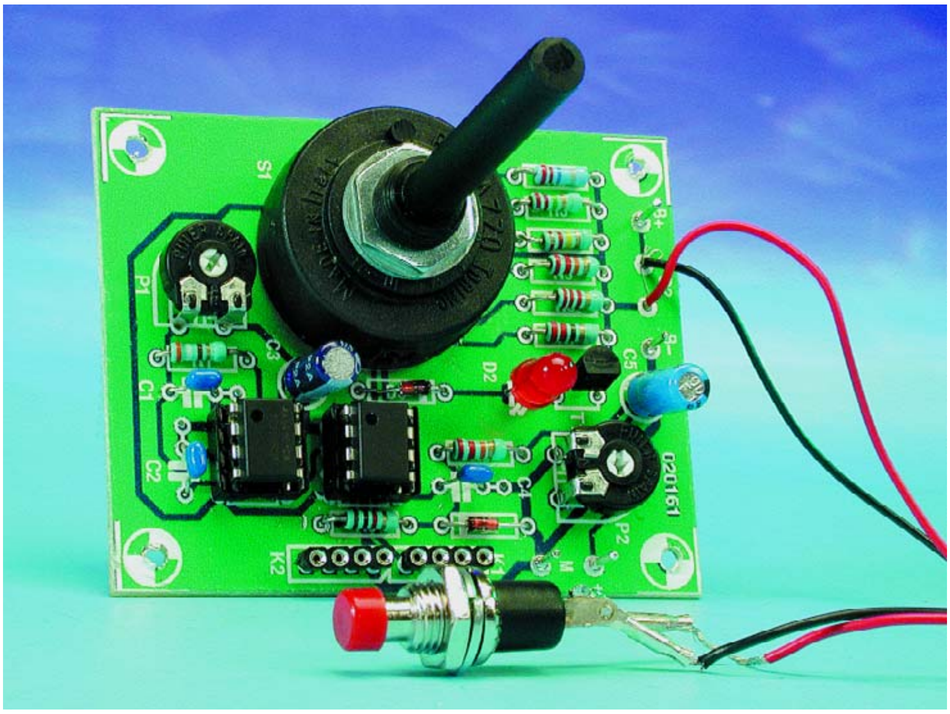


Figure 3. PCB layout, component mounting plan and the way the peripherals are connected up.



ready-made. All components not accommodated on the board (push-button, battery and meter) are connected up via solder pins and short wires. Because long wires represent considerable stray capacitance, the capacitor under test should be plugged straight onto the board. This is made easy by K1 and K2, two ordinary SIL sockets with good-quality (i.e., turned or gold-plated) contacts. The farthest removed contacts allow capacitors with a lead pitch of 20.32 mm to be inserted. If that is not sufficient, there's more room on the board for a longer version of K2.

The circuit has to be adjusted before it is fitted into an enclosure. A suggested front panel layout is shown in **Figure 4**.

The two adjustment points are P1 and P2. P1 determines the measurement frequency and is initially turned fully counter-clockwise. P2 is set to mid-travel. Connect the moving-coil meter or the DVM (set to the 2-volts range), connect a 'known-good' 0.1-microfarad (100nF) high stability capacitor to the test socket, and finally turn S1 to the 200 nF range. Next, connect the battery (watch the polarity) and press S2. The meter may show some deflection at this point. Carefully turn P1 until the meter value suddenly drops by 50% (we know why, don't we?). Next, slowly turn P1 back until the about 90% of the previously noted vale is indicated again. Then adjust P2 for full-scale deflection (100 μA on the moving-coil meter or 1.00 volts on the DVM). That completes the adjustment procedure.

As already noted, we are not discussing a high-precision instrument here, so a measurement error of a few percent should be accepted. Using high-precision resistors in positions R2-R7 will not improve the accuracy — 1% tolerance types are sufficient in all cases. After all, the instrument is aimed at identifying capacitors from the E6 range, which is marked by factors 1, 1.5, 2.2, 3.3, 4.7 and 6.8. Each value is therefore about one and half times that of the previous one ($\sqrt[6]{10}$ or 1.47 to be accurate…). This should allow the present instrument to unerringly identify E6 series capacitors.

(020161-1)

A Star for Christmas

Design by A. Rossius

This circuit acts as a simple light effects generator. With the LEDs suitably arranged, it will produce the impression of a star and so makes an ideal Christmas ornament or decorative element. As you can see from the board layout, the LEDs have been arranged in the shape of a star.

The first LED to light is the centre one. Then follow the LEDs in the inner ring (D3-D19), followed by the next ring, and so on, right up to the outer ring (D43-D50). The sequence is then started again. The speed of the light effect depends on the setting of P1.

The operation of the circuit is just as sample as the light effect produced. A 555-based timer is configured as an astable multivibrator clocking a decimal counter (IC2). After a reset, output Q0 is activated. The next output on the counter, Q1, is activated on the next clock pulse, and so on. The counter outputs control the LEDs via buffer transistors. The seventh clock pulse causes a reset pulse and so forces the counting to start at Q0 again.

Apart from a functional circuit, an all-electronic Christmas decoration requires a suitable overall design. That's why we've designed a PCB layout with the LEDs suitably arranged in straight lines.

(020040-1)

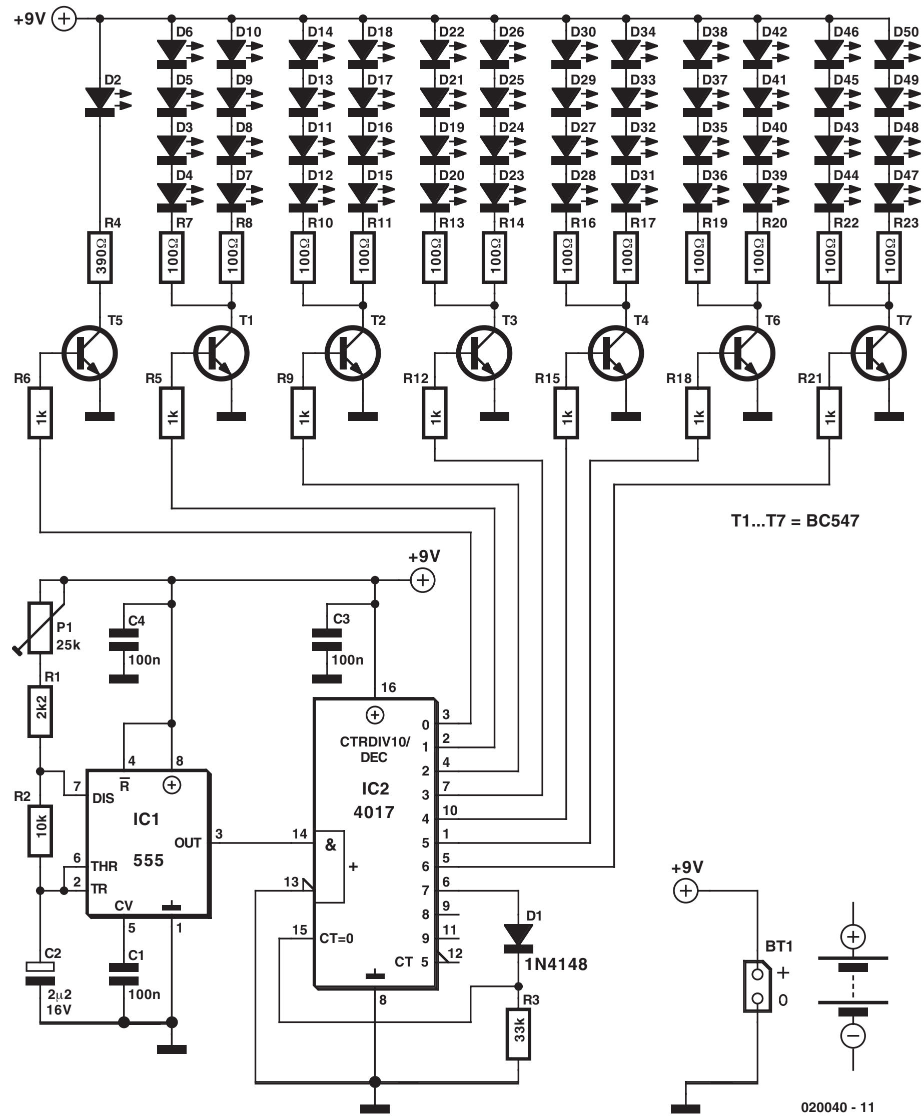


Figure 1.

COMPONENTS LIST

Resistors:

R1 = 2kΩ2
R2 = 10kΩ
R3 = 33kΩ
R4 = 390Ω
R5,R6,R9,R12,R15,R18,R21 = 1kΩ
R7,R8,R10,R11,R13,R14,R16,R17,R19,R20,R22,R23 = 100Ω
P1 = 25 kΩ preset

Capacitors:

C1,C3,C4 = 100nF
C2 = 2µF2 16V radial

Semiconductors:

D1 = 1N4148
D2-D50 = LED, red
T1-T7 = BC547
IC1 = 555
IC2 = 4017

Miscellaneous:

9V battery with clip-on connector

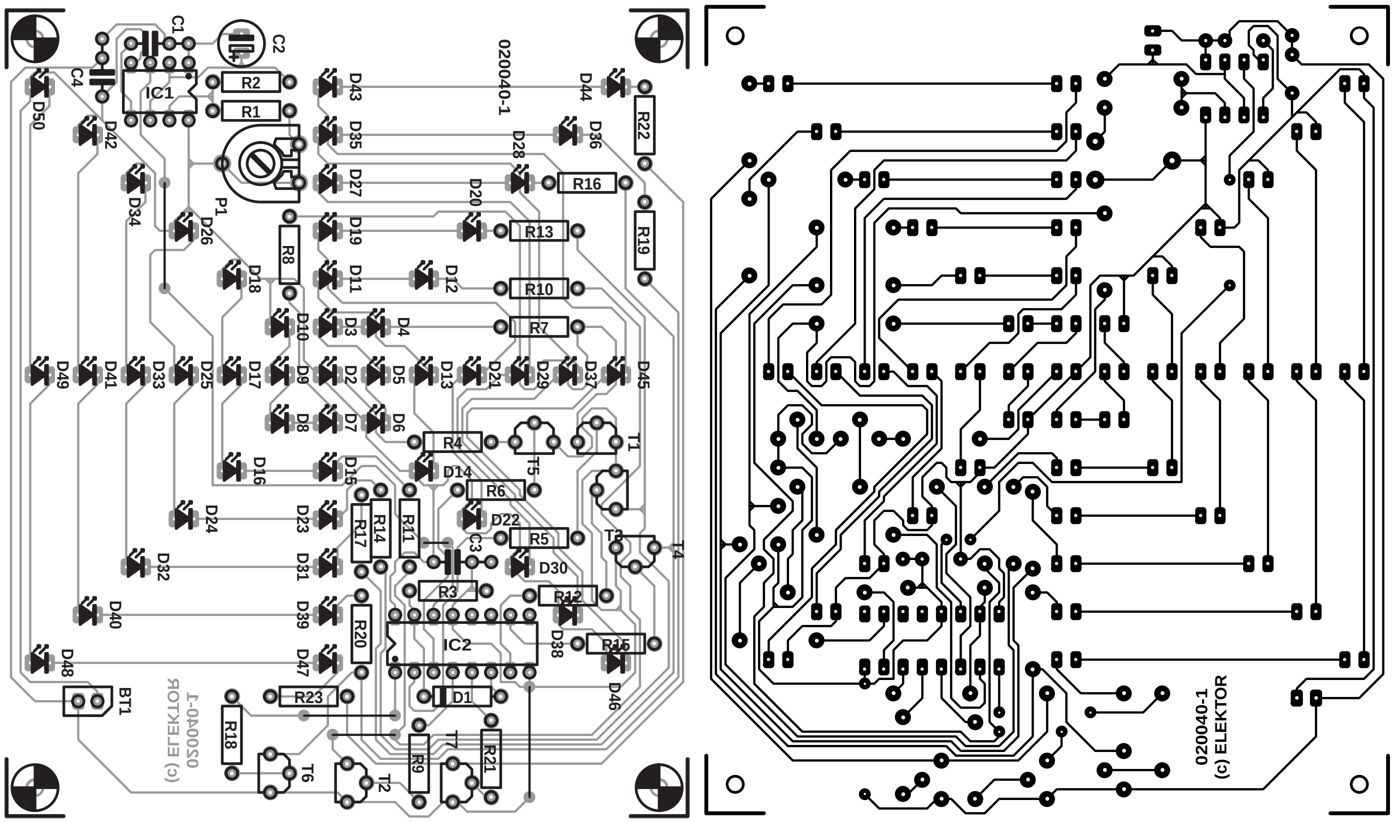
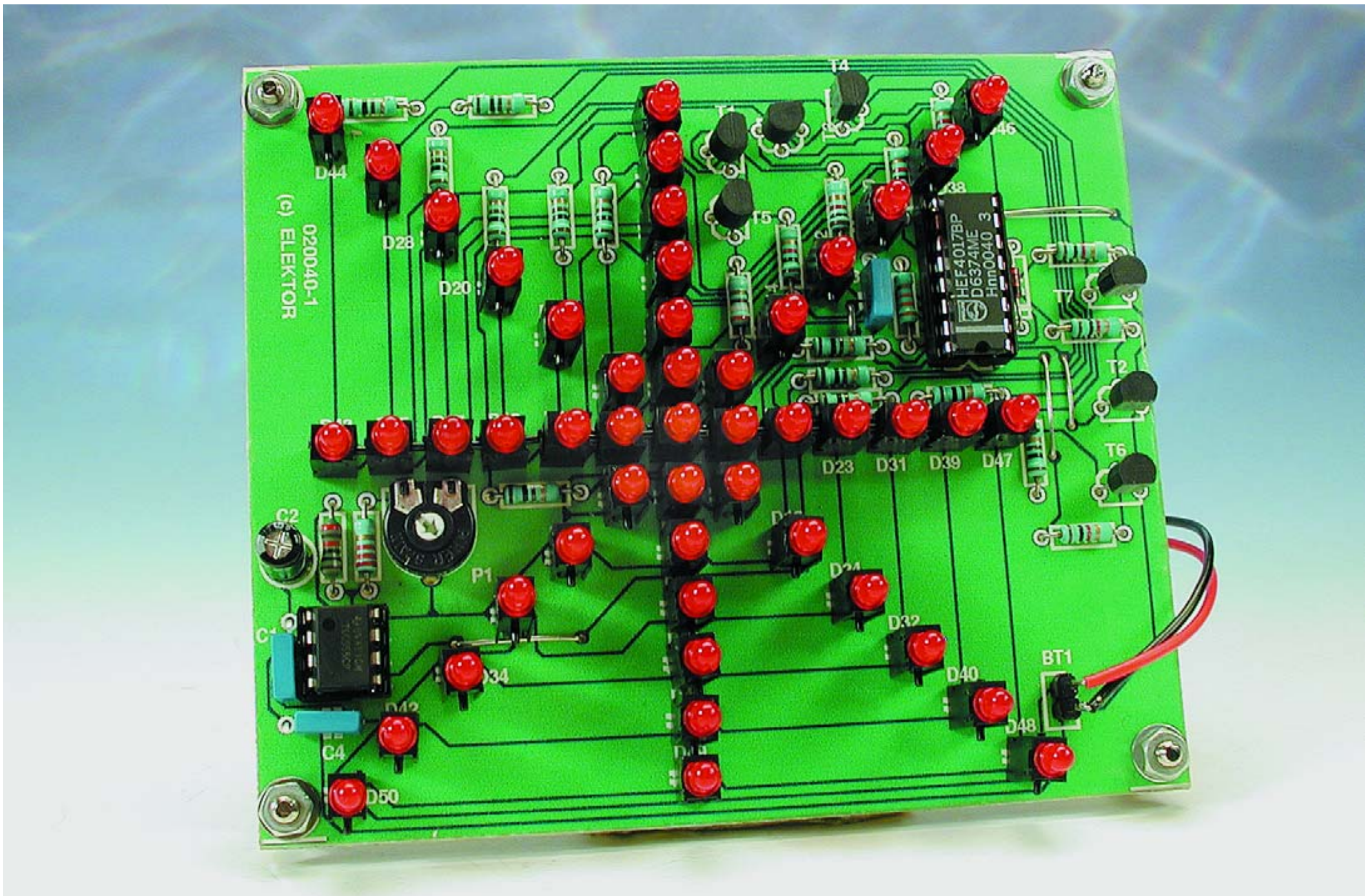

020040-1
(c) ELEKTOR
IC1
IC2
R1
R2
P1
C1
C2
C3
C4
BT1

Figure 2.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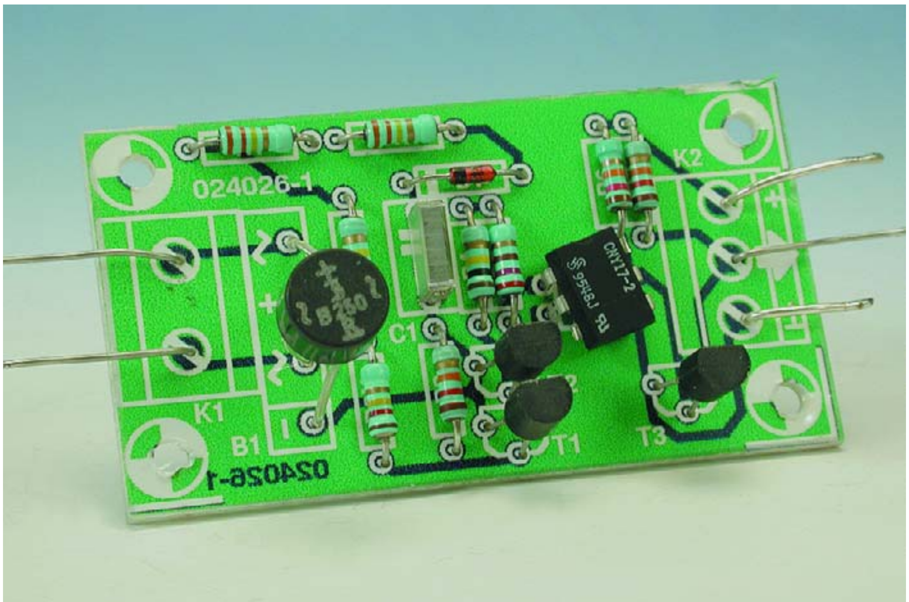
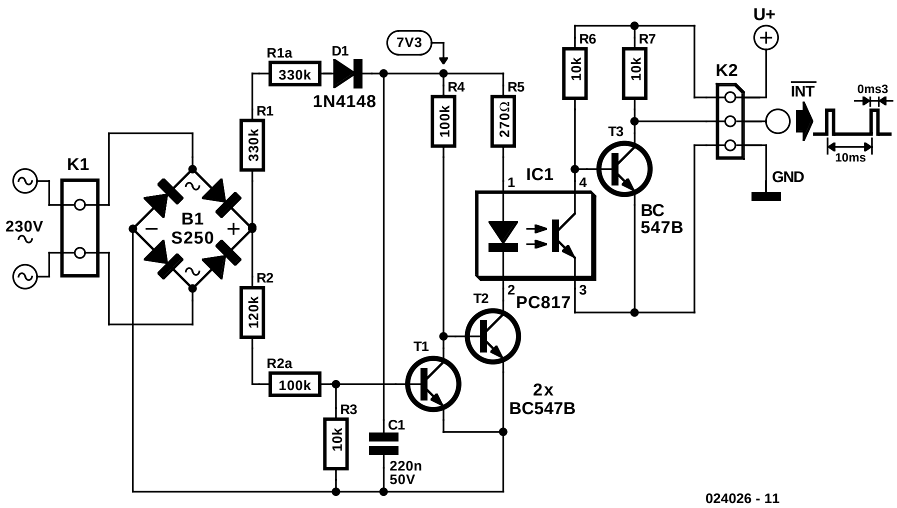


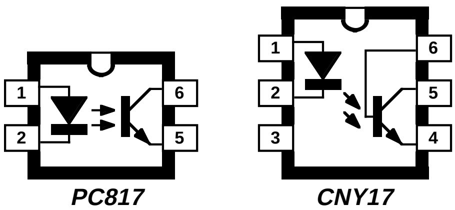
All power control circuits that use phase control require an adjustable delay element synchronised to the mains voltage. The adjustable delay determines the phase angle at which the thyristor, triac or transistor connects the mains voltage to the load. Simple passive dimmer circuits use RC phase shifters having a fixed relationship to the mains frequency. Nowadays, microprocessors are often used for precision controllers and complex control tasks. A zero-crossing detector is thus required for synchronisation with the mains frequency. If the microprocessor does not have to be electrically isolated from the mains, the detector can be constructed very simply: a voltage divider and two protection diodes at the interrupt input of the microcontroller are sufficient.

However, if the microcontroller must be electrically isolated from the mains network, a more elaborate solution is necessary. Due to reactive, non-uniform loads, zero crossing points can be exactly determined on the secondary side of the transformer only under certain conditions. The non-linear transfer characteristic often causes the secondary voltage to be deformed and offset in phase, so it cannot be assumed to be a clean, phase-aligned sine-wave signal.

Using a separate, dedicated secondary winding just for zero-crossing detection (or even a separate transformer with the appropriate protection class) is not particularly elegant in terms of circuit design, nor is it especially economical in terms of power consumption, due to unavoidable internal losses.

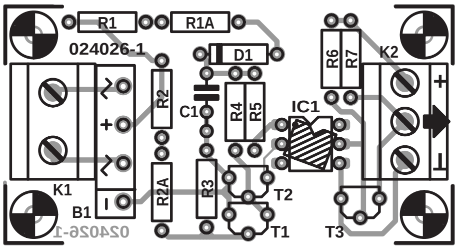
The circuit proposed here derives zero crossings directly from the primary-side mains voltage, using an optocoupler for electrical isolation. It uses only inexpensive standard components. Furthermore, it features low power consumption and small thermal dissipation. It generates precisely timed, clean and uniform pulses for all zero crossings (thus 100 times per second).

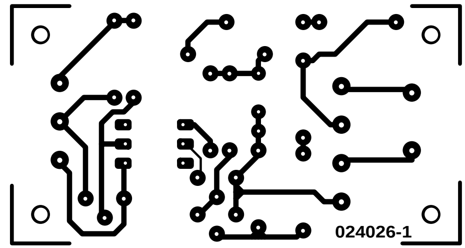




The circuit…

A full-wave rectifier (B1) generates a pulsating DC voltage. The supply voltage for the optocoupler is derived from this voltage (smoothed to around 7.3 V by R1/C1), as are the zero-crossing pulses (via voltage divider R2/R3). The amount of charge provided on each half-cycle is dimensioned to be just enough to provide power to the subsequent stage for the next zero-crossing pulse. Diode D1 prevents current from flowing from C1 back into the base of T1 when a zero crossing occurs, since otherwise T1 could not detect zero crossings.





The circuit generates zero-crossing pulses as follows: transistor T2 receives its base current directly from the rectified mains voltage via high-resistance resistor R4. Due to the rapid rise of the mains voltage, T1 is almost always switched fully on, being cut off for only approximately 50 µs before and after each zero crossing. Inverter T2 causes a current limited to approximately 15 mA by R5 to flow through the LED of the optocoupler for the exact duration of the 100-µs zero-crossing pulse. Since the LED of the optocoupler is driven only by very short pulses, the exact magnitude of the current is not critical.

The phototransistor is wired conventionally. Here it is connected to an inverting transistor, since a positive pulse was needed for the interrupt input of a microcontroller.

COMPONENTS LIST

Resistors:
R1,R1A = 330kΩ
R2 = 120kΩ
R2A,R4 = 100kΩ
R3 = 10kΩ
R5 = 270Ω
R6,R7 = 10kΩ

Capacitor:
C1 = 220nF, 50V

Semiconductors:
B1 = B250C500 or 4 off 1N41004
D1 = 1N4148
T1,T2,T3 = BC547B
IC1 = PC817 (Sharp)

Miscellaneous:
K1 = 2-way PCB terminal block, lead pitch 7.5mm
K2 = 3-way PCB terminal block, lead pitch 5mm

…and the PCB

Nearly the entire mains voltage appears across R1 and R2. For this reason, each of these resistors is split into a pair of resistors on the printed circuit board (R1 + R1A and R3 + R2A). All other components and the associated board layout can be designed for voltages less than 30 V. Naturally, adequate isolation distance (> 6 mm) for electrically isolated circuit elements bearing a protective low voltage must always be taken into account in the layout, particularly the region of the optocoupler. By contrast, a separation of 3 mm must be maintained between components bearing mains voltage. In operation, only R2 becomes slightly more than lukewarm (but please don't try to verify this yourself!). The four-pin Sharp optocoupler is fitted at an angle, as can be seen in the component layout, while the alternative CNY17-2 is fitted straight.

The PCB shown here is unfortunately not available ready-made.

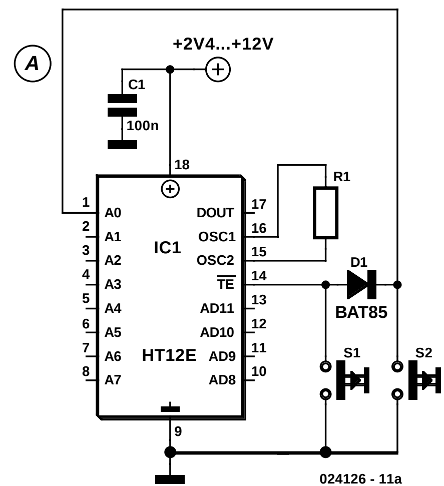
(024026-1)

HT12E Pushbutton Switch Extension

We have already used the Holtek HT12E as an encoder in several previous projects, primarily for remote controls. This encoder is triggered by a Low level on the TE (Transmission Enable) input. The transmitted address (and optionally data) can be set on the A0–A7 and AD8–AD11 inputs, for instance using DIP switches (internal pull-up resistors are present). The trick is now to change the address at the same time by pressing a second button. This is possible if a diode is added to the circuit.

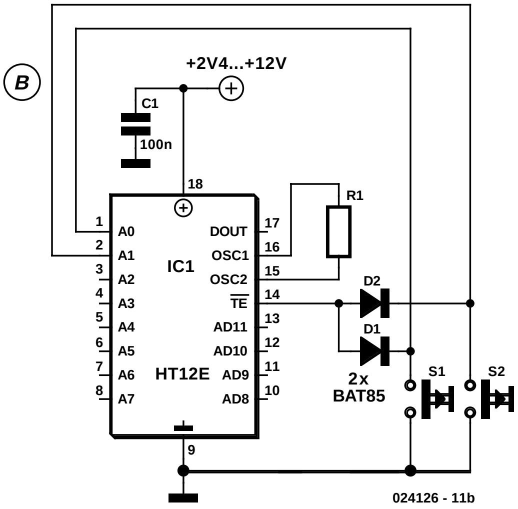
Schematic diagram A shows the simplest version. S1 is connected according to the standard application circuit for the IC, while S2 can also be used to connect the TE input to ground via a diode. When S2 is pressed, address input A0 is also connected directly to ground (any other address pin can also be used). If S1 is pressed, the diode is reverse biased and the address remains 0.

The disadvantage of this design is that in practice if S2 is



released at the ‘right’ time, address input A0 will be High even though a transmission cycle is still in progress, causing address 0 to be accepted one time by the decoder at the receiver end. A solution to this problem is provided by the design shown in diagram B. Here each pushbutton switch has its own diode and address 0 is not used by the receiver. Up to 12 pushbuttons can be connected in this manner. If a smaller number are used, the remaining addresses can be used to distinguish between various applications or devices.
For more information about the encoder, refer to the IC manufacturer’s website at www.holtek.com.

(024126-1)



1-dB Chebyshev Filter/Amplifier

003

Butterworth filters, and to a lesser degree Bessel filters, are probably the most commonly used types of analogue filters. However, in circuits where steep skirts are required it is necessary to us higher-order versions of these filters, which means more components and higher costs. In such cases, a possible alternative is to use a different type of filter, and in particular a Chebyshev filter, since it has considerably steeper skirts for the same order. The only disadvantage of this type of filter is the ripple in the passband and the associated overshoots in the square-wave response (much worse than with Butterworth filters), but it is possible to select component values to control the amount of ripple.

Here is an example of a third-order Chebyshev filter with a ripple of 1 dB. Although active filters are almost always combined with unity-gain buffers, this is by no means mandatory. Most filters can be readily combined with a voltage amplifier. Since this renders a supplementary amplification stage unnecessary, we have gratefully taken advantage of this possibility in the design presented here.

The illustrated low-pass filter thus has a ripple of 1 dB, with the rated frequency passing through the –1-dB point. The ‘true’ corner frequency (–3 dB) is only 9.4% higher. We have printed two tables. **Table 1** lists the theoretical capacitor values, for a circuit having three equal resistor values, for six dif-

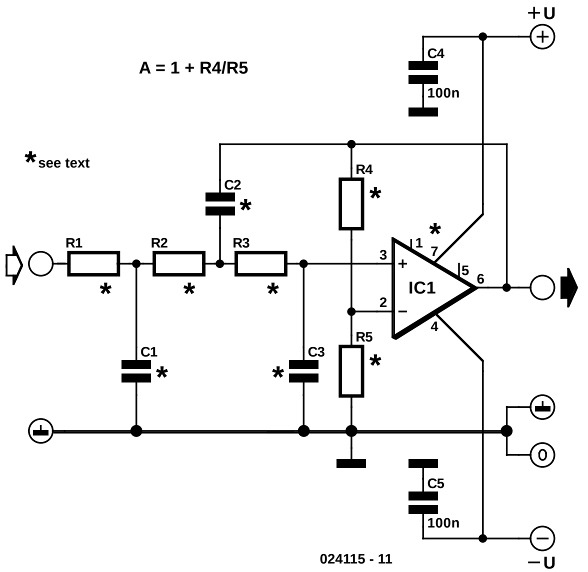


Table 1: 3 x 10 kΩ, 1 kHz (f_c = –1 dB!)

A[dB]	C1	C2	C3
0	37.314 n	235.31 n	934.56 p
5	43.422 n	20.175 n	9.3665 n
6	44.283 n	17.746 n	10.442 n
10	47.708 n	11.836 n	14.532 n
14	51.504 n	8.4738 n	18.801 n
20	58.426 n	5.3733 n	26.137 n

Table 2: 1 kHz (f_c = –1 dB!), caps : E-12

A[dB]	C1	R1	C2	R2	C3	R3
0	39 n	9.5283 k	220 n	9.8193 k	1 n	10.222 k
5	47 n	9.3191 k	22 n	9.0553 k	10 n	9.4040 k
6	47 n	9.4716 k	18 n	9.5007 k	10 n	10.778 k
10	47 n	10.182 k	12 n	9.9738 k	15 n	9.5505 k
14	47 n	11.391 k	8.2 n	10.136 k	18 n	10.244 k
20	56 n	11.229 k	5.6 n	9.2570 k	27 n	9.3231 k

ferent gain levels, namely 0 dB (1 ×), 5 dB (1.778 ×), 6 dB (2 ×), 10 dB (3.162 ×), 14 dB (5 ×) and 20 dB (10 ×). The first table is also necessary if you want to convert the filter from low-pass to high-pass.

Table 2 shows more practical component values for the same gains. Exact E12 values have been used for the capacitors, and we have calculated the theoretical values of the resistors for you so they can be implemented very accurately by connecting two E96 values in parallel.

At the higher gain levels, and particularly at high frequencies, a very fast type of opamp must be used to avoid having it affect the signal transfer. In order to keep deviations (in frequency and amplitude) as small as possible, the use of 1% components is highly recommended (especially at higher gains).

(024115-1)

Long-Interval Timer

004

G. Ruschitzka

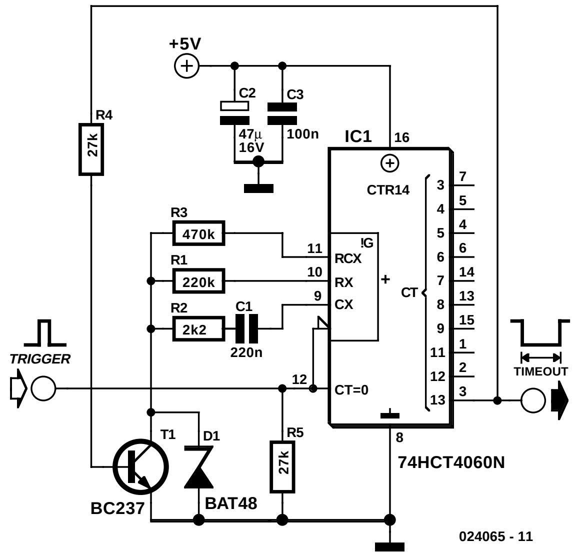
Occasionally there is a need for a timer circuit for tasks such as switching off a circuit element (such as an LC display) after a given interval or generating a time delay for an application. Short intervals can be conveniently generated using a 555 timer, but if the switch-off time lies in the range of minutes or longer, a 555 is no longer suitable due to the large value required for the capacitor, which leads to inaccuracies or instability. In such cases, a digital counter circuit with an oscillator is a better solution.

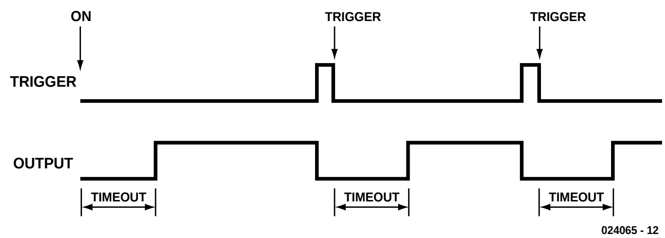
The 74HCT4060 IC, with its built-in oscillator, can cover a wide range of frequencies in a simple and reliable manner and can also generate very low frequencies. The 14-bit divider chain can divide the oscillator frequency by up to 16,384, which makes it easy to obtain long time intervals.

The circuit presented here acts like a digital monostable. The timeout time starts when the system is switched on, since a Low level is initially present on the selected output of the counter IC (Q13 or any other desired output Q2–Q12). This represents the active (On) state for the connected circuit. After the counter chain has counted up enough for the selected output to switch to the High state, the oscillator is cut off by transistor T1 so that no further counting pulses can be generated. The circuit thus remains in this state. The High signal level represents a 'rest state' for the connected circuit.

In order to reactive the timeout, a positive pulse is applied to the Reset input (pin 12). The circuit re-triggers, the Q output goes Low immediately (active) and a new timeout starts.

To make the selection of counter outputs flexible, a DIP switch can be used as long as only one switch at a time is activated, since otherwise short circuits will be created between the counter outputs. It is also useful to connect one of the switches to V_{CC} via a small resistance. If this switch is activated, the connected circuit is permanently disabled, while if neither this switch nor any of the other switches is activated, the circuit is permanently enabled. This covers all possible operating situations. It is important to keep the load small. If necessary, a CMOS gate (inverter) can be used to buffer the following circuit.





The timeout interval is given by the formula

$$\text{timeout} = 2^n \div f_{osc}$$

with

n = selected output stage (n = 3–13)

$f_{osc} = 1 \div (2.5 \cdot (R1 \cdot C1))$

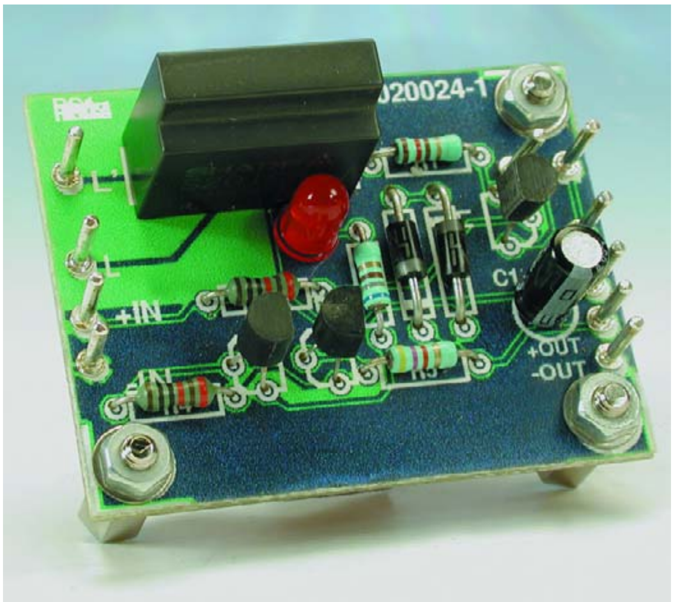
With the indicated component values (R1 = 220 kΩ, C1 = 220 nF), the frequency is 8.3 Hz and the timeout interval at Q13 is 16.5 minutes.

(024065-1)

Switch for Switch-free Power Supplies

005

U. Reiser



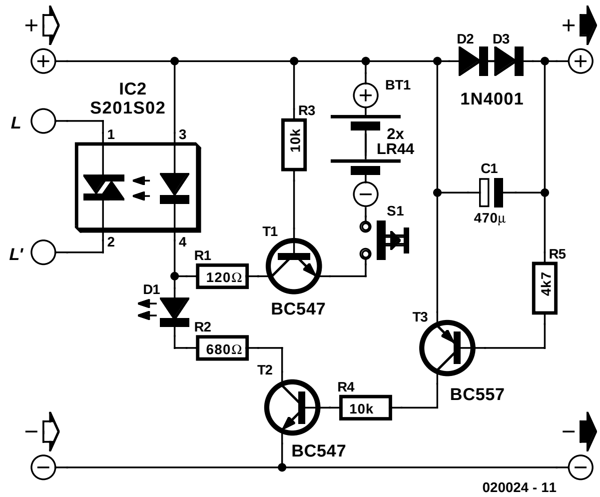
Portable radios, CD-players and cassette recorders that can also be operated from mains power often do not have a mains power switch, but instead are switched off on the 'DC side'. This means that the power supply is permanently connected to the mains network if the mains cable is not unplugged. The situation with equipment requiring a mains adapter is similar. This is not ideal for the environment or for your pocketbook.

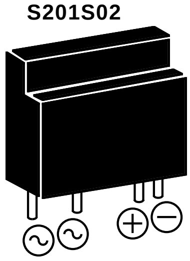
The following circuit allows power to be switched on manually and switched off automatically, directly at the equipment. Optoelectronic isolation between the mains voltage and the switching stage ensures continued compliance with safety regulations.

Switching on

The circuit consists of the switch-on stage T1 and the hold-on and switch-off stage T2/T3. Both stages drive the power switch, which is implemented using a semiconductor relay (IC1). The voltage from the two button cells (2–3 V) is connected to the LED of the semiconductor relay by pressing pushbutton switch S1. R1 allows a diode current of around 10 mA to flow. At the same time, T1 prevents a 'charging current' from flowing into the batteries when the semiconductor relay that switches the mains voltage is energised by T2. Although such a current can only flow while the pushbutton is pressed, this possibility must be taken into account for safety reasons.

1



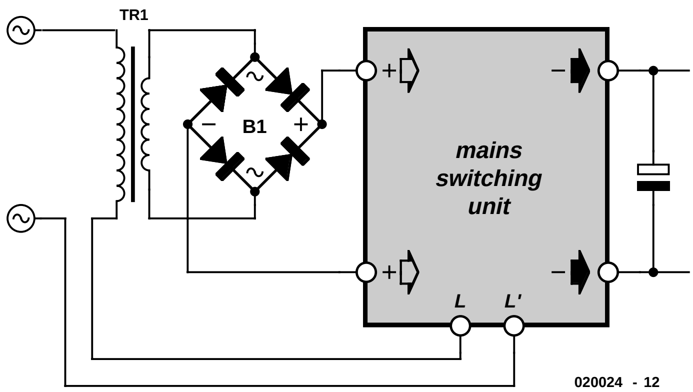


When the LED of the semiconductor relay is energised by the battery current, the triac connects the mains voltage to the transformer of the power supply. The DC voltage provided to the load is twice reduced by 0.65 V by diodes D2 and D3. This threshold voltage, smoothed by C1, provides a base current for T3, which drives T2 into conduction. T2 in turn supplies current via R2 to LED D1 and the LED in IC1. R2 must be matched to the DC voltage of the equipment to allow a LED current of 10 mA to flow. As long as the pushbutton is pressed, two LED currents flow, and together they should not amount to more than 20 mA in order to avoid destroying the LED in IC1.

Switching off

The voltage drop across D2 and D3 is only present if a current drawn by the connected equipment flows from the output of the circuit. If this current is interrupted by switching off the equipment, T3 and T2 will

2



be cut off. The semiconductor relay will then open, and the mains voltage will be switched off. This switch-off process is delayed by capacitor C1, so that (for example) you can exchange an audio cassette without causing the recorder to be disconnected from the mains.

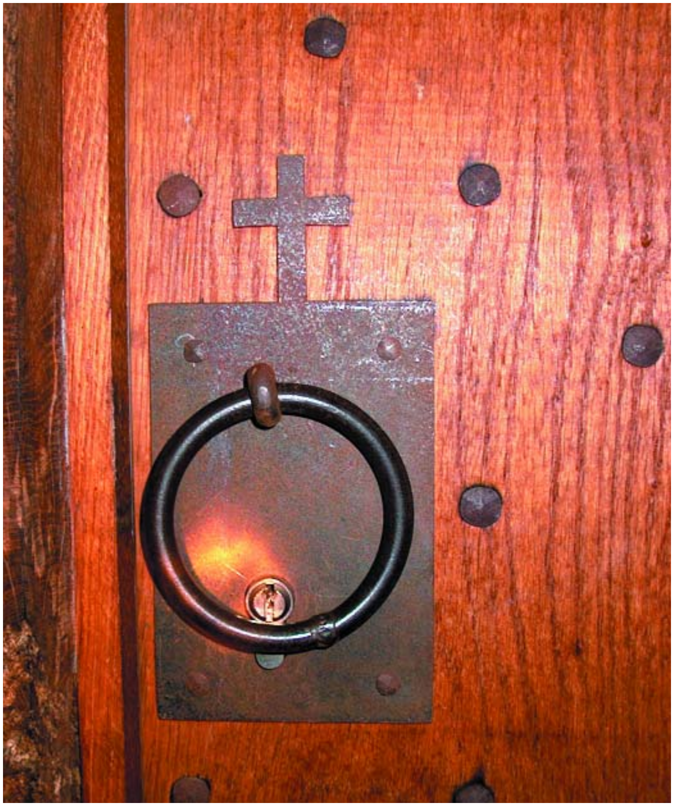
For the semiconductor relay, you should select a type having a zero-crossing switch. This means that the triac will only switch on at the zero point of the mains voltage, regardless of when the pushbutton is pressed. Almost no current will thus flow at the instant when the triac switches, which prevents inductive switching spikes and associated interference. The S201S01 semiconductor relay used here can switch currents up to 8 A (continuous) or 80 A (single-cycle peak).

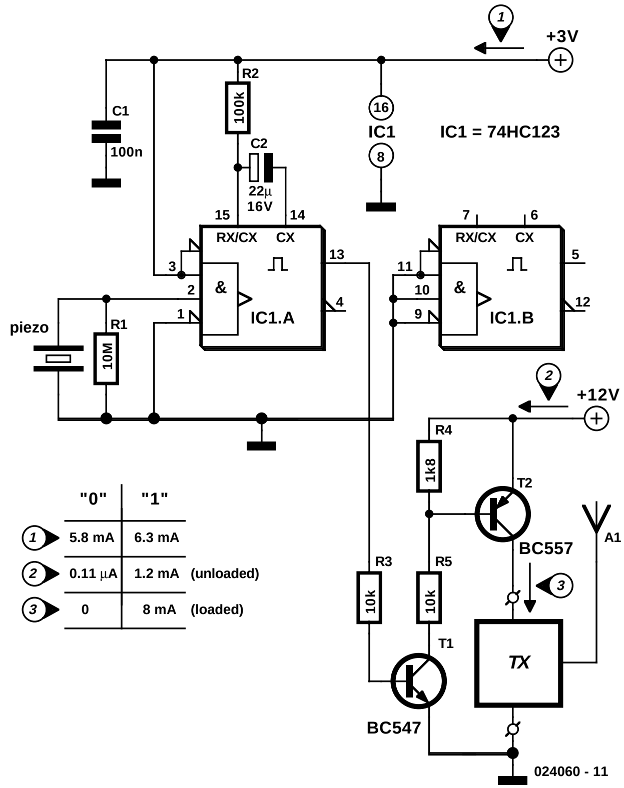
Figure 2 shows how to connect the circuit between the power supply and the charging capacitor. When laying out the circuit board, ensure that all components carrying mains voltage are separated from each other by at least 3 mm and from the low-voltage area by at least 6 mm. Naturally, the same considerations apply to fitting the circuit board into the equipment to be switched. If there is not sufficient space inside the equipment, the circuit can be fitted between the equipment and the mains adapter as a sort of cable switch.

(020024-1)

Door Knocker Bell

006





If you have an old house, it's nice to have only a door knocker and no doorbell, since 'back then' no-one had a doorbell and it destroys the illusion of authenticity. Although a door knocker makes quite a racket, if you happen to be in the garden, the attic or the cellar it might not be enough. The circuit shown here solves this problem by acting as a sort of 'electronic extension' for the door knocker.

A standard piezoelectric buzzer (not an active type) is used here as a vibration pickup (or 'knocking pickup', if you will). If you tap on such a buzzer it can easily produce a voltage of around 1 V, which is more than enough to trigger monostable IC1a. This in turn produces a pulse with a duration of approximately one second to drive transistors T1 and T2. into conduction. The second of these transistors can be used to energise a relay (to switch on a suitable bell or beeper) or drive a 443-MHz licence-exempt transmitter (as shown here). If you use a transmitter, simply connect T2 in place of the pushbutton. The associated receiver can be carried around everywhere within and around the house, so you can always hear knocking signals from visitors no matter where you are.

With a transmitter, a monostable time of one second is adequate, but with a relay it is better to increase this time somewhat by proportionally increasing the value of C2. By the way, the relay should not draw more than 100 mA, and don't forget the usual flyback diode.

The nice thing about this circuit is that in the rest state it draws almost no current (only a few microampères), so two penlight cells can serve as a power source for quite a long time. Only while someone is knocking does the current consumption rise to several milliampères.

Naturally, the pickup (the piezoelectric buzzer) must be fitted flat in the vicinity of the knocker. Excellent results can be obtained if it is mounted on the inside of the door. If you're handy with tools and want to have everything finished off as neatly as possible, you can also drill a hole in the door and recess the pickup into it.

One final remark: depending on the type of buzzer used, the sensitivity may be too great, with the result that the bell rings at the slightest provocation. In this case, the value of the parallel resistor (R1) can be reduced until the desired sensitivity is obtained.

(024060-1)

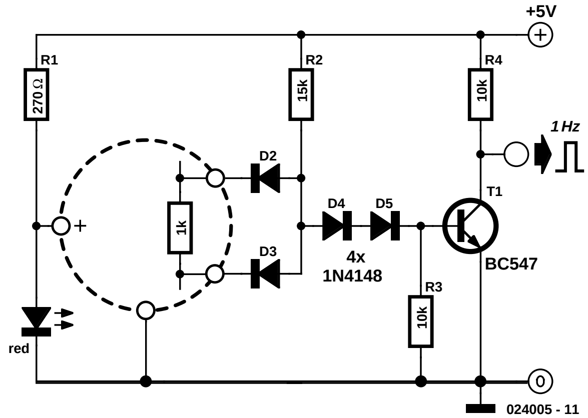
Seconds Reference with Quartz Accuracy

007

M. Köhler

Simple analogue quartz watches or watch movements, which can be obtained inexpensively by mail order or at flea markets, contain a circuit that drives the watch motor with pulses at the rate of one per second. If you build such a watch movement into a small circuit, you have an inexpensive but nevertheless accurate 1-second frequency standard.

Watch movements normally have four pins: two for the supply voltage and two for the motor coil. Connect a 1-kΩ resistor in place of the motor coil. Negative pulses at a one-second rate with a duration of around 50 ms (depending on the type of movement) can now be found alternately on the two pins. These are combined using an OR gate made from discrete components. The output of the circuit thus provides positive pulses, buffered by T1, for use in other applications.



This circuit can be used with any desired supply voltage, since the supply voltage for the watch movement is tapped off from a red 20-mA LED fitted with a suitable series resistor.

(024005-1)

Modified Time Clock Switch 008

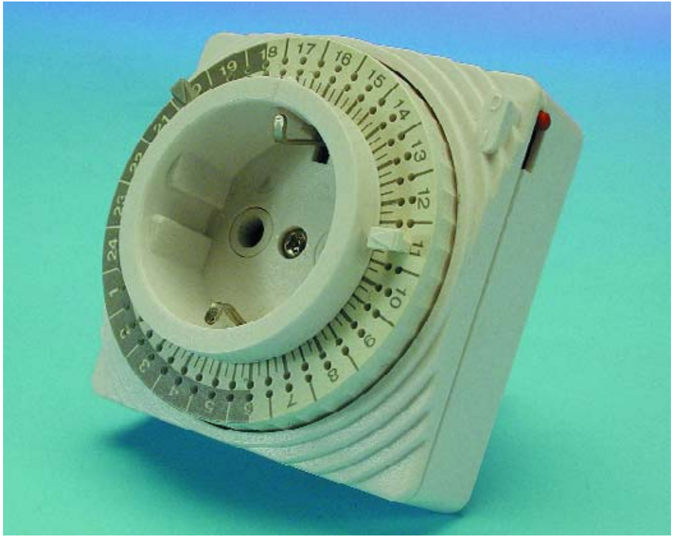
H. Steffes

It doesn't take a lot of effort to convert an electromechanical time clock switch into a simple time switch, and it can be done quite simply. All you have to do is open the case and disconnect the series resistor for the motor from the switch contact. Next, use a length of insulated wire to reconnect it to the other side of the switch contact. The difference between the two versions is shown in the figure.

To operate the time switch, all that you need is a tab for switching off. Set the time ring to the Zero position and fit the tab at the desired switch-off time. A mechanical on/off switch is used to start the time switch. After the set interval has expired, the motor is de-energised and the time switch is thus stopped.

Please bear in mind that you are working with the mains voltage. The device must still be safe to touch after the modification, and the switch must be a type that is suitable for use with the mains voltage.

(024038-1)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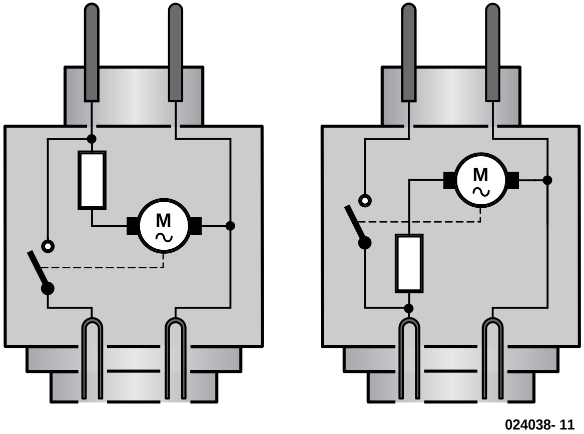
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024038- 11

Turn That Down, Please

009

A. Baur

Many people, both at home and at work, like to have the radio on for some background music or news. Your preferred sound volume, however, may well be annoying when a phone call has to be made or answered. This little circuit keeps music lovers and phone addicts happy at the same time by automatically reducing the music volume when the phone is taken off the hook. No need to walk over to the radio!

The circuit is simple and built from off the shelf components. As long as the receiver is on the hook, the phone line voltage will be high, causing the optocoupler to conduct and the relay to remain off. Via the relay contacts, the radio is then connected to the loudspeakers in the normal fashion.

Once the receiver is lifted, the situation reverses with R2 providing enough base current for T1 to start conducting. With the relay energized, the contacts connect 22-Ω resistors in series with the loudspeakers lines, causing much reduced volume and allowing you to complete the phone call without yelling.

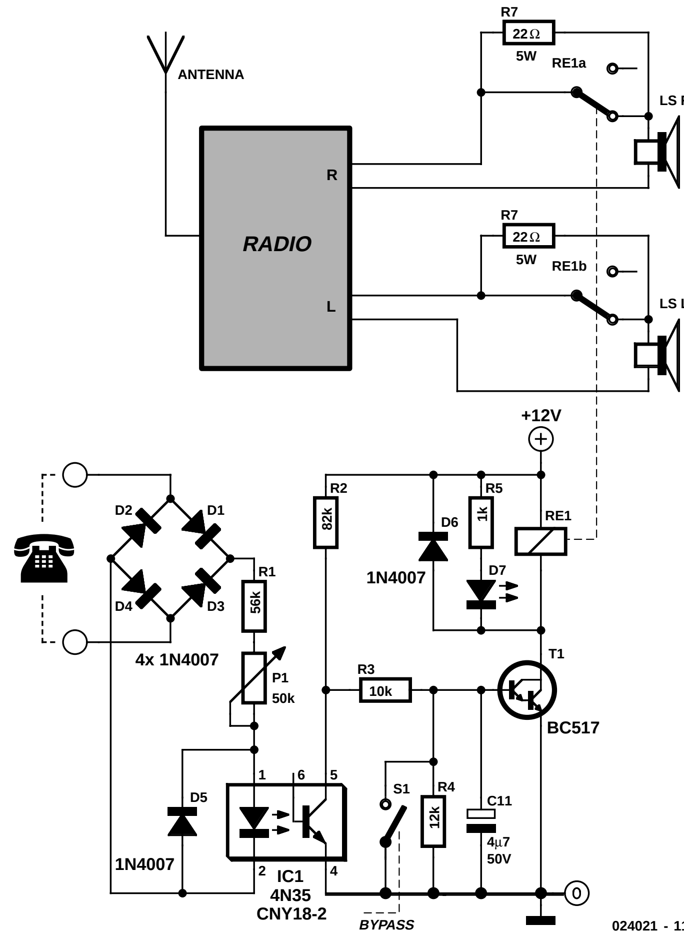
Switch S1 when closed defeats the action of the optocoupler and so acts as a ‘bypass’ control.

The relay may be 12-volt type with two change-over (c/o) contacts or just two make contacts. Preset P1 is adjusted until the relay comes on reliably when the receiver is lifted.

Finally, of the two alternatives shown in the circuit diagram, only the CNY17-2 optocoupler will provide an isolation voltage specification compliant with Class 2 equipment. The 4N35 will still satisfy Class 1, however.

The circuit is conveniently and safely powered from a battery eliminator (a.k.a. mains adaptor) with a (loaded) output voltage of about 12 VDC.

(024021-1)

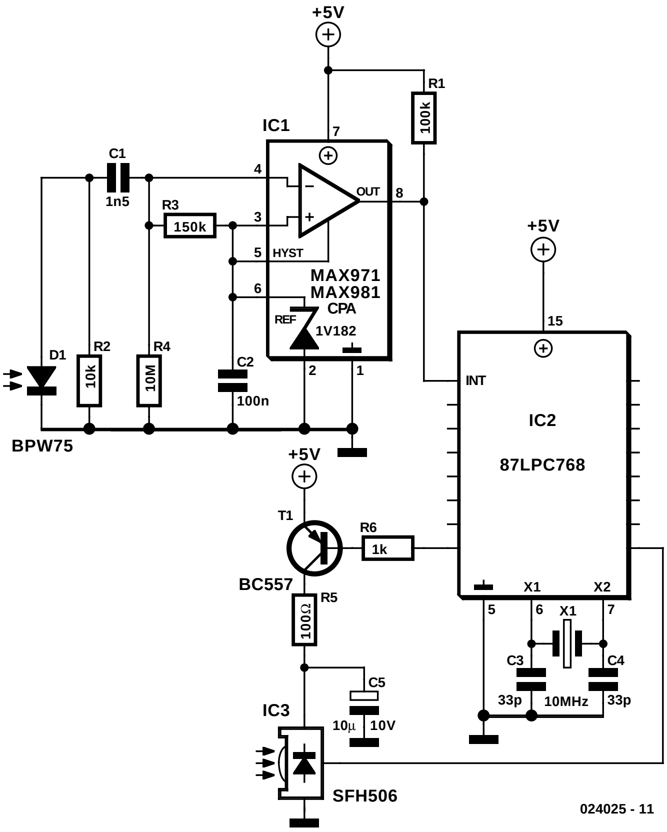


Infrared Wake-Up Circuit

010

For all battery-operated devices, regardless of whether they use disposable or rechargeable batteries, the lower the current consumption is, the longer the operating time of the device. For this reason, all functions not needed at the moment are switched off if possible and only switched on when needed or by the user. Any circuit containing a receiver used for remote control or communications is faced with the problem of current consumption if the circuitry always has to be active. For instance, the current consumption of typical photosensor module fitted as an infrared receiver in entertainment electronics equipment is around 1–2 mA, which defeats economical battery operation. It is thus necessary to find a way to circumvent this inconvenience without noticeably affecting the user.

Using the supplementary circuit described here, the photosensor module that is actually responsible for controlling the device is only activated when infrared light (originating from a remote control unit, for example) strikes a second photodiode. This photodiode is followed by an especially low-power comparator, whose operating current of around 4 µA represents an insignificant load to the battery and which generates a switching signal when the photoelectric current exceeds a particular value. Due to the absence of an amplifier stage, the wake-up circuit is naturally not very sensitive. Depending on the type of photodiode used, the range extends to approximately 50 cm.



The circuit is built around a Maxim MAX971 IC (http://pdf-serv.maxim-ic.com/arpdf/MAX971-MAX984.pdf), which contains a reference voltage source in addition a comparator and is particularly suitable for battery-operated equipment, due to its typical current consumption of 2.5 µA (4 µA max.). The MAX971 is a member of a whole family of low-power comparators (see Table).

The photoelectric current of photodiode D1, which is operated as a photoelectric generator, produces a voltage across resistor R2. This voltage is capacitively coupled to the comparator input. This mode of operation was chosen because the current consumption is significantly lower than if the diode is operated as a photodetector with a bias voltage. The reference voltage U_{ref} and voltage divider R3/R4 provide a voltage of around 18 mV to the comparator inputs. Thanks to the built-in reference, this voltage is independent of the supply voltage. A high-pass filter formed by C1, R3 and R4 eliminates low-frequency interference, such as 50-Hz mains hum. The voltage across C1 consists of U_{ref} less the bias voltage of 18 mV. Any voltage generated by the photoelectric current through R2 adds to the voltage across C1. Consequently, any infrared signal that exceeds the threshold level of 18 mV across R2 causes the comparator output to switch to Low. Due to the input offset voltage, the IR triggering threshold varies over a range of approximately 6–28 mV. R1 acts as the load resistor for the open-drain output of the comparator and can be omitted if the following microcontroller has an internal pull-up resistor.

Type	Internal reference	Number of Comparators	Internal hysteresis	Package
MAX971	1 %	1	yes	8-pin DIP/SO/µMAX
MAX972	none	2	no	8-pin DIP/SO/µMAX
MAX973	1 %	2	yes	8-pin DIP/SO/µMAX
MAX974	1 %	4	no	16-pin DIP/SO
MAX981	2 %	1	yes	8-pin DIP/SO/µMAX
MAX982	2 %	2	yes	8-pin DIP/SO/µMAX
MAX983	2 %	2	yes	8-pin DIP/SO/µMAX
MAX984	2 %	4	no	16-pin DIP/SO

In order to reduce the current consumption to a minimum, the microcontroller (IC2) is put into the Sleep mode by the application software when there is nothing for it to do. This causes the oscillator to be switched off, which 'freezes' all of the activities of the IC. With a Philips 87LPC768 microcontroller, for example, the current consumption drops from a typical level of 15 mA at a 10-MHz clock frequency to typically 1 µA. A High–Low edge on the INT pin triggers an interrupt that causes the oscillator to automatically resume operation, so the software continues to run from the location where it stopped on entering the Sleep mode. After the supply voltage for IC3 is switched on, the output of the photosensor module is checked for the presence and activity of a coded sequence of signal level changes. If this is not seen, it can be assumed that there was some sort of noise and the microcontroller again ceases its activities. The transistor can be omitted if the associated output can supply enough current for IC3.

The photosensor module IC3 is naturally only needed if it is necessary to receive and decode a carrier-based infrared signal, for example using RC5 coding and a 36-kHz carrier frequency. If the limited range is sufficient for the intended use, the microcontroller can also directly process a signal sent in Flash mode that is present at the comparator input. With such a signal, the information content is represented by the times between successive light flashes.

(024025-1)

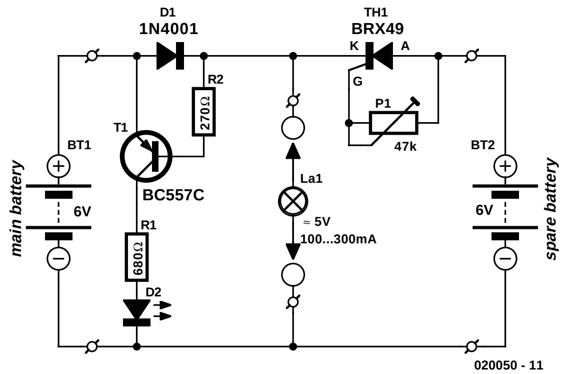
Automatic Battery Switchover 011

K.-H. Lorenz

This circuit, which is designed for use with 6-V rechargeable batteries, provides automatic switchover to a reserve battery when the voltage of the main battery approaches the fully discharged level. The clever thing about this circuit is that the actual switchover is voltage-dependent and adjustable, even though the circuit essentially consists of only two components. The active element is a small thyristor (type BRX49), which is connected between the load and the reserve battery. For calibrating the switchover point, an incandescent lamp is connected as a load. In actual use, however, the load can be anything having a maximum current consumption of 300 mA at around 5 V.

The cathode of the thyristor is connected to the load, with the anode connected to the positive terminal of the reserve battery. The gate of the thyristor is also connected to the positive terminal of the reserve battery via a 47-kΩ trimpot (P1). This already clearly suggests how the automatic switchover works.

The voltage across the thyristor is the difference between the two battery voltages. Initially, with both batteries fully charged, the voltages of the two batteries are nearly the same. The thyristor is thus cut off, since there is not any significant voltage across it and no gate current flows via P1. As the main battery becomes increasingly discharged, the voltage across the load decreases, which means that the voltage at the cathode of the thyristor decreases. The anode thus becomes positive with respect to the cathode and the gate. A gate current starts to flow via P1, with its magnitude depending on the voltage and the value of P1. As soon as the gate current exceeds the triggering threshold of the thyristor, the thyristor fires (which means that it suddenly starts to conduct), causing the reserve battery to be connected to the load. Since the voltage of the reserve battery is higher than that of the discharged main battery, diode D1 is cut off, preventing any current from flowing from the reserve battery into the main battery. We thus



have a circuit that indeed switches from the main battery to the reserve battery.

Diode D1 not only prevents a reverse current flow from the reserve battery into the main battery, it also forms part of an indicator circuit, in combination with transistor T1 and LED D2. This circuit works as follows: as long as a current flows from the main battery through D1, a base current also flows through the base–emitter junction of the transistor, which together with the base resistor R1 is connected in parallel with D1. This causes the transistor to conduct, so LED D2 is illuminated to indicate that the main battery is in use. When the circuit switches over to the reserve battery, T1 is also cut off, and the LED is immediately extinguished.

To calibrate the circuit, connect only the reserve battery to the circuit (a non-rechargeable battery can also be used), and replace the main battery by an adjustable power supply whose output voltage can be varied over (at least) the range of 5 V to 8 V. After first setting P1 to maximum resistance, adjust the power supply voltage to match the voltage of the reserve battery. After it is connected to the circuit, the LED will illuminate.

Now slowly reduce the power supply voltage to approximately 5.3 V, and then slowly rotate the trimpot until the switchover occurs, which can be recognised by the LED going out. Next, increase the power supply voltage and then reduce it again, in order to verify the operation of the circuit.

If necessary, the setting of the trimpot should be readjusted until switchover occurs reliably when the desired voltage is present at the main battery terminal.

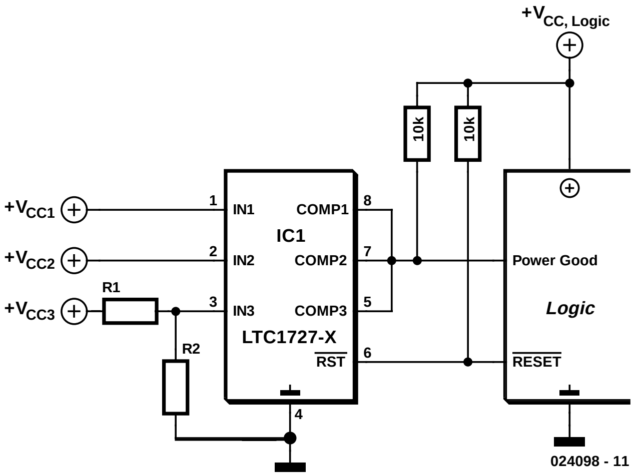
(020050-1)

Triple Voltage Monitor with 'Power Good' Signal

012

In order to monitor multiple power supply voltages it is possible to use one comparator per voltage, coupled with some logic to combine the output signals and, for example, generate a reset signal for a microprocessor.
Things are simpler with the LTC1727 from Linear Technology (www.linear-tech.com/pdf/17278fa.pdf). This IC is available in different voltage variants. The threshold voltages are as follows:

Type	Vcc1	Vcc2	VccA
LTC 1727-2.5	3.08 V	2.34 V	1.0 V
LTC 1727-5	3.08 V	4.67 V	1.0 V



As long as one of the three voltages is below the threshold value, the open drain $\overline{RST}$ output remains at ground potential and thereby holds the logic connected to it in a reset state. If all three voltages are above the threshold, $\overline{RST}$ will remain low for a further 200 ms, in order to ensure that the system is properly reset. A clear reset signal is then generated as long as one of the two fixed supply voltages is at least 1 V.
On the LTC1727 the individual comparator outputs are brought out to separate pins in the form of open drain outputs COMP1, COMP2 and COMPA. They can be connected together and then, with the aid of an external pull-up resistor, create a 'power good' signal which goes high to indicate when all the voltages are above their threshold values.

(024098-1)

Model Train Lighting

013

One thing that's still always very irritating with model train setups is that the locomotive or carriage lights often flicker with the train passes over a turnout or a bad section of track. This simple circuit can put an end to this. Even better, it ensures that the lights burn at a constant brightness (within certain limits), regardless of the speed of travel (which means the voltage on the rails), and the lights remain on when the locomotive is stationary for a while.

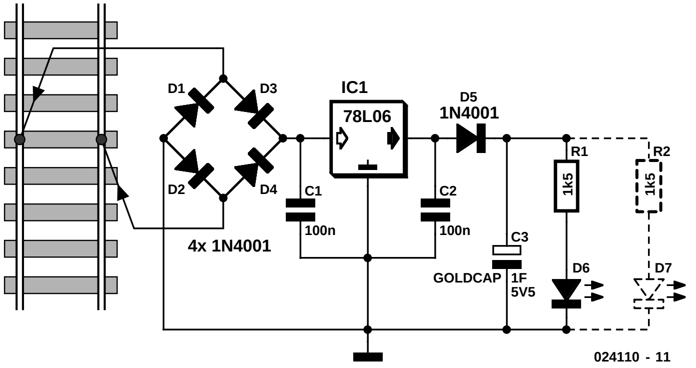
With ac systems, bridge rectifier B1 ensures that the ac voltage is converted into a dc voltage. This rectifier is also necessary with dc systems, since the polarity constantly changes according to the direction of travel. The voltage, now with a fixed polarity, is then stabilised at 6 V by voltage regulator IC1. Two small capacitors (100 nF) are added to ensure stability; they should be fitted as close as possible to the regulator. Next comes a diode (D5) that prevents energy from being lost through the voltage regulator when there is no voltage on the rails. This is followed by the central element of the circuit: a megacapacitor (C3) that acts as a 'storage reservoir' for the energy. This 'Goldcap' is available in values of 0.1 F to 22 F (yes that's farads, not microfarads!). Since C3 can be charged by the 78L06 at a maximum current of 100 mA, it will take slightly less than a minute for a 1-F type to become fully charged.

The lights are powered from the Goldcap. It's best to use low-power, high-efficiency LEDs, each with its own series resistor. A current of 2 mA per LED is sufficient, so a value of around 1.5 kΩ can be used for the series resistors. The length of time that the lights remain illuminated depends on the total current consumption and the size of the Goldcap. If you have enough space, don't skimp, and instead select one with a bit more capacitance.

You can experiment with the circuit to your heart's content, but note that the Goldcap cannot tolerate voltages greater than 5.5 V. With a 6-V regulator followed by a voltage drop of 0.6V across the diode, we have 5.4 V.

To calculate how long the LEDs will remain illuminated, you can use the formula time = (capacity) × (voltage change) ÷ (current). For example, suppose there are five LEDs drawing 2 mA each. When the Goldcap is fully charged, the voltage across it is 5.4 V. Once it has been discharged to 2.5 V, the LEDs will scarcely generate any more light. The voltage change is thus 3 V. The length of time that the lights remain on is therefore (1 F) × (3 V) ÷ (0.01 A) = 300 s, or 5 minutes. With a 0.1-F capacitor the duration is half a minute, but with al value of 22 F the duration is 110 minutes, or nearly two hours!

(024110-1)

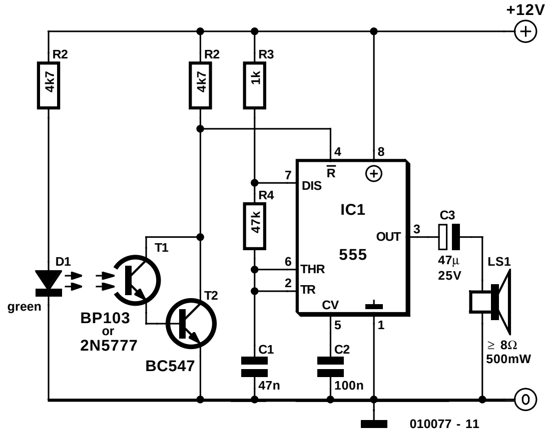


Mailbox Alarm

Pradeep G.

Here's a 555-based project that can be used as mailbox alarm. By suitable mounting of the LED and the phototransistor, the circuit is able to detect when a letter is dropped in your mailbox. Our younger readers should know that a 'letter' is not the result of hitting any of the A-Z keys on the PC keyboard, but a precursor of the email message. For some mysterious reason, some people are still sending messages to each other using letters. In case you've never seen one, a letter is usually contained in an 'envelope', it takes ages to deliver and can sometimes be seen in the hands of a life form called 'postman', which is an antediluvian version of the anonymous Postmaster at your ISP.

When the mailbox is empty, light emitted by the green LED is detected by the phototransistor. In this condition, the 555 IC is held disabled via its pin 4. When a letter is dropped in the box, the disable condition is lifted and an alarm sound — not remotely resembling the Windows *You have New Mail* sound — is produced by the loudspeaker (min. impedance 8 ohms).



The loudspeaker may also be mounted inside the mailbox, with a few holes drilled in the mailbox side panel acting as a grille.

The LED and the phototransistor should be spaced a few centimetres apart.

(010077-1)

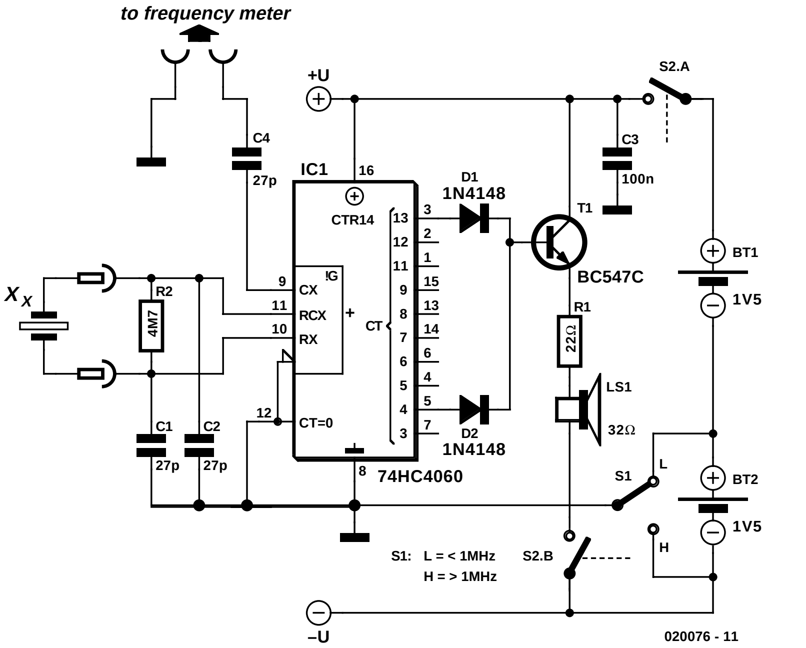
Crystal Tester

015

K.-H. Lorenz

This general-purpose crystal tester can be used to test and measure quartz crystals having frequencies from 30 kHz to 100 MHz. It is suitable for use as a front-end accessory for a frequency counter to directly measure the frequencies of fundamental-mode crystals up to approximately 24 MHz. For overtone crystals, however, only the fundamental frequency can be measured. For example, the counter will indicate a frequency of 20 MHz for a 5th-overtone crystal that oscillates at 100 MHz.

This behaviour of the crystal tester is due to the supply-voltage dependent maximum operating frequency of the HC logic family, among other things. At room temperature, a maximum clock rate of around 30 MHz (with a 3-V supply voltage) can be expected. For crystals with frequencies lower than 1 MHz, a 1.5-V supply voltage (switch S1 set to 'L') is fully adequate, so measurements can be made in this region using especially little power. For higher-frequency crystals, S1 is set to the 'H' position, for which the maximum frequency is significantly higher.



The principal component of the tester is a type 4060 14-stage counter. The crystal to be measured is connected to the input of the counter chain, but the signal exits the counter IC directly (buffered and inverted) in the direction of a frequency counter. The counter IC is only used to divide the crystal frequency down to a frequency in the audible range. The two diode-ORed counter outputs divide the crystal frequency by 32 (Q5) and 16384 (Q3), respectively. If the crystal oscillates, the resulting frequency is made clearly audible by a 32-Ω miniature speaker.

The current consumption depends primarily on the speaker and is around 25 will also be rewarded by reduced current consumption. The most economical operation is achieved by dispensing with the speaker and using the circuit only as a front-end accessory for a frequency counter.

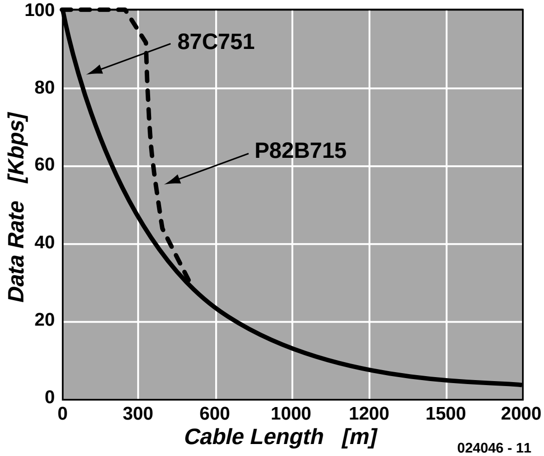
(020076-1)

I^2C over Long Distances

016

At the time that the I^2C bus was developed, a maximum bus capacitance of 400 pF was assumed. This means that with properly designed interconnections, in theory signal transport is possible over a distance of several metres. This initially appeared to be more than adequate, but the desire to be able to cover even longer distances soon arose. For this purpose, an 'electronic transformer' was developed in the form of a special IC with the type designation P82B715. Using this IC makes the signal impedance a factor of ten lower, which means that the maximum distance increases by the same factor. An 'I^2C Extender' based on this driver IC has already been described in the May 1994 issue of *Elektor Electronics*.

The nice thing is that it is now evident that 'ordinary' audio cable is eminently suitable for use as a transport medium, with distances of up to 300 m being attainable. With flat cable it is possible to go as far as 400 m if the leads between the signal leads (SCA and SCL) are connected to ground. Twisted-pair telephone cable scores quite a bit lower, with a maximum distance of 100 m. Even greater distances are possible, but only at the expense of transmission speed. The associated chart shows that the achievable data rate drops rapidly for distances greater than around 300 m. At a certain point, the decrease is so great that the P82B715 no longer has any effect and can just as well be omitted.



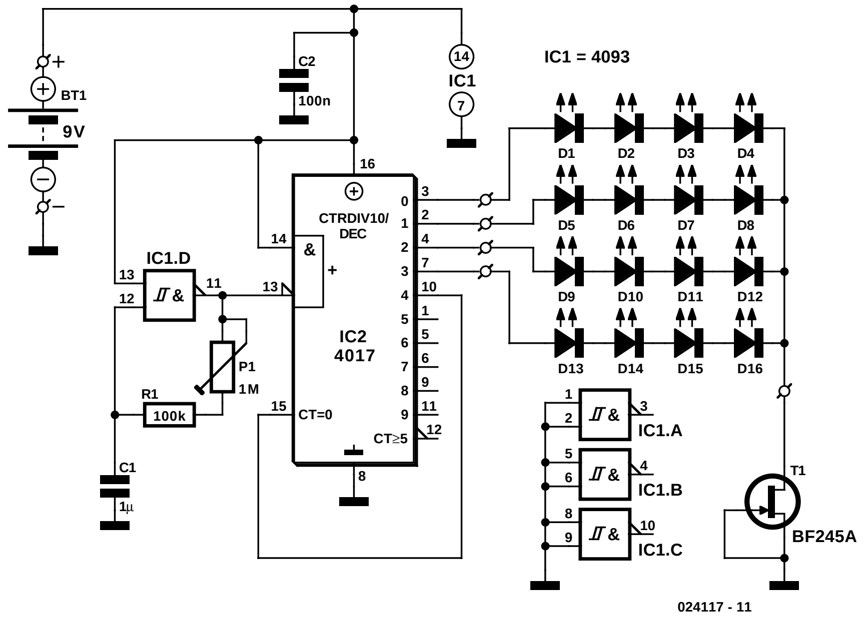
Readers that want to know all the details can download application notes AN444 and AB452 from the Philips website at www.semiconductors.philips.com. (024046-1)

Carnival Glasses

017

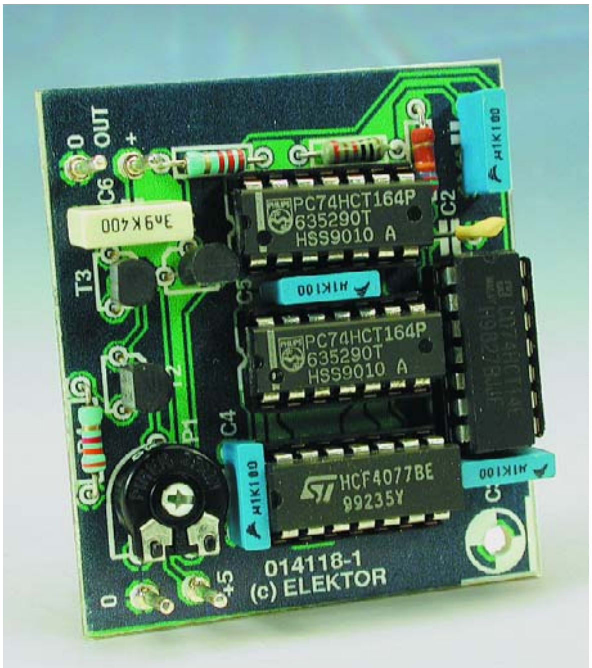
By now we know that circuits that generate light effects or sound effects can always count on a large group of interested readers. Consequently we present here yet another simple running-light display, this time designed such that it can be fitted into a pair of 'carnival glasses'. This means that the party lovers among our electronics hobbyists have something to satisfy their interests.
The details of the actual implementation are naturally a question of personal taste, but for the prototype we thought it a nice idea to distribute the total of 16 LEDs over the frame such that the running lights move in mirror image over the two halves of the glasses (D1 on the left, D2 on the right, D5 on the left, D6 on the right and so on). Of course, everyone is free to decide exactly how to build the running light display. Due to its small size, this circuit is also quite suitable for fitting into an illuminated brooch or button.
The oscillator built around IC1d is about the simplest imaginable Schmitt-trigger type using a 4093 gate. The frequency can be varied by a factor of approximately ten using potentiometer P1 (roughly speaking, the frequency is a few Hertz). You can also experiment with other values if necessary. The oscillator drives a five-stage Johnson counter, which always has only one active output. Here we have assumed a total of 16 LEDs in groups of four, so there is always one group on and three groups off. The fifth output immediately resets the counter, causing the first output to again become active.
The circuit is powered by a 9-V battery. Depending on the manufacturer, the voltage drop across each LED is more than 1.7 V. If we still want to see something with a nearly empty battery, we thus cannot connect more than four high-efficiency LEDs in series. Since only one row of LEDs is on at once, a FET wired as a simple constant-current source (T1) ensures that the brightness remains good for as long as possible. T1 also prevents excessive current (more than around 4 mA) from flowing when the supply voltage is relatively high.
Fit the LEDs into holes drilled to fit and secure them with two small drops of glue each. The wiring can also be attached in a creative manner. Only five wires are required between the glasses and an external enclosure containing the circuitry and battery. A small control potentiometer can be used for P1, so that the speed of the LEDs can be easily adjusted after everything has been fitted into the enclosure.

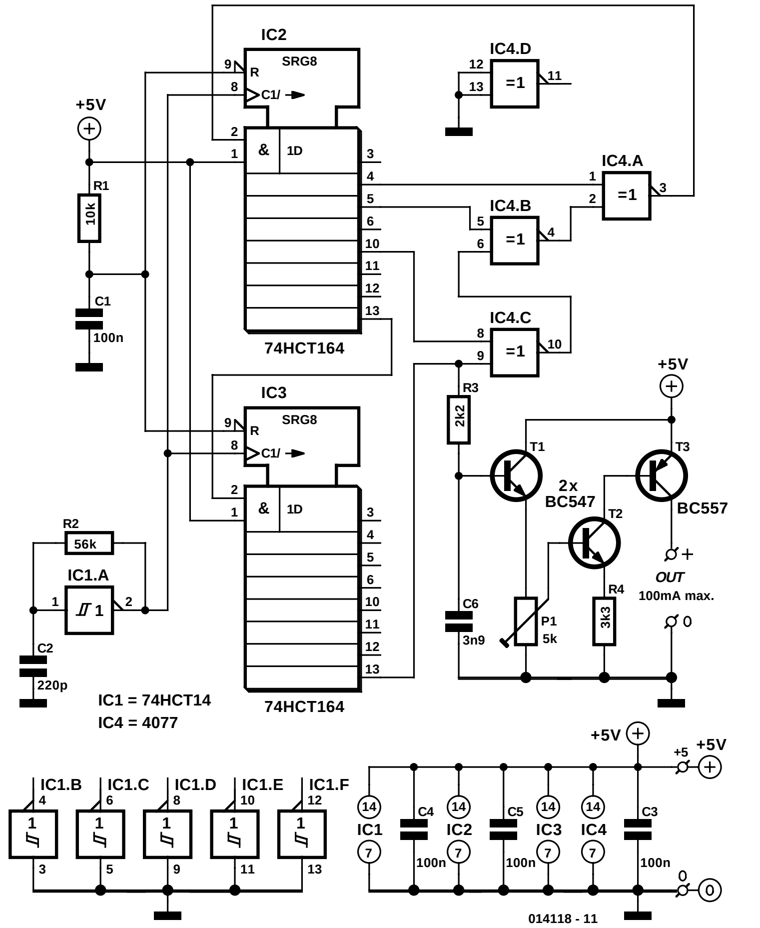
(024117-1)



Noise Generator

018





The noise generator proposed here operates according to the digital principle, in contrast with the more classical noise generator, which usually employs the noise voltage of a base/emitter junction to generate the signal. The big difference between the method used here and the classical analogue design is that we are not generating a real noise voltage but a collection of discrete frequencies.

The clock generator built around IC1a produces a signal of about 40 kHz. This signal is used to clock shift registers IC2 and IC3. The data at the input of the double shift register is provided by a network of XNOR gates. (IC4a through c), the output of which depends in turn on the state of the outputs of the shift-register.

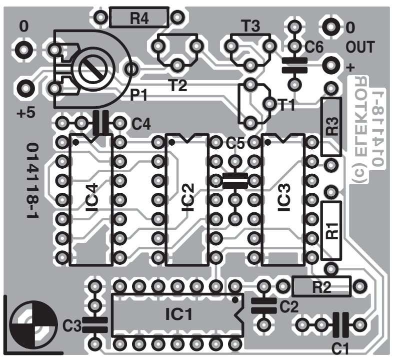
If the feedback network forms a primitive polynomial (in this case $1+V^2+V^3+V^5+V^{16}$), then all possible combinations of ones and zeroes will appear at the output before the cycle will be repeated again. This way you will obtain the longest possible cycle and as a consequence the repeat time is very long. The individual distance between the discrete frequencies is $(f_{clock})/(2^n–1)$ = 40 kHz/65535 = about 0.61 Hz, which is a good approximation to 'real' noise.

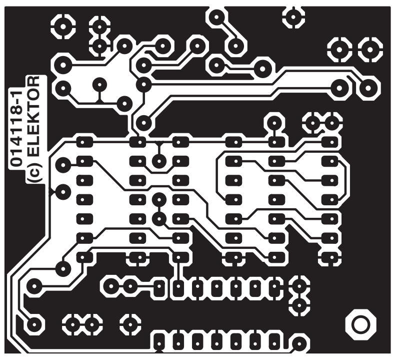
COMPONENTS LIST

Resistors:
R2 = 56kΩ
R3 = 2kΩ2
R4 = 3kΩ3
P1 = 5kΩ preset

Capacitors:
C1,C3,C4,C5 = 100nF
C2 = 820pF
C6 = 3nF9

Semiconductors:
T1,T2 = BC547
T3 = BC557
IC1 = 74HCT14
IC2,IC3 = 74HCT164
IC4 = 4077





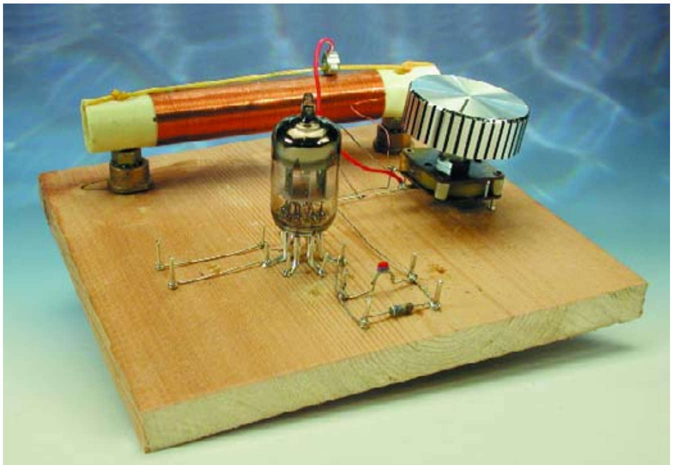
The output is delivered by a current source. But if you prefer a voltage source as output, then the signal at the emitter of T2 can be used instead. Note that the output has a DC offset, so make sure that any equipment that is connected can cope with that. If that is not the case, connect an electrolytic capacitor in the signal path.

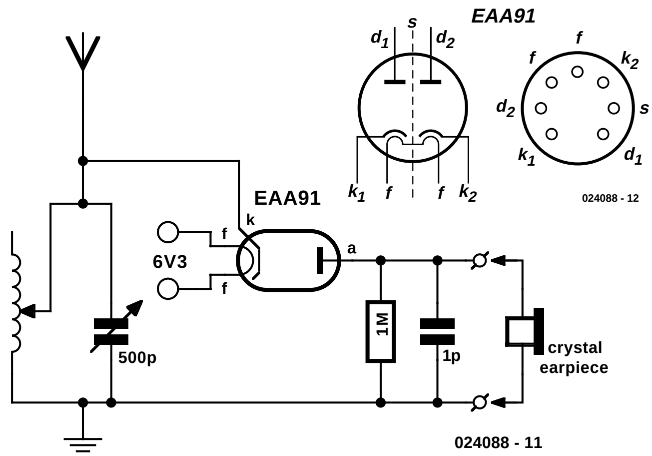
The circuit operates from a regulated power supply voltage of 5 V. This can be according the usual 7805 recipe with as input power source a 300-mA mains adapter that can supply at least 8 V out. If you make use of the PCB layout shown here, then the construction is unlikely to take you more than half an hour or so. The PCB is unfortunately not available ready-made.

(014118-1)

Valve Detector Receiver

019





B. Kainka

The valve detector receiver is the logical extension of the crystal detector. This circuit can achieve astonishingly good selectivity, since the rectifier circuit is designed to have very high impedance. The valve detector receiver can be connected to an active PC speaker or a crystal earphone, for example, and it generates genuine 'valve sound'.

The EAA91 is a dual diode with a 6 V / 300 mA filament. In contrast to a semiconductor diode made of germanium or silicon, it does not require a minimum voltage (threshold voltage) to arrive at the knee of its characteristic curve. In fact, some electrons will reach the anode even if there is no anode voltage present. A short-circuit current of around 30 μA can be measured. A voltage of no less than 0.5 V appears across a load resistance of 1 MΩ. The valve itself generates a suitable bias voltage.

As can be seen from the photo, the coil is wound in the form of a close-wound coil on a piece of PVC conduit with a diameter of 15ter enamelled copper wire. If the full number of turns is used, the tuning range of the rotary variable capacitor essentially covers the medium-wave band. To extend the range to higher frequencies in the low and medium short-wave bands (above around 1.5 MHz), a tuneable version of the coil can be constructed using an adjustable tap (slider), as shown in the schematic diagram. The practical implementation of this can also be seen in the photo.

The variable capacitor does not have a fixed connection to both ends of the coil, but only to the grounded end of the winding. The aerial terminal of the variable capacitor is connected to a movable coil tap (slider). To obtain an adjustable connection to the coil, carefully sand the top surface of the coil to remove the enamel coating along the path of the slider. The sliding contact consists of a small brass or steel ring. It can be made by cutting a short length (approximately 3 mm) from a metallic tube with a diameter of around 8 mm, which can be found ready-made in electronics parts catalogues under the category of 'assembly materials' in the form of a nickel-plated standoff. The guide can be formed by a strip of plastic or rubber stretched over the length of the coil and attached to each end of the PVC tube (drill fastening holes in the ends of the tube for this purpose). Use a length of flexible, insulated stranded wire soldered to the slider roller to connect the slider to the aerial terminal of the variable capacitor.
The capacitance of the rotary tuning capacitor is 500 pF.

A large number of European transmitters can be received using a wire aerial with a length of around 5 m. Reception for transmitters in the short-wave bands is good during both the daytime and evening hours, but for medium-wave transmitters it is usually best in the evening.

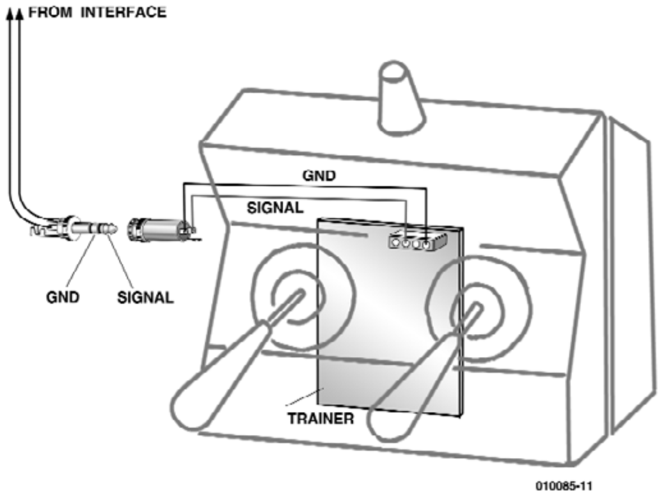
(024088-1)

Low-cost Reflex Interface

020

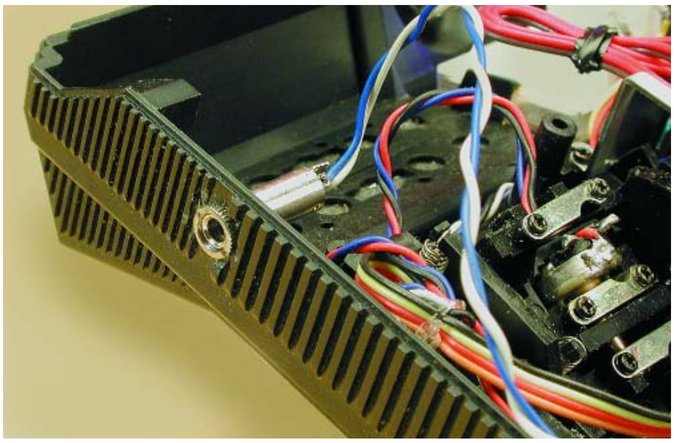
This interface links a Futaba FC-16 R/C transmitter to the parallel interface of a Reflex model aircraft simulator. This is a commercially available simulator that has been specially developed for model aircraft. Included with this program is an interface with several adapters that allow you to use your own transmitter to fly the virtual airplanes. This has the advantage that you don't have to get used to the PC joystick or keyboard, but that you can continue to use the same stick, switches, etc as you would use during real flight

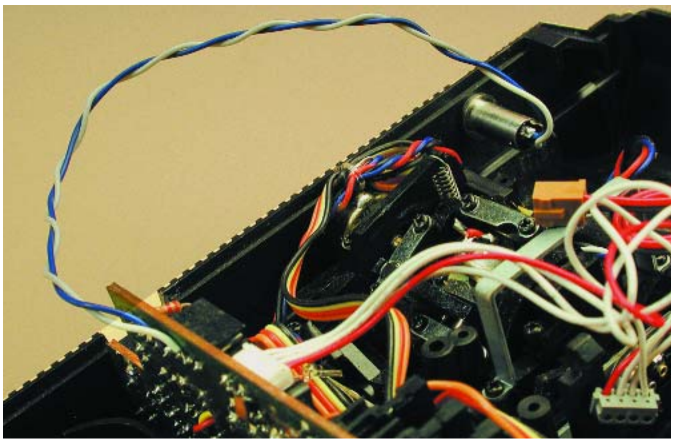
R/C transmitters sometimes have a so-called teacher/student connection. This connection makes it possible to link two transmitters together and switch between the two for flying the model. This teacher/student-connection is perfect for use with a Reflex simulator, but unfortunately most senders don't have such a connection as standard. This is only made available as a (needlessly expensive) extra. The addition of this connector is relatively simple, as can be seen in the accompanying drawing. The reason for using a 3.5 mm stereo jack plug instead of the usual DIN plug is that the Reflex interface itself also uses a 3.5 mm jack for its input. The adapters that are supplied for the various makes of R/C transmitters are therefore superfluous.

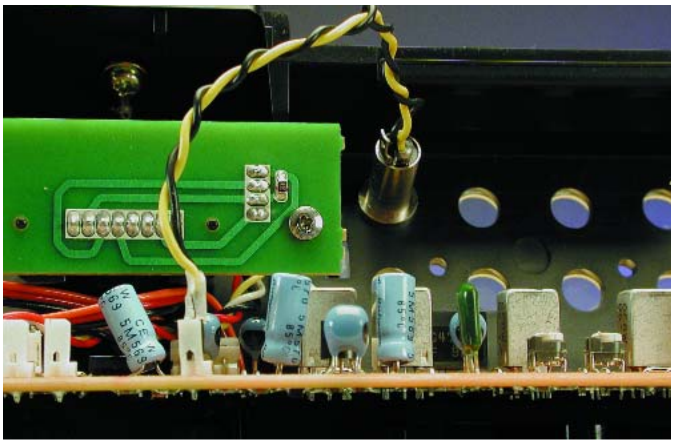


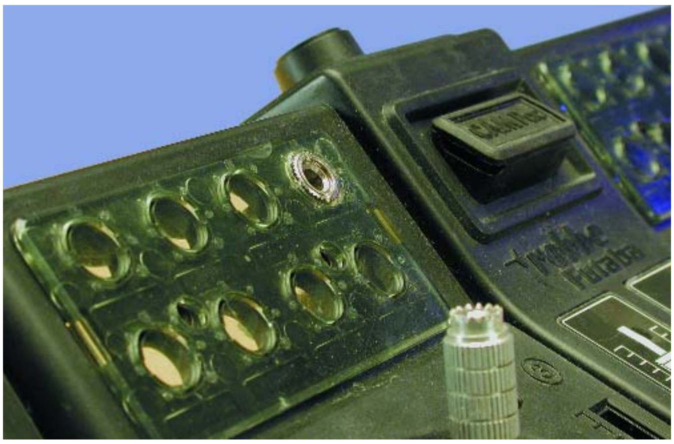
A further advantage is that the jack plug fits snugly in the holes meant for switches and mini potentiometers. There is therefore no need to make another hole for the connector in the transmitter case.

For the modification you should refer to the photos, one of









which shows the connector in a Futaba transmitter, and the other in a Graupner transmitter. Please note that Futaba transmitters make use of connectors with a pitch of 2 mm (instead of 2.56 mm). Normal (imperial) SIL connectors (with a 0.1 inch pitch) are therefore unsuitable for use with these transmitters!

The right connectors may be obtained from Conrad Electronics, part number 672-348.

The connection described here should in principle be suitable for use in other transmitters as well, but you will have to find the right signal in the transmitter yourself (usually present on a connector). The relevant signal should look like that shown on the oscilloscope screen-shots printed here. Sometimes there is a label with the words 'TRAINER' or 'EXTERNAL COMMAND' on the PCB near a connector. One of the pins on that connector is likely to have the required signal.

To avoid any confusion, we would like to make one thing clear: this connection is not suitable for teacher/student operation!

(010085-1)

Door Opener de Luxe

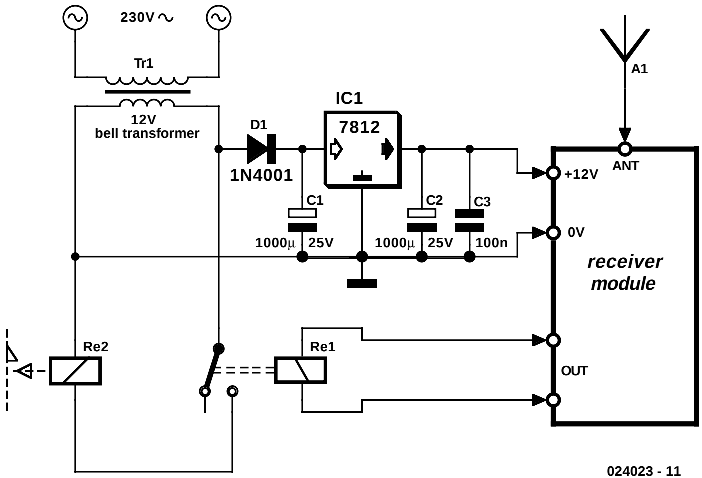
021

G. Liebefrau

An electrical door opener can be controlled by an electronic code lock or a transponder. However, this always requires running a cable, installing a keyboard (tamper-proof) or fitting a concealed coil. All of this can be avoided by using a radio remote control of the type used for cars. The receiver can be fitted directly to the electrical door opener. Various types of aftermarket sets for controlling a centralised locking system are available in accessories shops. They cost around 50 (£ 30), including a handheld transmitter.

Connecting the radio module is child's play. Instead of the servomotor, a 12-V relay with normally-open or changeover contacts is connected to close the circuit to the door opener. The supply voltage for the radio module can be taken from the door opener. Models that operate from 230 VAC, 12 VDC or 24 VDC are commercially available.

(024023-1)



Free Processors

022

For some time now, all sorts of designs using FPGAs, CPLDs and other programmable logic devices can be found on the Internet. The complexity of these designs is often limited to the level of simple adders, BCD-to-7-segment decoders and similar standard circuits, but there are also other circuits that can be downloaded from the Internet free of charge. Presently, a large group of people is working on implementing well-known processors in FPGAs.

What motivates such people to spend several weeks of their free time designing a processor that can be bought for next to nothing in every electronics shop? At first glance, this may appear to be madness, but if you think about it more carefully, it's actually not all that strange. The most obvious reason is that they want to know how a processor works and want to experiment a bit with its operation; their motivation is thus educational. Naturally, this by itself is a good reason to work on designing a simple processor. A second reason might be that FPGAs are very flexible. If the processor design does not use all the resources of the FPGA, it is easy to incorporate a portion of the external circuitry in the FPGA, thus making the ultimate circuit smaller.

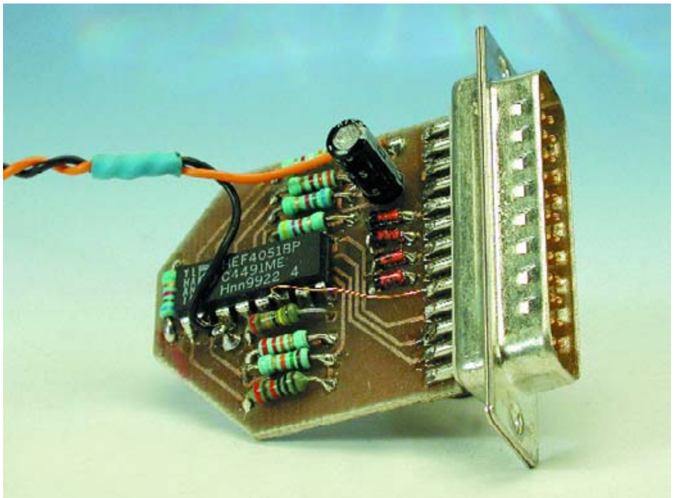
Designing a processor is not particularly easy, and naturally it demands a certain understanding of digital technology and processor architecture. If you download a design from the Internet, you will of course also need to be able to program an FPGA on your own. Even this goes beyond the scope of your resources, you may nevertheless find it informative to have a look at the Internet addresses listed below, even if only to conclude that these people are a bit wacko…

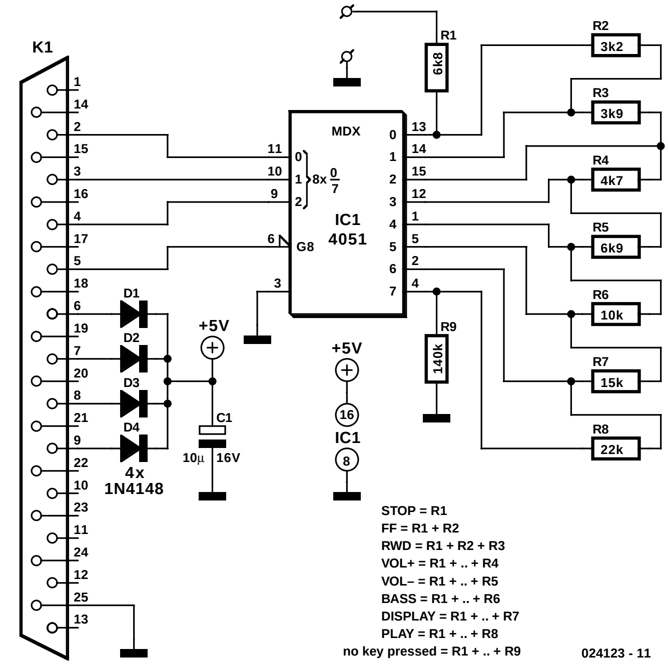
(024125-1)

www.cmosexod.com/
www.openip.org
www.fpgacpu.org
www.free-ip.com

Titler for Portable MD Players

023





Portable MD recorders continue to be popular. Among other things, they allow titles to be entered, in order to make it easier to find disks and tracks, but this is a rather time-consuming task. Such recorders do not have an alphanumeric keypad, so titles must be entered by using the + and – buttons to step through a character set and selecting the desired characters using the Enter button. This can be done using the actual recorder, or by using the buttons on the remote control unit connected to the MD recorder. Every since the beginning, Asian manufacturers have used a simple two-wire system for such remote controls. Each button on the remote control causes a particular resistance to be connected to this 'bus', and the recorder recognises which button has been pressed by the resistance value.

The circuit that Thomas H. Meier has developed for the Sharp MD7xx series (http://www.iq-tm.de/MD/MD70X.html) shows that it does not take very much hardware to simulate such a remote control using the parallel port of a PC. Here an analogue multiplexer is driven by four data lines from the parallel port. In the quiescent state (no button pressed), the total resistance of the remote control is equal to the resistance of R1 through R9 connected in series. If the Stop button is pressed, pin 13 of IC1 is internally connected to pin 3, so 6k8 is connected to the remote control lines. For Fast Forward, pin 14 is selected, yielding a total resistance of 10 kΩ (R8 + R9), and so on. Other makes use different resistance values and different connectors, but the principle remains the same. Elsewhere in this issue, we describe how you can adapt this circuit for the remote control units of other makes and models by making a few simple measurements.

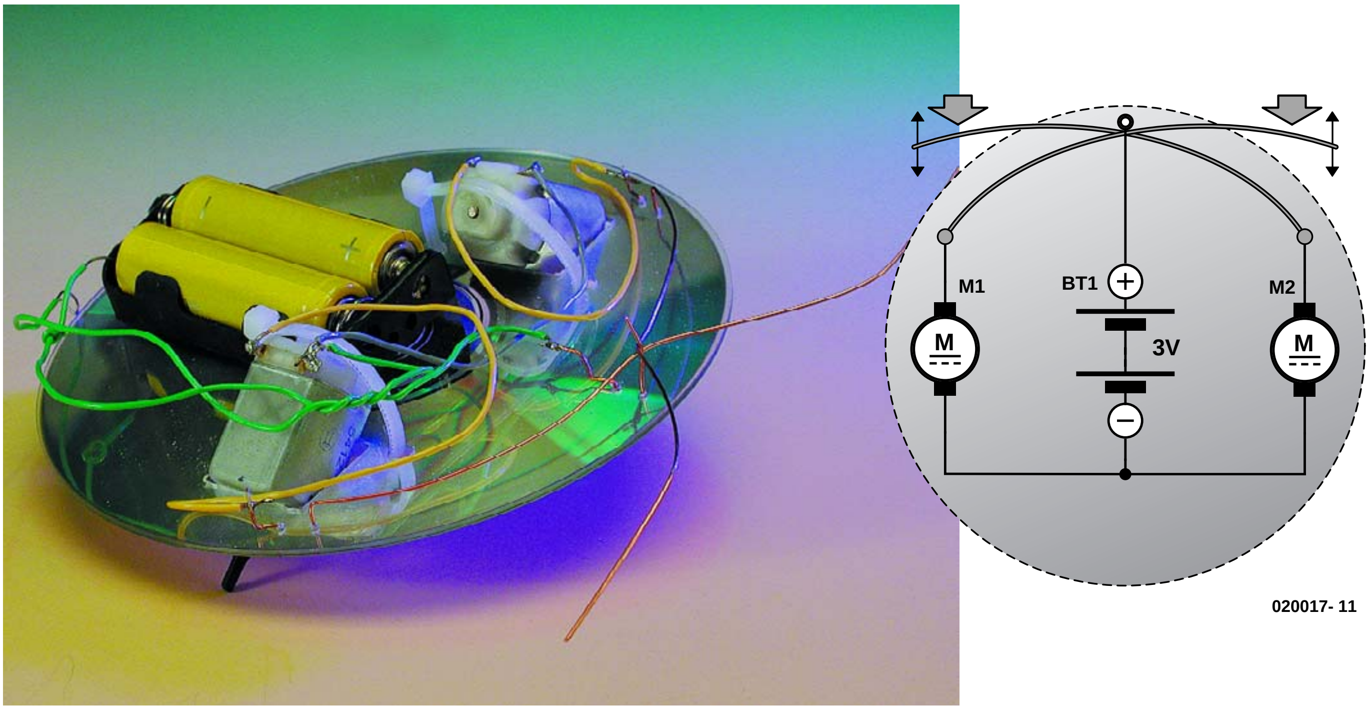
Naturally, this circuit isn't of much use if you don't have a program on your PC to cause a title entered into the computer to be stored in the right place on the MiniDisc. Unfortunately, the manner in which titles are entered (the required sequence of button presses) varies from make to make. What's worse, it can even differ from model to model for the same manufacturer. A search on the Internet, starting under the 'Hacking' and 'Filing and Titling' menu at www.minidisc.org, will yield links to software that can look after this task for various makes and models. And if your model isn't included, some programmers have placed their source code on the Internet, so you can use it as a starting point for your own program.

The PCB shown here is unfortunately not available ready-made.

(024123-1)

512-MB ROMBot

024



A. Vreugdenhil

What requirements should a modern robot satisfy? What do you expect from an advanced robot and its memory, operating system, browser version, sensors, supply, address and data bus width, propulsion method, construction and chassis material? These are all points that have to be considered carefully when designing a robot. This doesn't appear to be a simple task.

If we make a list of actions that our robot should perform for it to survive in this hostile world, the most important is that it should be able to avoid any obstacles in its path. It should detect all objects that are in its way and then adjust its behaviour in order to move round them. A bit of thought led to the conclusion that this could be achieved with two motors for the propulsion. **Table 1** shows the truth table for the workings of this robot.

We can draw the following conclusions from the truth table. The first is that the robot presented here is 100% digital, because it works solely with ones and zeros. The second is that it is a two-bit machine. That may sound simplistic, but the most modern 64-bit Pentium-IV machine works along the same underlying principle. As far as the operating system is concerned, these days you would expect at least Windows 98. ME and XP should work pretty well too. IE5 is a minimum requirement, with Netscape a good second choice. It would need a lot of memory for it to react well to its surroundings; 512 MB seems to be an amount that would add some 'real' intelligence to the system. For the chassis we'll use plain but very strong materials. Here as well we see the trend towards light, strong composite materials, including plastic and aluminium. All modern Pentium processors nowadays run at 3.3 V; we'll go one step further and use 3 V.

We turn on our robot and let it loose in the big bad world. It moves around objects and satisfies all other requirements mentioned above. Where else can you find this for under a fiver nowadays? Two diagonally mounted motors on a CD chassis, two AA cells and two push-to-break switches made from copper wire – and it works too!

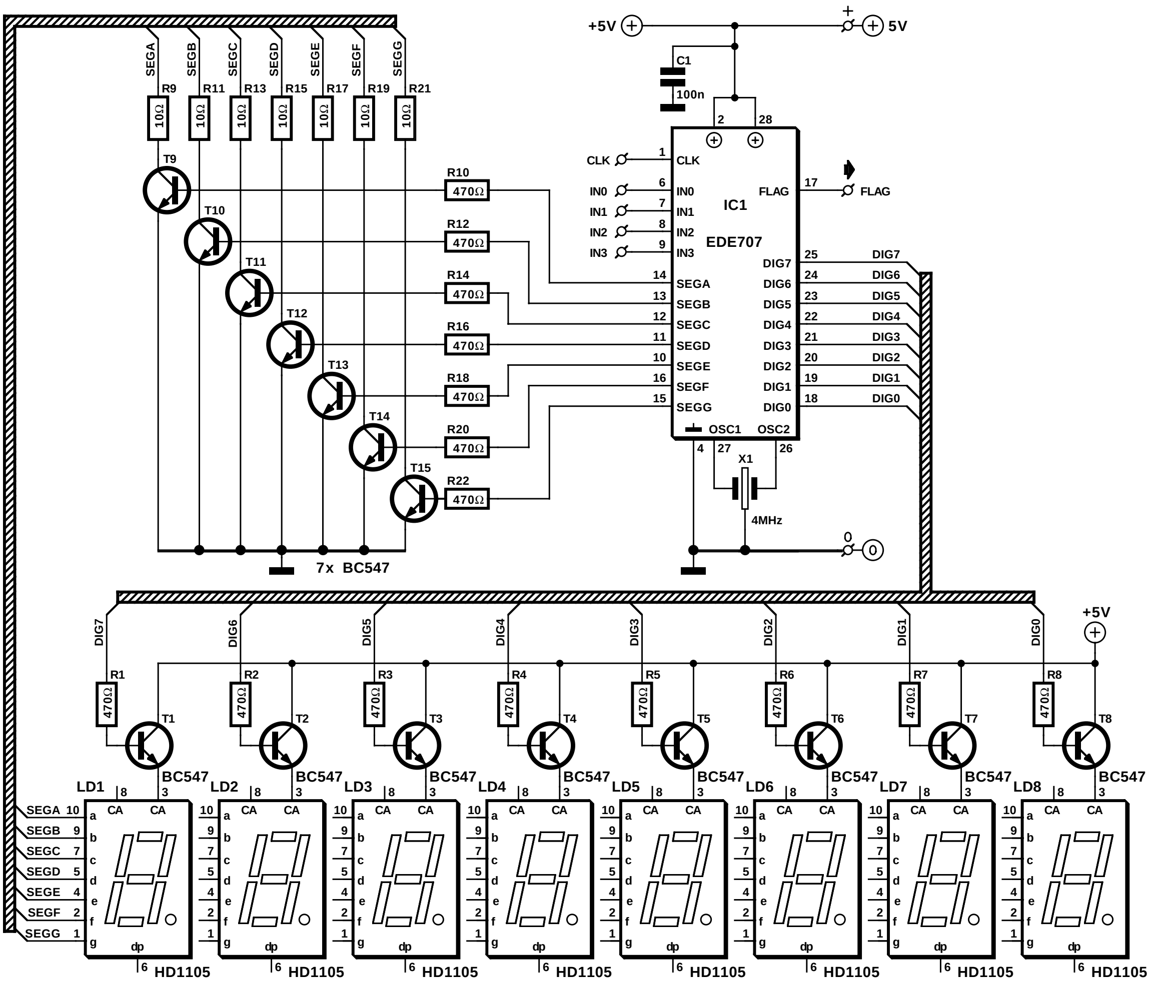
(020017-1)

Table 1. Truth Table

Lefthand sensor active?		Right-hand sensor active?		Response	Left-hand motor		Right-hand motor	
no	0	no	0	straight on	on	1	on	1
no	0	yes	1	turn left	off	0	on	1
yes	1	no	0	turn right	on	1	off	0
yes	1	yes	1	stop	off	0	off	0

7-segment Display IC

025



014115 - 11

The EDE707 from E-Lab Digital Engineering (www.elabinc.com) has been designed to drive a maximum of eight 7-segment displays, using only four data lines and a clock signal. The IC takes care of the display multiplexing, leading zero suppression, can function as a counter and can display the complete hexadecimal character set (0 to 9, A to F). It is suitable for use with either common anode or common cathode displays.

The state of the four inputs In3-In0 (pins 9 to 6) is read on the falling edge of the CLK/latch input (pin 1). When In3 is high, the inputs select a certain function (see **Table**); when In3 is low, the other three inputs select one of the digits. In this case the address of the digit is always sent first, followed by the value that has to be displayed. If, for example, the last digit has to show a '2', we send '0000' (address) followed by '0010' (data).

The IC can also function as a decimal counter. When the four inputs are set to '1000', the counter is incremented by one on every falling edge of the CLK input or decremented by one when '1001' is put on the databus. The maximum permissible clock frequency is 800 Hz.

The circuit diagram shows the design for common anode displays. When common cathode displays are used the collectors of T1 to T8 are connected to the cathode and the emitters to ground; the collectors of T9 to T15 are connected to +5 V, the 10 Ω resistors are between the emitter and the segment connection.

(014115-1)

IN3	IN2	IN1	IN0	ACTION
0	a	b	c	The following byte is the value for digit 'abc'.
1	0	0	0	Increment the counter by one.
1	0	0	1	Decrement the counter by one.
1	0	1	0	Reset the display to zero (00000000).
1	0	1	1	Lamp test (88888888).
1	1	0	0	Blank the whole display.
1	1	0	1	Enable the display (default).
1	1	1	0	Suppress leading zeros.
1	1	1	1	Show leading zeros (default).

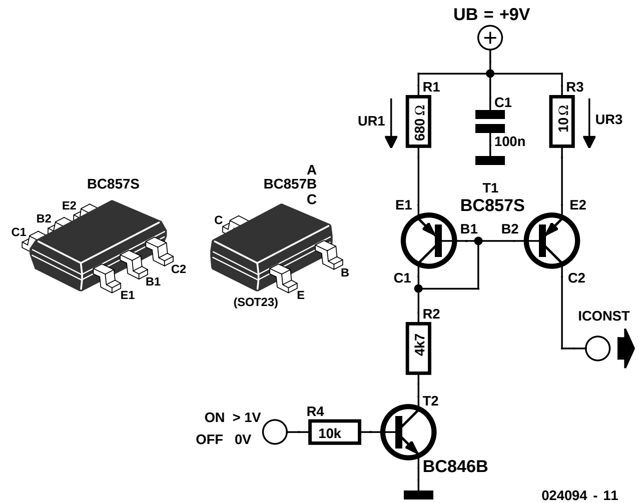
Switchable Current Source

026

The circuit diagram shows a simple current source constructed from discrete components, which can deliver a constant current into a load connected to ground. The circuit can be switched on and off using transistor T2.
Optimum temperature compensation can be achieved by using a BC857S dual PNP transistor with the left-hand half connected as a diode. The current delivered can be determined via the following calculation: when T2 is turned on, the voltage across potential divider R1/R2 is the supply voltage minus the voltage dropped across the pn-junction in the left-hand half of T1, which we shall assume is 0.7 V. The current through the voltage divider is thus

$$I = (U_b - 0.7\ V) / (R1 + R2)$$

We can use this to work out the voltage across R1, which, because the bases of the transistors comprising T1 are connected, is precisely the same as the voltage across R3. For stable operation this voltage should be at least 1 V.
The current delivered can be adjusted by changing R3: the BC857S will not pass more than about 100 mA. The dual transistor contains two BC857s, a surface-mount version of the well-known BC557. The current source can of course be constructed from these 'normal' devices, although the temperature compensation will not be as good.



(024094-1)

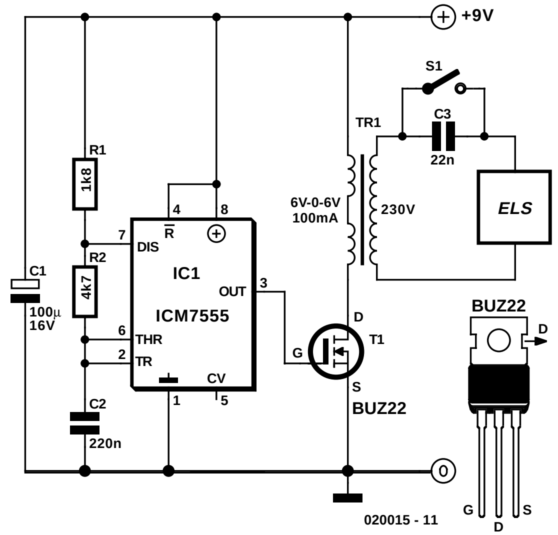
Luminescent Torch

027

Rev. T. Scarborough

An electro-luminescent sheet (ELS) is capable of emitting an appreciable amount of very cool, white light. These devices come in a variety of colours including white, and can be cut to shape or curved. A standard 5 cm by 6 cm sheet manufactured by Seikosha emits 1.5 candelas (blue-green emits 2.2 candelas). This is sufficient for reading at night, or to light a pathway (albeit dimly), or to take in a room at a glance. Moreover, being just 0.7 mm thick, these sheets take up hardly any space at all. RS Electronics stock a number of ELS devices. Surprisingly, Toshiba ELS's are also (occasionally) seen on radio rallies where they are offered of rock-bottom prices, complete with a HV inverter board secured to the back side.

Electro-luminescent sheets typically require an operating voltage of 115 Vac, so a suitable inverter is needed to power them. The circuit diagram shows such an inverter, based on a CMOS 7555 timer IC, which is designed specifically to power the smaller 5 cm by 6 cm sheets. This draws about 120 mA, and will run for 5 hours off an alkaline PP3 battery — or



24 hours continuous off 6 alkaline AA batteries. A 22-nF capacitor provides current limiting for a dimmer setting when S1 is open, so that the Luminescent Torch may run for up to

36 hours continuous off 6 alkaline AA batteries — with about 30% reduction of light.

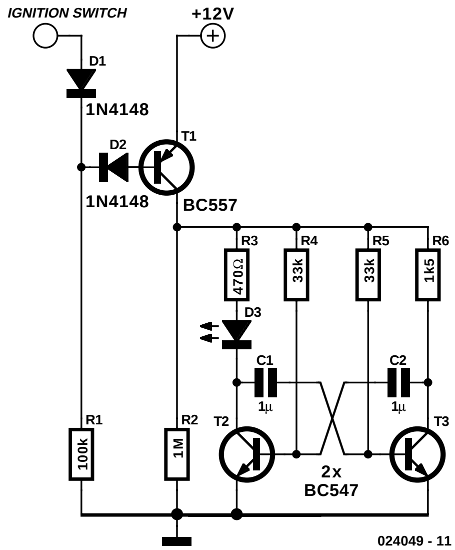
The 7555 IC is configured as a standard astable oscillator, and runs at about 600 Hz. A power MOSFET pulses 9 V through the series-connected 6-0-6 V primary windings of the transformer, stepping up the voltage to 115 Vac on load. The negative half-cycle is provided through back-EMF. Virtually any 'logic MOSFET' may be used in place of the BUZ22. No protection circuitry was found to be necessary. The transformer should be rated 100 mA per secondary winding, and the current limiting capacitor and switch S1 should be rated 250 Vac.

Warning electrical shock hazard — this circuit supplies a voltage which is dangerous to touch. Never work on the circuit when it is switched on.

(020015-1)

Flashing Alarm LED

D. Kluts



Unfortunately, these days it is no longer an inordinate luxury to protect your car against break-in and theft. Many car insurance companies even make installation of a certain class of car alarm a condition for providing insurance. However, having an effective alarm system installed is not economically justified for the owner of an old and/or inexpensive car, since such systems are not exactly cheap. Naturally, in case of theft the financial loss experienced by the owner of such a car is relatively small, but this does not make the emotional sense of loss any less.

This circuit has been specially designed to create a certain degree of protection for low-budget cars without alarm installations. It is a simple bit of electronics that causes an LED to start flashing as soon as the ignition is switched off. Of course, we all know that such a dummy alarm will not stop a determined thief, but an impulse thief will probably have second thoughts on seeing a flashing LED.

As far as the electronics are concerned, the circuit is quite simple. The input to the circuit is connected to a point on the ignition switch that is live only when the ignition is switched on. A voltage of 11.4 V (12 V – 0.6 V) will then appear across R1, with only 0.6 V appearing across the base–emitter junction of T1 and diode D2. Transistor T1 will thus be cut off, so the rest of the circuit will not receive any power.

This will change when the ignition is switched off, since a base current will then flow through T1 via D2 and R1, causing T1 to conduct and provide power to the rest of the circuit. This consists of a multivibrator built around T2 and T3, which causes LED D3 to be periodically illuminated. Any desired colour of LED can be used for D3, but the circuit appears quite a bit more modern and effective with a blue LED than with an ‘ordinary’ red LED.

(024049-1)

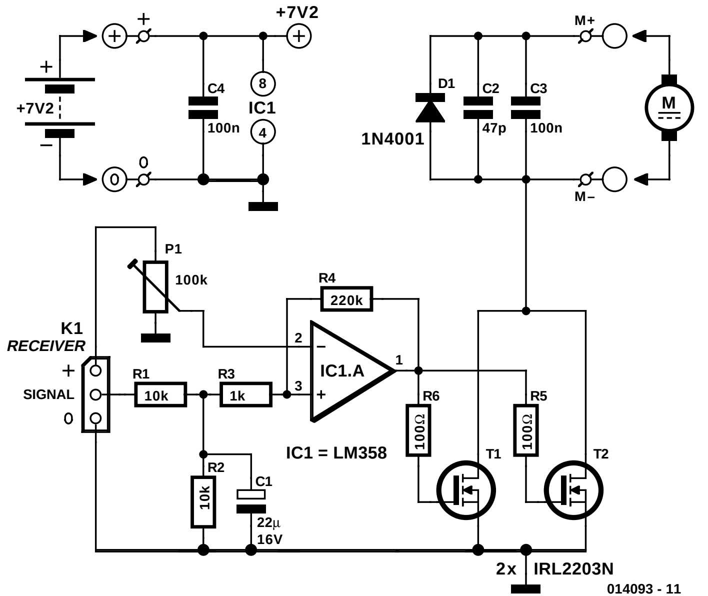
A Simple Switch for R/C Models 029

H. Switkowsky

This circuit is a switch for electric motors, which can be operated by a R/C model remote control unit. The electronics are very simple, and what the circuit can do is just as simple: it can only switch on and off, and it does not even have soft-start capability. However, if that is exactly what you want, it is unquestionably the ideal circuit.

The circuit responds to a 50-Hz PWM signal with a pulse width of around 1–2 ms. This is the usual frequency for R/C model remote control units, even though some manufacturers (Simprop) prefer 40-Hz signals. After being smoothed by a filter (R1, R2 and C1), the signal arrives at the non-inverting input of the opamp, which is wired as a comparator. The other input of the comparator is connected to a reference voltage that can be adjusted using P1. If the reference voltage is lower than the rectified PWM voltage, the comparator output goes High, FETs T1 and T2 are switched on and the motor runs. R4 provides hysteresis to prevent the comparator from responding to every minor fluctuation in the voltage on the non-inverting input. The comparator output will only return to Low when the signal voltage is distinctly lower than the reference voltage.

Two power FETs that can handle extremely high currents are built into the circuit. According to the manufacturer, International Rectifier (see http://www.irf.com/product-info/datasheets/data/irl2203n.pdf for the data sheet), the chip itself can switch 113 A, but the thermal resistance of the package limits the maximum switching current to 75 A. However, this value can only be recommended with optimum cooling, and since this switch will usually have to manage with no heat sink at all, the current should be limited to 40 A per



transistor. Even 80 A is unquestionably already a lot of current, and there is adequate margin for higher transient currents.

(0140093-1)

Automatic Power-Off

030

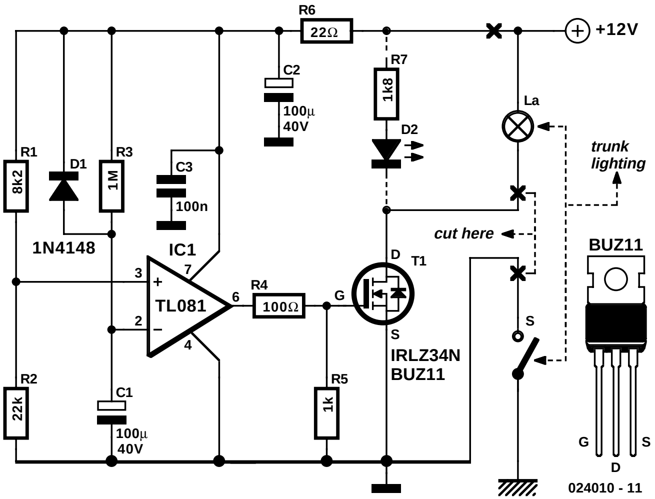
M. Mattiza

This circuit represents a general-purpose automatic shut-off switch. The author uses it in his car to ensure that any lamp left on by accident (boot lamp, interior lamp etc.) does not drain the battery while the car is parked in the garage for a few days. Of course, it can also be used in a large variety of other applications.

The operating principle is both simple and effective. The operational amplifier is wired as a comparator. A fixed voltage equal to approximately three quarters of the supply voltage is applied to one input. On the inverting input, the voltage is zero when the circuit is switched on, and it rises slowly as C1 charges via R3. The opamp output is thus High. If the voltage reaches the value determined by voltage divider R1/R2, the comparator output switches to Low. With the given component values, this occurs after approximately 100 seconds.

The comparator drives an n-channel MOSFET (BUZ31 or IRLZ34N). This transistor conducts when its gate is High, and it interrupts the lamp circuit when the comparator output switches to Low.

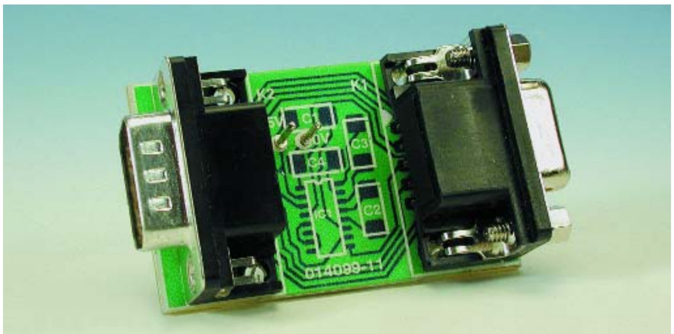
Assuming that S is the boot lamp switch in the car, it is open when the boot is closed. The circuit is then without supply voltage and C1 quickly discharges via D1. Note that the circuit may only be connected to the car chassis via S. When the boot is opened, S is closed causing the circuit to be powered and lamp La to light. The LED will also light, indicating correct operation of the circuit. After the above mentioned delay, the lamp goes out again and the current consumption of the circuit is reduced to about 3 mA, which represents a negligible load on the car battery.

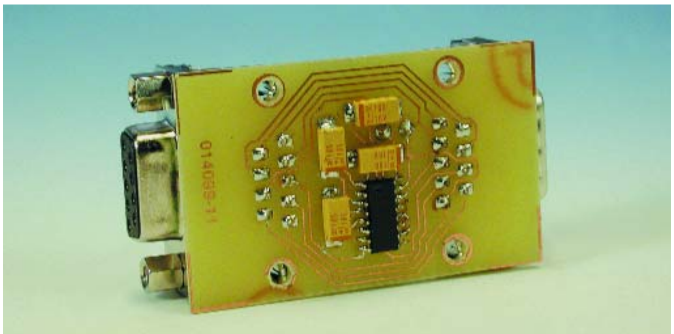


(024010-1)

Real RS232 for Laptop PCs

031





F. Schröter

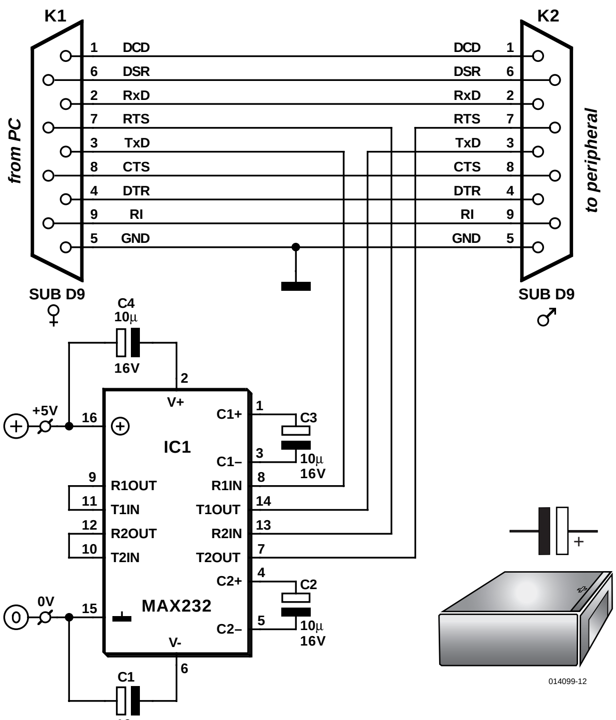
Many Metex DVMs feature a serial interface (RS232) which enables measured values to be copied to a PC for processing. Although this works just fine with most desktop PCs, problems may arise — as the author found out the hard way — when a laptop PC like the IBM Thinkpad 370C is hooked up to the Metex DVM. The cause of the problems is the limited voltage swing of just ±5 V on the 370C's serial interface. This is simply not enough for the Metex DVM, which will appear 'deaf' to the laptop.

The voltage swing on the serial interface lines is easily increased with the aid of a dedicated interface driver like the MAX232. With the resultant circuit designed in SMD, it is easily accommodated on a small double-sided PCB that can be fitted a 9-way sub-D adaptor housing. The converter receives its +5 V supply voltage from the PS/2/mouse interface (pin 4 = +5 V, pin 3 = ground). Current consumption is a modest 4 mA or so which has no noticeable negative effect on battery life.

The two interface signals TxD and RTS are taken from the laptop to the MAX232 driver inputs, pins 8 and 13. Inside the MAX232, they are first shaped to proper TTL/CMOS levels and then applied to the actual level converters. The resultant signal then reaches +10 V, which is accepted without problems by the interface inside the Metex DVM.

The PCB designed for the converter is small and single-sided. SMDs are the only option when it comes to fitting it all inside the adaptor housing. Do observe the polarity of the electrolytics in this circuit, since an SMD circuit, once built, is difficult to troubleshoot and repair. Unfortunately, the PCB for this project is not available ready-made.

(014099-1)



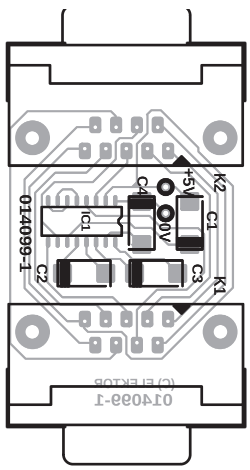
014099 - 11

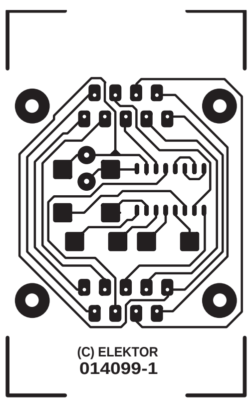
COMPONENTS LIST

Capacitors:
C1-C4 = 10µF 16V (SMD)

Semiconductors:
IC1 = MAX232-CSE (SMD)

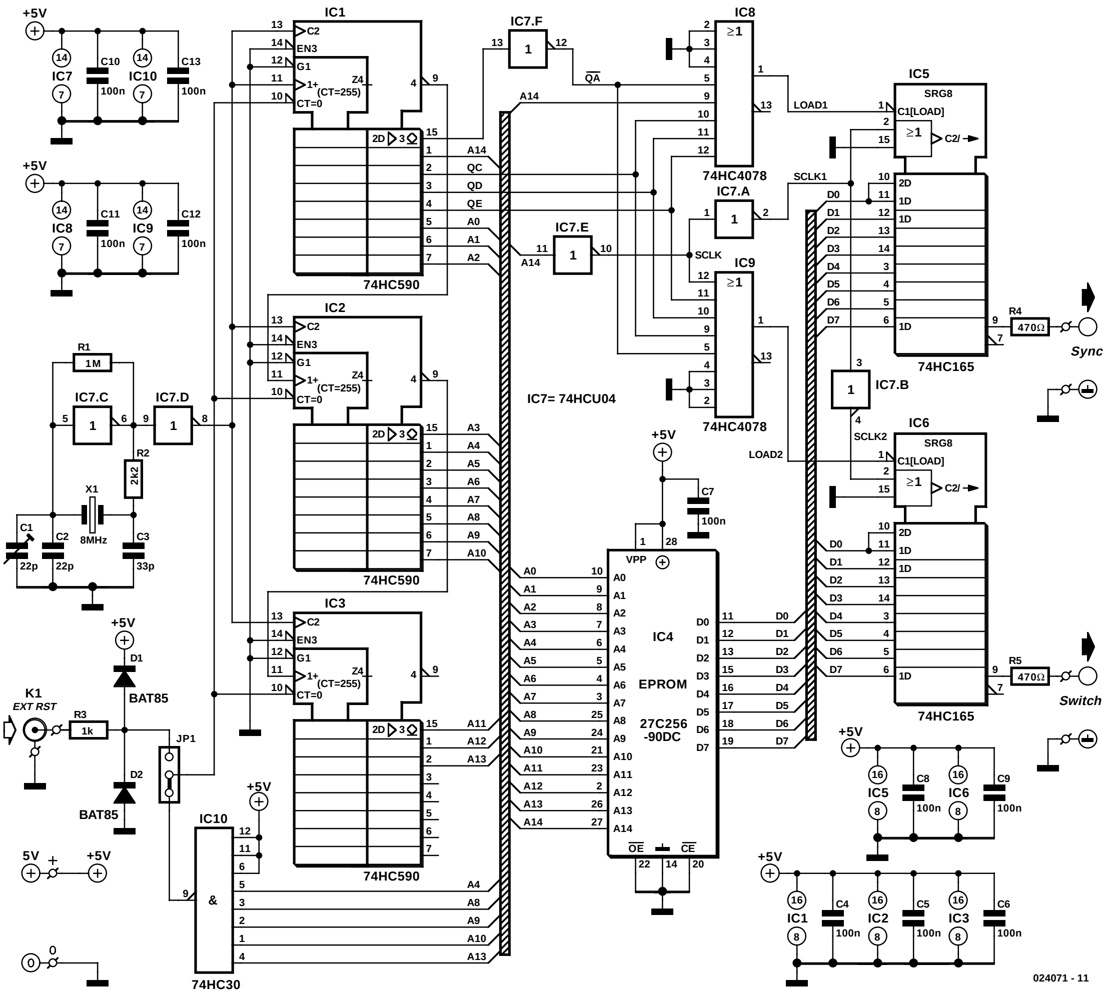
Miscellaneous:
K1 = 9-way sub-D socket (female), PCB mount, angled pins
K2 = 9-way sub-D plug (male), PCB mount, angled pins
2 solder pins





Video Sync Generator

032



Special ICs, such as the Fairchild 74ACT715 (formerly National LM1882) and the Philips SAA1001, have been developed for generating video synchronisation signals. However, the annoying thing about such ICs is that they are often difficult to obtain. On top of that, there are other problems, such as that the one has to be initialised by a processor and the other is difficult to synchronise to an external signal or ends up being incorrectly synchronised. However, it is also possible to use a 'discrete' circuit to generate the video sync signal for a project such as a homemade test pattern generator.

In the design described here, we assume a field rate of 50 Hz and a horizontal line rate of 15,625 Hz. Our solution is based on using an EPROM containing a 'sampled' version of the signal. A second table is also programmed for operating a video switch. If you can program the EPROM yourself, you can modify the second table to produce a black-level clamping signal or generate a simple monochrome test pattern, among other possibilities.

The circuit is designed to make it easy to view and modify the content of the EPROM using a hex editor. Each video line is constructed from the data contained in 16 successive data bytes. If the hex editor always displays 16 bytes per line, you can 'view' the video lines as they actually are (in hexadecimal form, of course).

With the exception of the EPROM, the circuit consists of only standard logic devices. The 15-bit address for the EPROM is generated by three synchronous counters (IC1–IC3) connected in series. In order to allow the two tables in the EPROM to be clearly distinguished, the highest address line (A14) is switched 16 times faster than the A0 line. This means that the two tables in the EPROM are located one above the other, rather than interleaved. This makes it much easier to modify the second table for your own applications.

The counters are clocked by a standard 8-MHz crystal oscillator (built using IC7c, a 74HCU04 buffer). The first counter (IC1) and its output register are clocked by the oscillator. The

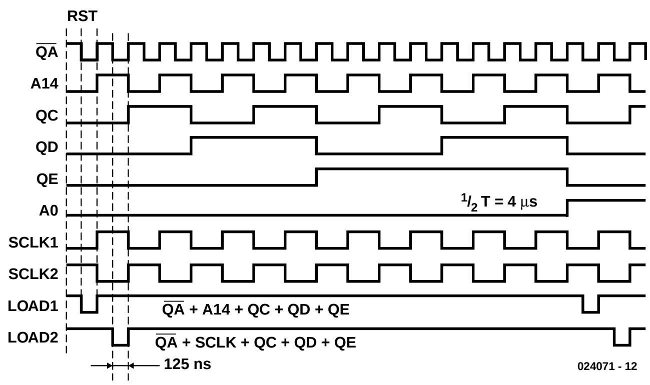


Table 1

```
0000h: 00 00 00 00 00 00 01 FF 00 00 00 00 00 00 01 FF
0010h: 00 00 00 00 00 00 01 FF 00 00 00 00 00 00 01 FF
0020h: 00 00 00 00 00 00 01 FF 07 FF FF FF FF FF FF FF
0030h: 07 FF FF FF FF FF FF FF 07 FF FF FF FF FF FF FF
0040h: 07 FF FF FF FF FF FF FF 07 FF FF FF FF FF FF FF
0050h: 00 7F FF FF FF FF FF FF FF FF FF FF FF FF FF FF
0060h: 00 7F FF FF FF FF FF FF FF FF FF FF FF FF FF FF
1340h: 00 7F FF FF FF FF FF FF FF FF FF FF FF FF FF FF
1350h: 00 7F FF FF FF FF FF FF FF FF FF FF FF FF FF FF
1360h: 07 FF FF FF FF FF FF FF 07 FF FF FF FF FF FF FF
1370h: 07 FF FF FF FF FF FF FF 07 FF FF FF FF FF FF FF
1300h: 07 FF FF FF FF FF FF FF 00 00 00 00 00 00 01 FF
1390h: 00 00 00 00 00 00 01 FF 00 00 00 00 00 00 01 FF
13A0h: 00 00 00 00 00 00 01 FF 00 00 00 00 00 00 01 FF
13B0h: 07 FF FF FF FF FF FF FF 07 FF FF FF FF FF FF FF
13C0h: 07 FF FF FF FF FF FF FF 07 FF FF FF FF FF FF FF
13D0h: 07 FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
13E0h: 00 7F FF FF FF FF FF FF FF FF FF FF FF FF FF FF
13F0h: 00 7F FF FF FF FF FF FF FF FF FF FF FF FF FF FF
26C0h: 00 7F FF FF FF FF FF FF FF FF FF FF FF FF FF FF
26D0h: 00 7F FF FF FF FF FF FF FF FF FF FF FF FF FF FF
26E0h: 00 7F FF FF FF FF FF FF 07 FF FF FF FF FF FF FF
26F0h: 07 FF FF FF FF FF FF FF 07 FF FF FF FF FF FF FF
2700h: 07 FF FF FF FF FF FF FF 07 FF FF FF FF FF FF FF
2710h: F0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
2720h: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
2730h: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
```

Table 2

```
4000h: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
4010h: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
4020h: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
4030h: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
4040h: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
4050h: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
4060h: 00 3F 80 00 00 00 00 00 00 00 00 00 00 00 00 00
4070h: 00 3F 80 00 00 00 00 00 00 00 00 00 00 00 00 00
4080h: 00 3F 80 00 00 00 00 00 00 00 00 00 00 00 00 00
4090h: 00 3F 80 00 00 00 00 00 00 00 00 00 00 00 00 00
40A0h: 00 3F 80 00 00 00 00 00 00 00 00 00 00 00 00 00
40B0h: 00 3F 80 00 00 00 00 00 00 00 00 00 00 00 00 00
40C0h: 00 3F 80 00 00 00 00 00 00 00 00 00 00 00 00 00
40D0h: 00 3F 80 00 00 00 00 00 00 00 00 00 00 00 00 00
40E0h: 00 3F 80 00 00 00 00 00 00 00 00 00 00 00 00 00
40F0h: 00 3F 80 00 00 00 00 00 00 00 00 00 00 00 00 00
4100h: 00 3F 80 00 00 00 00 00 00 00 00 00 00 00 00 00
4110h: 00 3F 80 00 00 00 00 00 00 00 00 00 00 00 00 00
4120h: 00 3F 80 00 00 00 00 00 00 00 00 00 00 00 00 00
4130h: 00 3F 80 00 00 00 00 00 00 00 00 00 00 00 00 00
4140h: 00 3F 80 00 00 00 00 00 00 00 00 00 00 00 00 00
4150h: 00 3F 80 00 00 00 00 00 00 00 00 00 00 00 00 00
4160h: 00 3F 80 00 00 00 00 00 00 00 00 00 00 00 00 00
4170h: 00 3F 87 FF FF FF FF FF FF FF FF FF FF FF FF F8
4180h: 00 3F 87 FF FF FF FF FF FF FF FF FF FF FF FF F8
5340h: 00 3F 87 FF FF FF FF FF FF FF FF FF FF FF FF F8
5350h: 00 3F 87 FF FF FF FF FF FF FF FF FF FF FF FF F8
5360h: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
5370h: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
5380h: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
5390h: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
53A0h: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
53B0h: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
53C0h: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
53D0h: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
53E0h: 00 3F 80 00 00 00 00 00 00 00 00 00 00 00 00 00
53F0h: 00 3F 80 00 00 00 00 00 00 00 00 00 00 00 00 00
5400h: 00 3F 80 00 00 00 00 00 00 00 00 00 00 00 00 00
5410h: 00 3F 80 00 00 00 00 00 00 00 00 00 00 00 00 00
5420h: 00 3F 80 00 00 00 00 00 00 00 00 00 00 00 00 00
5430h: 00 3F 80 00 00 00 00 00 00 00 00 00 00 00 00 00
5440h: 00 3F 80 00 00 00 00 00 00 00 00 00 00 00 00 00
5450h: 00 3F 80 00 00 00 00 00 00 00 00 00 00 00 00 00
5460h: 00 3F 80 00 00 00 00 00 00 00 00 00 00 00 00 00
5470h: 00 3F 80 00 00 00 00 00 00 00 00 00 00 00 00 00
5480h: 00 3F 80 00 00 00 00 00 00 00 00 00 00 00 00 00
5490h: 00 3F 80 00 00 00 00 00 00 00 00 00 00 00 00 00
54A0h: 00 3F 80 00 00 00 00 00 00 00 00 00 00 00 00 00
54B0h: 00 3F 80 00 00 00 00 00 00 00 00 00 00 00 00 00
54C0h: 00 3F 80 00 00 00 00 00 00 00 00 00 00 00 00 00
54D0h: 00 3F 80 00 00 00 00 00 00 00 00 00 00 00 00 00
54E0h: 00 3F 80 00 00 00 00 00 00 00 00 00 00 00 00 00
54F0h: 00 3F 87 FF FF FF FF FF FF FF FF FF FF FF FF F8
5500h: 00 3F 87 FF FF FF FF FF FF FF FF FF FF FF FF F8
66C0h: 00 3F 87 FF FF FF FF FF FF FF FF FF FF FF FF F8
66D0h: 00 3F 87 FF FF FF FF FF FF FF FF FF FF FF FF F8
66E0h: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
66F0h: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
6700h: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
```

second counter (IC2) is clocked by the ripple-carry output of the previous counter, with its output register being clocked by the oscillator. The same applies to the third counter (IC3), with the result that the outputs of the counter ICs change state simultaneously. This is necessary to have the data on the EPROM outputs become stable as quickly as possible.

The data from the EPROM are converted into the actual video waveform by two shift registers (IC5 and IC6, which are 8-bit PISO types). The timing diagram shows how all of this works for a single byte. The correct control signals for the shift registers are formed from the first counter outputs of IC1 using a bit of logic. The Load1 signal (IC8) loads the data for the synchronisation signal into IC5. At this point, A14 is Low and data from the first table are present at the EPROM outputs. After this, the Load2 signal (IC9) performs the same function for the data from the second table (A14 High), and IC6 provides the signal for a video switch (or something else). Inverters IC7a and IC7b ensure that the data in the shift registers are clocked through at the correct time. Note that IC8 and IC9 must have a non-inverting output (pin 1); the original 4078 from the standard CMOS family has only an inverting output. Here we have used Texas Instruments types. If a non-inverting output is not available, two additional inverters will naturally be needed.

IC10 is used to reset the counters at the end of line 625. This occurs after 10,000 bytes (16 × 625), or 80,000 bits. The resolution is thus 0.05 µs, with each line consisting of 128 samples. For the sake of completeness, we should note that the signal at the output of IC6 lags the signal at the output of IC5 by 0.25 µs, but this does not have any practical consequences. A fast (90 ns) EPROM from AMD is used here, since the data must be transferred to the shift registers within 125 ns, and this time is further reduced by the various propagation delays.

If jumper JP1 is placed in the upper position, an externally generated signal (a 'needle pulse' with a repetition rate of 25 Hz) can be used to reset the counters and thus synchronise the entire process to an external system. The trick here is to have the oscillator run slightly slower, so the final bit of line 625 or the first bit of line 1 is present at the outputs when the next external reset occurs. A trimmer capacitor (C1) is added to the oscillator for this purpose, and it can be adjusted as necessary. The current consumption of the finished circuit is approximately 25 mA.

Table 1 lists the principal addresses and data for the synchronisation signal. The data for the first field and the equalisation pulses are contained in lines 00 through 49 (all addresses are shown in hexadecimal form). In addresses 50 through 135F, identical data appear in each group of 16 bytes. The data for the equalisation pulses and the second field pulse can be seen at addresses 1360 through 13DF. The data for addresses 13E0 through 26DF are again identical for each group of 16 bytes. No data are used from address 2710 to the first address of the second table, so all of these locations are set to '0'. Here only the first following nibble is set to '1', in case it is desired to have the counters continue to count. This causes the level to remain High until line 1 starts again when the counters are reset.

Table 2 is primarily intended to serve as an example that shows where relevant video information and the colour-burst data should be located. The arrangement of Table 2 is similar to that of Table 1, although here the nature of the signal is different, and we show somewhat more of the full table. This is primarily done to indicate the addresses where colour-burst data should be placed with **no** video data. Pay careful attention to the address numbers if you want to copy this table.

Table 3 shows the most important timing specifications for the synchronisation signals, alongside the timing data for this circuit. Bear in mind that one bit represents 0.5 µs. One final remark: the EPROM content can be downloaded as file number **024071-21** from the Free Downloads page at www.elektor-electronics.co.uk.

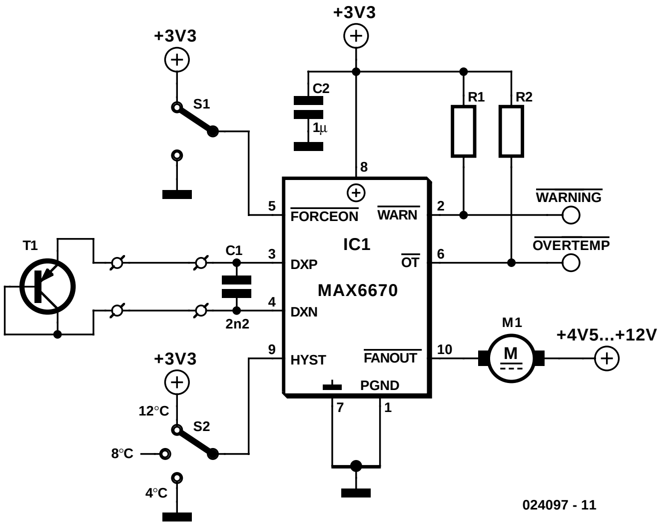
(024071-1)

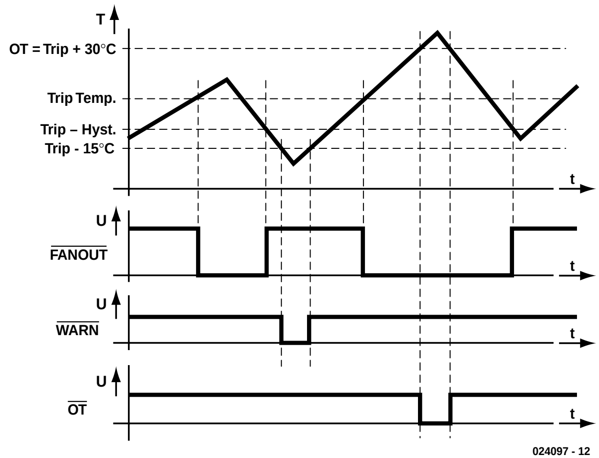
Table 3

	CCIR (PAL)	sync-generator
Line period	64 µs	64 µs
Front porch	1.5 ± 0.3 µs	1.5 µs
Line sync. width	4.7 ± 0.2 µs	4.5 µs
Back porch	5.8 ± 0.2 µs	6.0 µs
Start line to burst	5.6 ± 0.1 µs	5.0 µs
Burst duration	2.25 ± 0.23 µs	3.5 µs
Line blanking	12 ± 0.3 µs	12 µs
Field period	20 ms	20 ms
Field blanking	1.6 ms	1.676 ms
Eq. puls width	2.35 ± 0.1 µs	2.5 µs
Duration pre/post-eq.	160 µs	160 µs
Field sync. width	160 µs	160 µs
Interval in field sync.	27.3 ± 0.1 µs	27.5 µs

Fan Controller with Remote Temperature Sensor

033





The Maxim MAX6670 (http://pdfserv.maxim-ic.com/arpdf/MAX6668-MAX6670.pdf) is an integrated circuit for temperature-dependent fan control. The p-n junction of a transistor is used as a temperature sensor, which can be mounted remotely. The various versions of the IC are programmed by the manufacturer with a range of trip temperatures from +40 °C to +75 °C. The devices are available in 5 °C steps. Hysteresis is programmed via the HYST input at 12 °C (HYST tied to +3.3 V), 8 °C (HYST left open-circuit), or 4 °C (HYST tied to ground). For example, if the hysteresis is set to 8 °C, the fan will turn off when the temperature falls below the trip temperature minus 8 °C. It will only turn on again when the temperature again reaches the trip value. Fans operating on voltages from +4.5 V to +12 V, drawing currents of up to 250 mA can be used. A test facility is provided via the FORCEON connection: tying this input to ground turns the fan on immediately.

The MAX6670 indicates under- and over-temperature conditions via two further outputs. The $\overline{\text{WARNING}}$ output goes low when the temperature is more than 15 °C below the trip value; $\overline{\text{OVER TEMP}}$, on the other hand, goes low when the temperature at the sensor T is more than 30 °C above the trip temperature.
The p-n junctions found in microprocessors make suitable sensors, as do small-signal transistors such as the BC307, BC546, BC557 and 2N3904.
The device is also available without the $\overline{\text{WARNING}}$- and $\overline{\text{OT}}$ outputs as the MAX6668. This has a fixed hysteresis of 8 °C and can also be obtained in 5 °C steps from +40 °C to +75 °C. The ICs are available in 10 pin (MAX6670) or 8 pin (MAX6668) µMAX packages.

(024097-1)

1 kHz to 30 MHz Oscillator using only Three Components 034

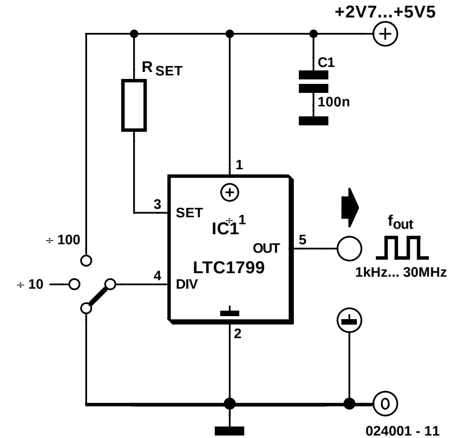
Building a square-wave oscillator using only three components is always a desirable accomplishment when space is tight, and if you can achieve a frequency range of 1 kHz to 30 MHz at the same time you have a component that can be used an a wide variety of applications.

The Linear Technology LTC1799 (www.linear-tech.com/pdf/1799f.pdf) is the first IC that can manage this feat. It needs only an external resistor R_{SET} to set the output frequency. The value R_{SET} of can be calculated using the formula

$$R_{SET} = 10\ \Omega \times [10\ \text{MHz} / (N \times f_{OSC})\ ]$$

The frequency range *N* is selected by the voltage applied to the DIV pin (see the table). The output voltage of the IC switches back and forth between the supply voltage and ground ('rail to rail'). The duty cycle is 1:1 or 50%. The LTC1799 comes in an SOT-23 SMD package and thus takes up only a very amount of space on the circuit board.

(024001-1)



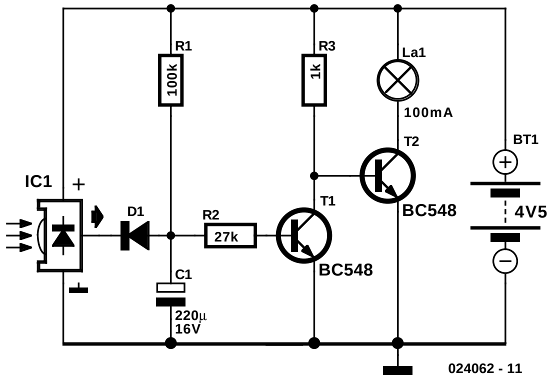
DIV (pin 4)	N	Frequency range
V_{CC}	1	500 kHz to 30 MHz
open	10	50 kHz to 1 MHz
ground	100	1 kHz to 100 kHz

Infrared Light Switch

035

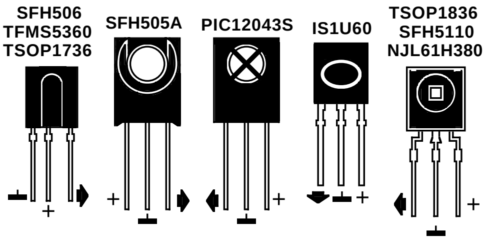
B. Kainka

Inexpensive receivers for standard infrared remote control units for television sets and video recorders are available in the form of integrated circuits. Normally, a computer or micro-controller looks after decoding the light signals. However, this circuit shows that there are alternatives. It reacts to an IR signal, or at least to a signal sent with a carrier frequency of 36 kHz (other types of ICs are available for other frequencies). When such a signal is received, the infrared receiver IC discharges the capacitor, causing the first transistor to be cut off



and the second one to conduct. The lamp goes on and remains on until the IR signal stops and the capacitor recharges to the base–emitter voltage of the connected transistor via the 100-kΩ resistor.

(024062-1)



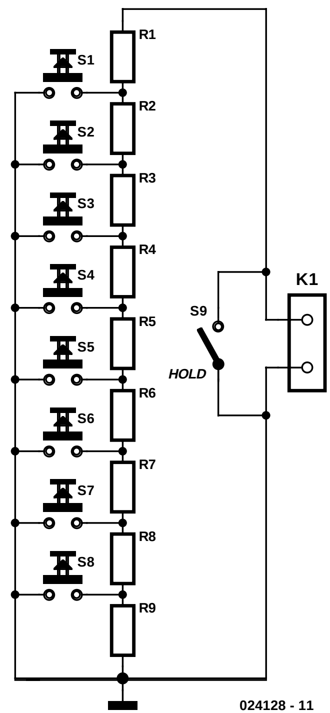
Portable MD Remote Control Demystified

036

Portable MD recorders have remote controls for the most commonly used functions. The term 'remote control' usually refers to a wireless TV zapper, but here we are talking about a small enclosure with pushbuttons that also serves as an extension cable for the headset. At the MD recorder end, there is a phone plug for the sound and a row of contacts for other functions – including the remote control, which requires two contacts for the buttons. Each button causes a specific resistance to be connected between these two contacts, and the recorder recognises the selected function from the resistance value.

Another one of the special circuit articles in this issue describes a circuit that simplifies entering titles for the tracks on an MD, using a program running on a PC. As noted in that article, there are many differences among remote control units used by different makes, and even with the same make there can be differences among various remote controls. Still, the principle of using different resistance values remains the same for all. The schematic diagram shows how a remote control is put together.

The first thing you need to do is to find out which contacts are used to control the MD recorder. With an ohmmeter, simply measure the resistance between each possible combination of contacts while pressing a button to see if the measured value changes. When you see a change, you have found the contacts you need. One tip is to engage the Hold switch if such a switch is present on your remote control. The Hold switch shorts out the remote control contacts in order to prevent the recorder from responding to an accidentally pressed button. All you have to do then is to measure the resistances between the contact pairs using the continuity mode (beeper).



Once you have found the proper contacts, press each button in turn and record the resistance value measured for each function. Then sort the measured values in increasing order. The smallest value corresponds to R1, the next value to R1 + R2 and so on. If none of the buttons is pressed, the sum of the values of R1 through R9 will be measured. The resistor numbers corresponds to those used in the schematic diagram of the MD titling circuit.

(024128-1)

Simple AVR Programmer

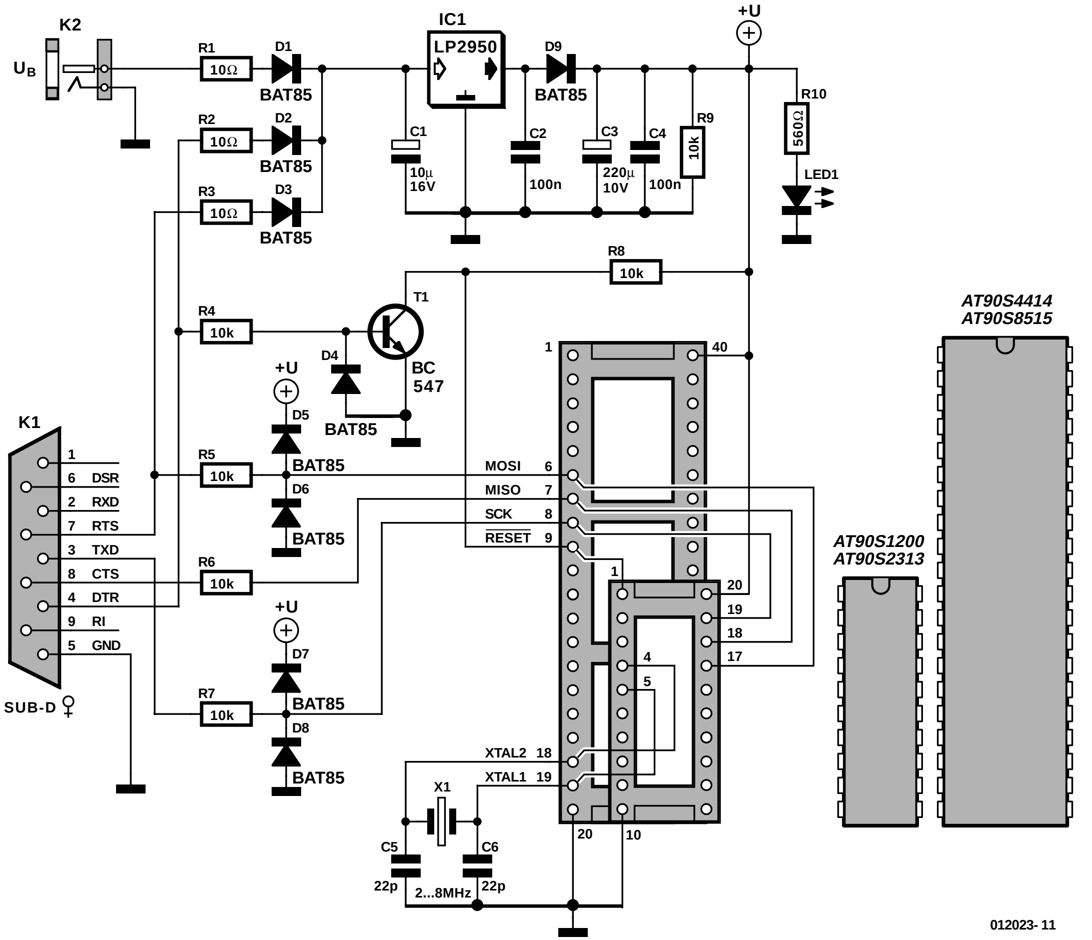
037

H.-J. Hanft

This simple programmer is a slimmed-down version of the programmer described in the March issue. It provides an extremely low-cost entry into developing applications using AVR microcontrollers. For this reason, particular attention has been given to achieving a simple, economical design.

The programmer is connected to the PC by a standard RS232 interface. No external supply voltage is required to use the programmer, since the necessary current (a few milliampères) can be drawn directly from the serial port of the computer.

In order to reduce costs, an inexpensive fixed +5-V regulator could be used for IC1 in place of the relatively expensive LP22950 low-drop regulator. However, in that case the circuit should be powered from an external supply having a voltage in the 8–15 V range (such as a mains adapter), since the supply voltage available from the RS232 port is generally too low for reliable operation with a standard voltage regulator.



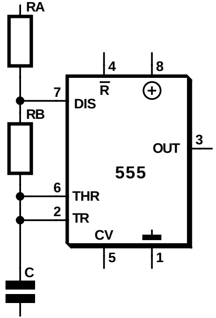
Programming activity is indicated by a red LED. The microcontroller to be programmed should not be inserted in the socket or removed from the socket while the LED is illuminated. The necessary general-purpose programming software is available as a console application suitable for use with common operating systems (Windows 95, 98, NT, ME, 2000 and XP). It can be downloaded free of charge from the *Elektor Electronics* website (March 2002 Free Downloads).

(012023-1)

Phantasia on a 555 Theme

038

1



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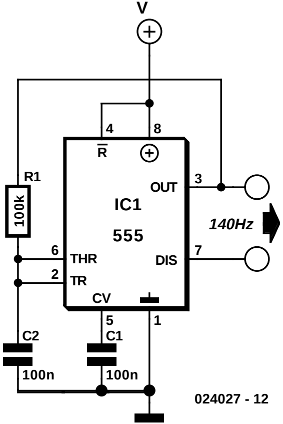


M. Feeney

The 555 timer chip is older than many Elektor readers and has been used in numerous configurations. The suggestion presented here has not been seen elsewhere by the author and has some interesting features.

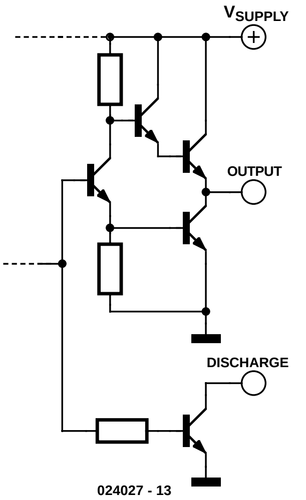
The configuration for which the device was designed is the well-known 'R_A-R_B-C' one that uses the internal discharge transistor to discharge the capacitor once it has reached 2/3rd of the supply voltage, see **Figure 1**. The author has often used the simpler arrangement where a single (usually variable or preset) resistor R1 charges and discharges capacitor C2 from the output pin — see Figure 2. This leaves the discharge transistor free and produces a (nearly) 50:50 duty cycle that does not vary with frequency. Note that only CMOS 555s like the 7555 and TLC555 achieve exactly 50:50 duty cycle — the standard 555 does 48% low, 52% high.

The main output of the 555 is shown much simplified in **Figure 3**. The upper Darlington pair arrangement means that the output voltage can never reach the full supply voltage and (in the standard 555) will always be about 1.5 V below this when the output is in the high state.

The discharge transistor at pin 7 has no collector connection to V+ and can function as an open-collector switch only. This transistor can be used to switch current through a load. The open-collector arrangement has some unexpected features:

1. The load can be resistive, an LED(s) (with resistor), an inductor or transformer (do not forget a back-EMF suppressor diode when connecting inductive loads).
2. The load can be supplied from a voltage higher or lower than the timer chip, up to the limiting voltage of the 555 (usually 15 or 17 V, but always stay below 18 V).
3. The load will have no effect on the frequency or duty cycle of oscillation (this also applies to the standard configuration).
4. A single resistor changes the frequency but the waveform retains a (nearly) 1:1 mark/space ratio. The frequency equals 1.44 / RC [Hz].
5. The transistor current will limit at about 200 mA. At 100 mA the transistor drops about 1 V. Since the standard 555 is spec'd to 650 mW dissipation, allowing a safety margin of 25%, the load can be current driven to about 500 mW / 200 mA = 2.5 V. Note that the CMOS version can only sink 100 mA and source 10 mA.

3

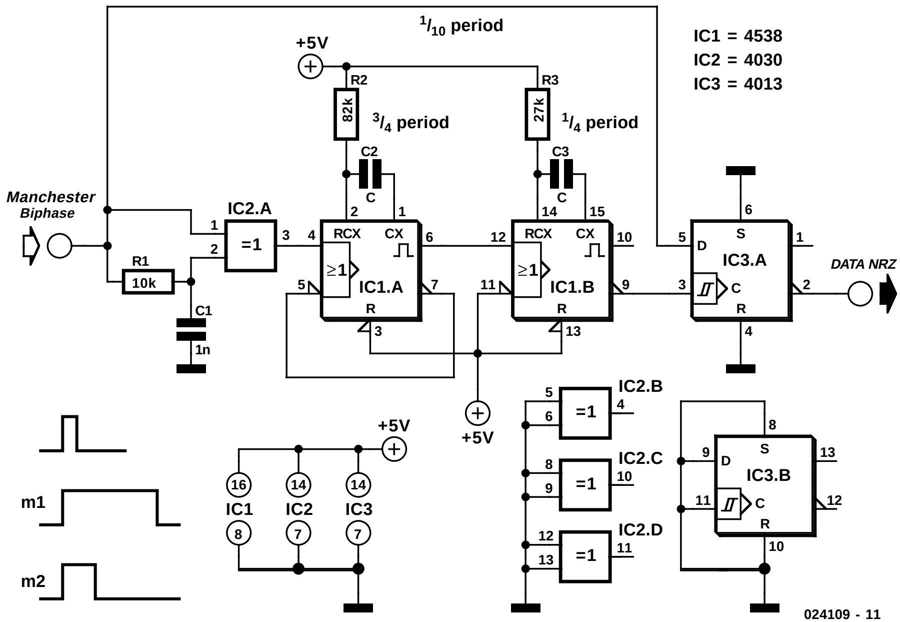


(024027-1)

Manchester Decoder

039

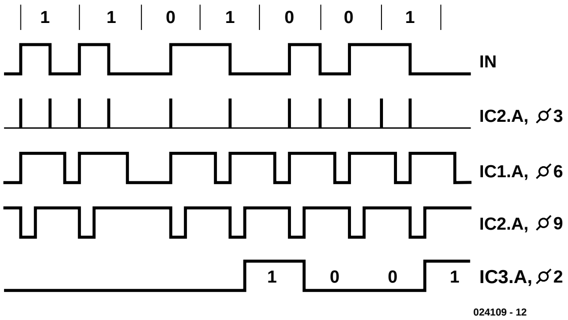
The Manchester or biphase code is used very frequently, (examples include hard disk drives and networks), because the code contains both the data and the clock and is therefore very compact. In addition, there are only two frequencies present and never contains low frequencies. A logic zero is defined as a ‘0 to 1 edge’, a logical one is represented by a falling edge. This works well as long as the data is continuously changing, but when multiple zeros or ones appear in a row, it becomes necessary to insert additional edges between the original rising or falling edges. This is done at a point halfway between the original edges, at the so-called bit boundaries.



In order to decode the Manchester-code, it is first necessary to decide which are the data edges and which are the bit-boundaries. It is therefore necessary to have a synchronisation period preceding every message. A number of 0101 (or 1010) patterns is transmitted so that the receiver can be synchronised. When 0101 patterns are being transmitted, the Manchester signal consists entirely of data edges and there are no bit-boundary edges.

The decoder circuit presented here works as follows: IC2 turns every edge (both rising and falling) into a short pulse. This is used to start the non re-triggerable monostable multivibrator (IC1a) with a monotime equal to ? of the time between data edges. When the 01 or 10 pattern comes along the monostable will automatically synchronise itself to the data edges. Every additional bit boundary edges that may be present in the signal that follows, will fall within the mono-time and will be ignored, the monostable remains synchronised. This signal can now be used to start a second monostable (IC1b), which will, with the aid of a flip-flop (IC3a), sample the data stream immediately after the data edge. That completes the decoding; the data is available at the Q output of the flip-flop. On some systems the Manchester code is reversed in phase, but this makes no difference to the decoder, because the data at the Q output can simply be inverted.

This circuit is intended to be more of a demonstration than a real circuit. Because of the IC family selected, the decoder is limited to a frequency range of up to a few hundred kilohertz. But programmers can also use this model as an example, because a software decoder can be implemented in a similar manner. The resistance ratios were selected such that C1 to C3 could all be the same value. The formula t = RC applies to the monostable multivibrators; so for a 1-kHz signal C needs to be about 9 nF.



In the timing diagram it can be clearly seen that the decoder doesn't work properly as long as it is not synchronised. After the first 10 or 01 change it synchronises and then supplies the correct data out.

(024109-1)

Random Flashing LED

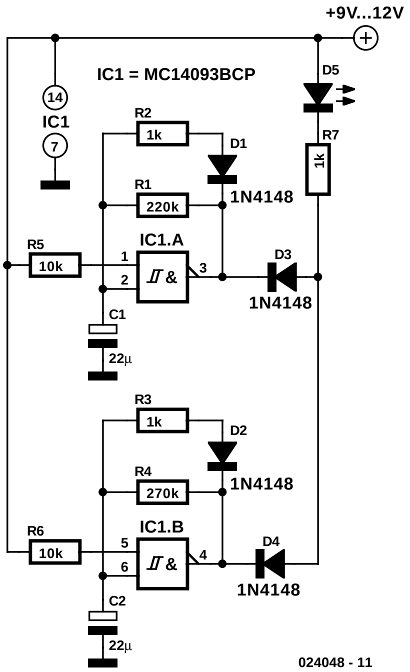
040

Rev. T. Scarborough

Here is a random flashing LED circuit which is economical at just 1 mA while using a minimum number of parts. With two spare gates available in the 4093 (a 2-input Schmitt trigger NAND), a single IC could separately control two random flashing LEDs. A particular advantage of this design is that both the minimum and maximum periods of the flashes may be adjusted, and in this way the degree of randomness itself.

The circuit as shown randomly flashes LED D5. Gates IC1.A and IC1.B are used to build two conventional oscillators, each of which runs at a relatively low frequency. R2 and R4, with D1 and D2, provide uneven mark-space ratios for the oscillators, so as to produce rapid negative pulses at IC1's output pins 3 and 4. These pulses are mixed through D4 and D3, switching on LED D5 and producing a pseudo-random effect.

(024048-1)



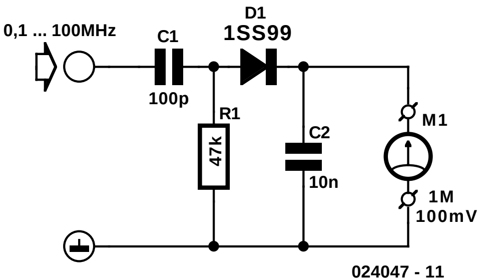
RF Probe

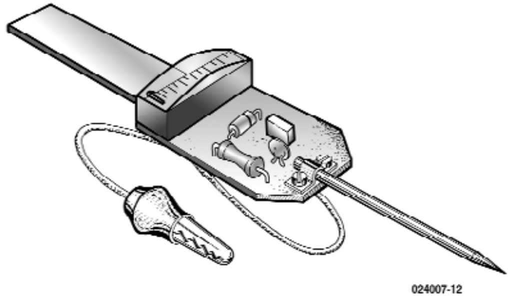
041

G.Baars

A RF probe is a handy piece of test equipment that converts a high frequency signal to a DC voltage. In this way it is very easy to measure RF voltages for either testing or adjustment purposes.

The RF probe described here is suitable for signals in the frequency range from about 100 kHz to 1000 MHz. Although the diode used here can, in principle, go up to 3 GHz, the impedance of the ground connection will adversely influence the measurement at such very high frequencies.





The probe delivers a DC output voltage that is equal to the peak value of the RF voltage minus the diode voltage drop, which amounts to about 100 mV. It is therefore necessary that the signals to be measured are greater than 100 mV. A multimeter is eminently suitable as the actual measuring instrument, provided it has a high enough input impedance (1 MΩ or more). When adjusting signals to their peak value, an analogue instrument is easier to use than a digital meter.

The enclosure for the prototype was a large aluminium felt-tip pen. After removing the felt tip itself, a metal pin was clamped in the (plastic) front of the pen; the four parts of the circuit can easily find a home inside the tube of the pen. A sharp point needs to be filed or ground on the end of the metal pin. A short, flexible piece of wire with a small alligator clip can be used as the ground connection. The aluminium housing can be grounded by placing a wire in the thread of the pen housing before screwing the tip back on. Drill a small hole in the bottom for the connections to the meter.

The accuracy of the RF probe is about 10%. The probe loads the circuit under measurement with about 47 kΩ and a very small capacitance.

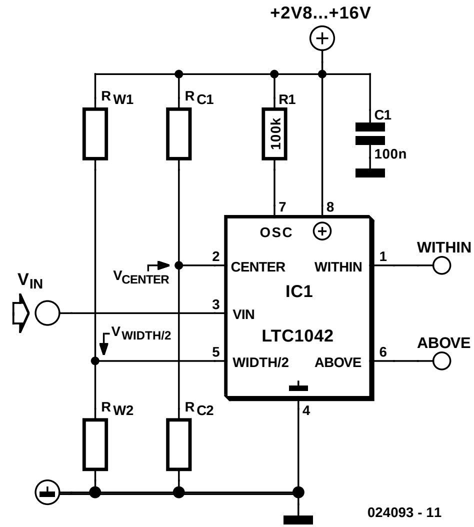
A final hint to conclude: the suggested diode 1SS99 (a low barrier Schottky-type, up to 3 GHz) is available from, among others, Barend Hendriksen of Brummen, The Netherlands (www.xs4all.nl/~barendh/Indexned.htm).

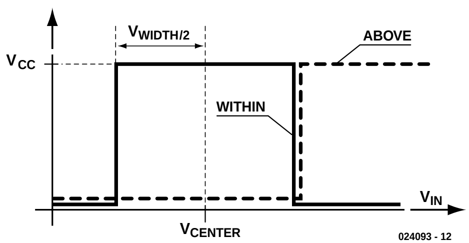
(024047-1)

Window Comparator

042

Many designs call for a window comparator to determine if a voltage level falls within two voltage thresholds. Linear Technology has produced a single chip solution to the problem with their LTC1042 device (www.linear-tech.com/pdf/lt1042.pdf). This versatile chip is very simple to use and just requires an input voltage level to define the centre of the voltage window (potential divider chain R_{C1}/R_{C2}) and another voltage level to define half of the width of the window (R_{W1}/R_{W2}). A useful feature is that the window width is referenced to earth potential and is therefore independent of the window level. The WITHIN output goes high when input voltage V_{IN} is within the upper and lower thresholds of the window and the ABOVE output goes high when V_{IN} is above the upper window threshold. If you need a BELOW output to detect V_{IN} below the lower threshold then it's a simple job just to swap the two inputs V_{IN} and CENTRE. V_{IN} will now be connected to pin 2 and the centre reference level to pin 3. Pin 6 will now be a BELOW output and will go high for V_{IN} less than the lower window threshold. The operating voltage is between +2.8 V und +16 V and a 100 KΩ resistor is necessary for the internal oscillator at pin 7 (OSC) up to the supply rail. The chip is supplied in an 8-pin Mini DIP outline.





(024093-1)

Magnetic Proximity Switch with Toggle

043

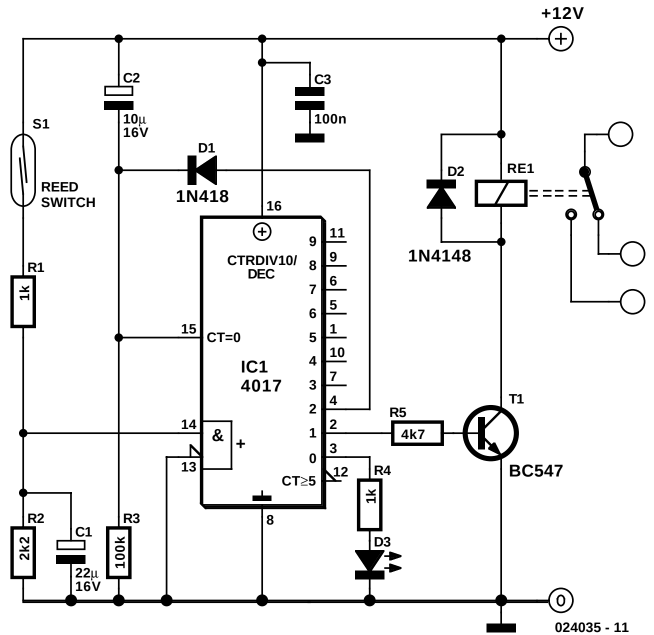
T.K. Hareendran

This proximity switch employs a reed switch as the sensor device and the good old CD4017 decade counter for pulse processing. When the circuit is first switched on, the 4017 is reset by the short pulse generated by C2-R3. This results in the Q0 output (pin 3) being pulled high and the LED coming on to indicate standby mode.

When a permanent magnet is held in the vicinity of the red switch, the switch closes, generating one clock pulse at pin 14 of the 4017. This is indicated by Q1 (pin 2) going high and relay Re1 being energized via transistor T1.

If the magnet is removed from the reed contact and then moved toward it again, IC1 is again clocked and the relay is de-energized. In this way a toggle function is realized. Actually, Q2 goes high (pin 4), which causes the counter to be reset via diode D1. Since the circuit draws only a few milliamps, almost any mains adapter with a (loaded) output voltage of about 12 VDC is suitable for powering the proximity switch. In all cases, the relay coil current will be the determining factor.

(024035-1)



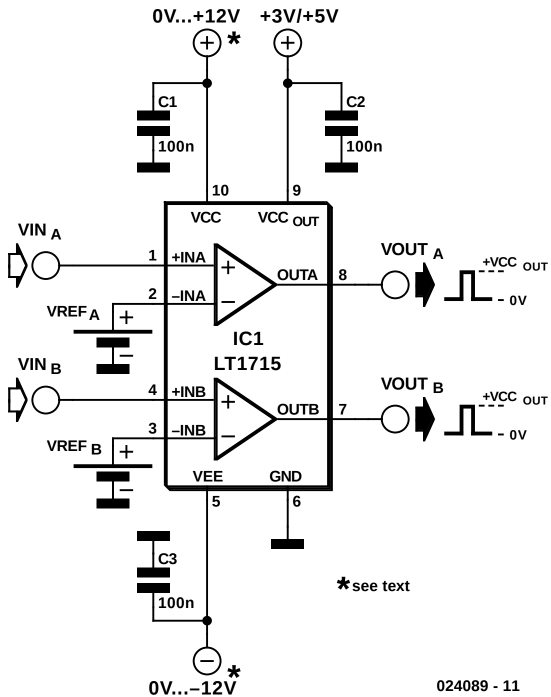
Super-Fast Comparator

044

Generating digital square-wave signals at logic levels from fast signals having frequencies up to 150 MHz (such as sinusoidal signals from quartz-crystal oscillators) is not particularly easy. The discrete circuits used for this purpose are relatively complex and require fast HF transistors.

This problem can now be solved in a considerably simpler manner using the fast Linear Technology LT1715 dual comparator (www.linear-tech.com/pdf/1715f.pdf). This IC has separate supply pins for the input region (V_{cc} and V_{ee}) as well as for the output region ($V_{cc,out}$). This makes it easy to match one side to the applied signal voltage, while the supply voltage $V_{cc,out}$ directly determines the logic level of the output signal. Note that the maximum allowable difference between V_{cc} and V_{ee} is 13 V. For instance, with negative input signals the input region of the comparators can be operated with V_{cc} = 0 V and V_{ee} = –12 V. The input voltage may range from V_{ee} to (V_{cc} – 1.2 V). The digital rail-to-rail output is laid out symmetrically inside the IC to achieve equal rise and fall times. The reference voltage sources shown in the figure symbolically represent the voltage dividers that determine the threshold levels of the two comparators. The LT1715 is housed in a 10-pin MSOP package.

(024089-1)



IR Receiver for the I²C Bus

045

A commonly encountered problem is that the code sent by an infrared transmitter cannot be evaluated by a microcontroller directly on being received, due to the fact that the microcontroller is busy with something else at the time or is simply too slow to sample the signal at a rate sufficient to achieve an error-tolerant evaluation. In such cases, a helpful solution is to use a Philips SAA3049 infrared television decoder, which is still available as an NOS (new old stock) item although it is no longer being manufactured.

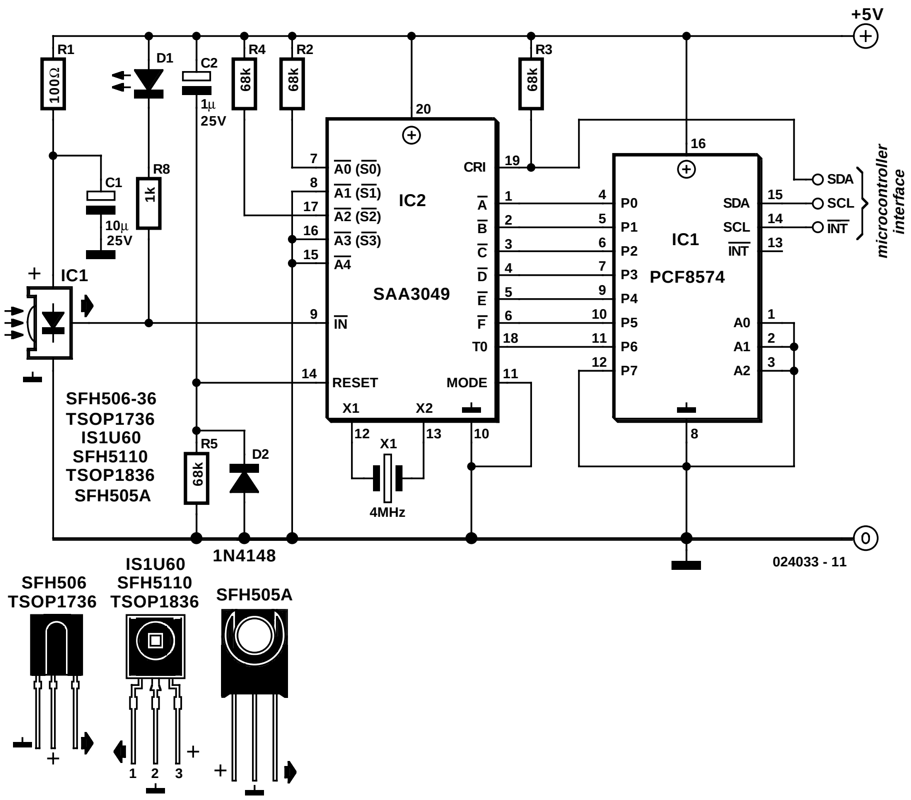
The SAA3049 is microcontroller-based and performs all the tasks necessary to decode an infrared signal in RC5 or RECS80 format. The transmitted command is available in binary form at the output pins (1–6) for further processing by a second microcontroller. If the second microcontroller has enough input pins to read in six bits plus the toggle bit in parallel, no further circuitry is needed. If the second microcontroller is short of port pins, which is usually the case, the signals must be converted to a different form. One possibility is to use a component that converts the command data into an I²C-compatible format and outputs the result via the SDA and SCL bus lines on request.

Philips Semiconductors offer a port expander (type designation PCF8574) with eight programmable input/output pins. All communications and programming take place via the I²C bus. With the circuit described here, the command data and toggle bit of an RC5 code set to system address 5 can be read serially by a microcontroller using only three port pins.

The address to which the IC should respond during bus communications is set using A0, A1 and A2. In this circuit, all of these pins are tied to ground, which means that the address is set to (40h + 0) = 40h. Although each change of signal level on pins P0–P7 triggers an interrupt and thereby causes the signal level on the INT pin to change from High to Low, in order to notify the following microcontroller that new data are available, it is unfortunately necessary to clear this signal by performing a data transfer on the bus before it can again be activated. This means that there is a risk of losing an interrupt pulse if it occurs during the Acknowledge clock.

Information regarding the timing for the I²C bus and the detailed programming of the PCF8574 can be obtained from the device data sheet available on the Philips website.

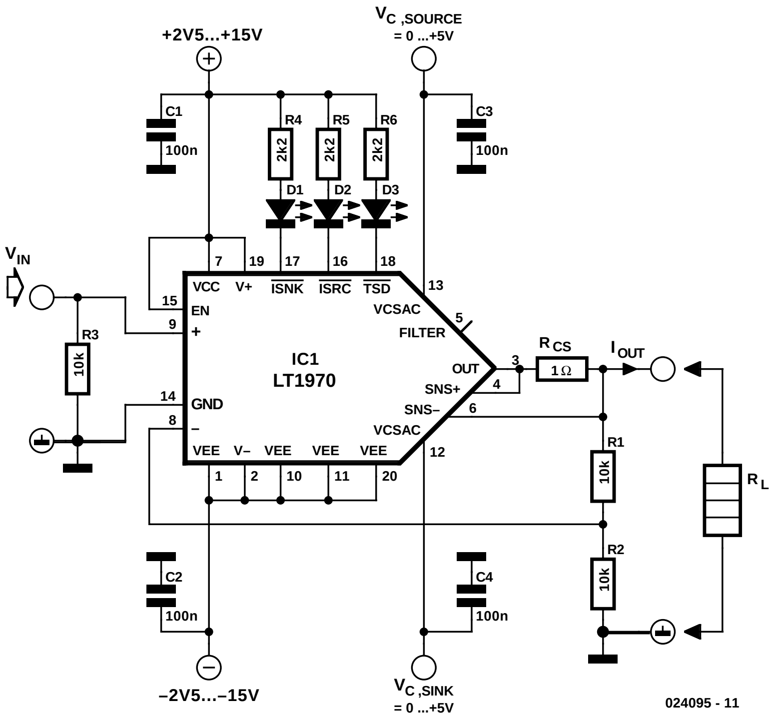
(024033-1)

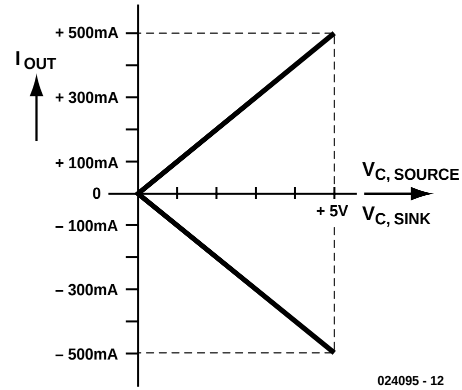


System address	Device
0	TV 1
1	TV 2
2	Videotext
3	Expansion for TV 1 and TV 2
4	Laser Vision Player
5	Video cassette recorder 1 (VCR 1)
6	Video cassette recorder 2 (VCR 2)
7	Reserved
8	AT 1
9	Expansion for VCR 1 and VC R2
10	SAT 2
11	Reserved
12	CD-Video
13	Reserved
14	CD-Photo
15	Reserved
16	Audio preamplifier 1
17	Tuner
18	Analogue cassette recorder
19	Audio preamplifier 2
20	CD
21	Audio rack or recording device
22	Audio satellite receiver
23	DCC recorder
24	Reserved
25	Reserved
26	Writable CD
27–31	Reserved

Power Opamp with Programmable Output Current

046





The LT1970 from Linear Technology (www.linear-tech.com/pdf/1970f.pdf) is a power opamp with adjustable current limit, available in a 20 pin TSSOP package. As well as the usual opamp connections the component sports a range of extra pins for the current limiting feature. The first thing that catches the eye is the current sense resistor R_{CS}, set at 1 Ω. DC voltages V_{CSRC} and V_{CSNK} set the current limit value, for the two polarities separately: the maximum allowable current flowing from the positive supply through the output OUT and R_{CS} into the load is set via V_{CSRC}. On the other hand, the maximum allowable current flowing through the load, through R_{CS} and then to the negative supply, is set via V_{CSNK}.

The LT1970 can deliver up to ±500 mA and operates from supply voltages between ±2.5 V and ±15 V. It can also operate from a single supply in the range +5 V to +30 V. The maximum output current can be further increased using external driver transistors.

A further current limit at ±800 mA protects the device, and there is also a thermal protection circuit. Open collector outputs indicate operation of the thermal cutout and when the current limits set via V_{CSRC} and V_{CSNK} are reached. Here the outputs are connected to LEDs.

An enable connection (EN) allows the opamp to be powered down, leaving the output in a high-impedance state.

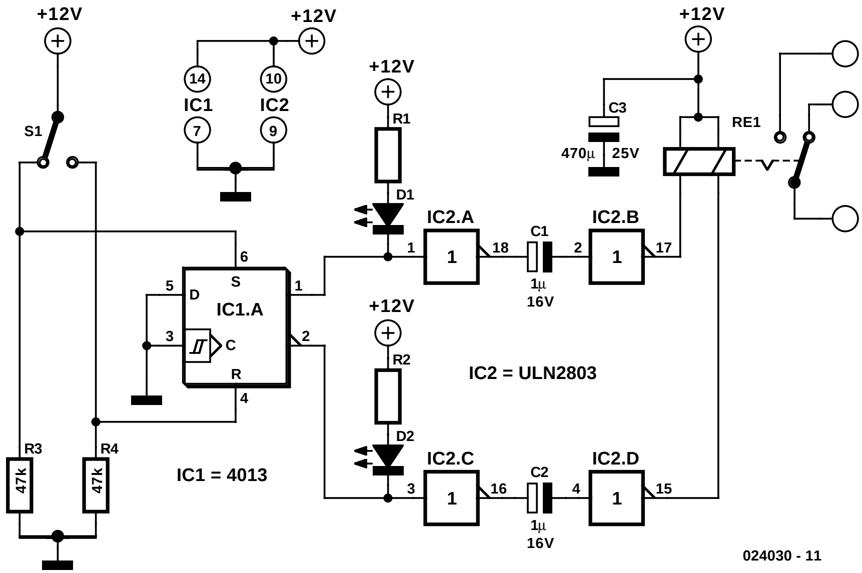
(024095-1)

Bistable Relay

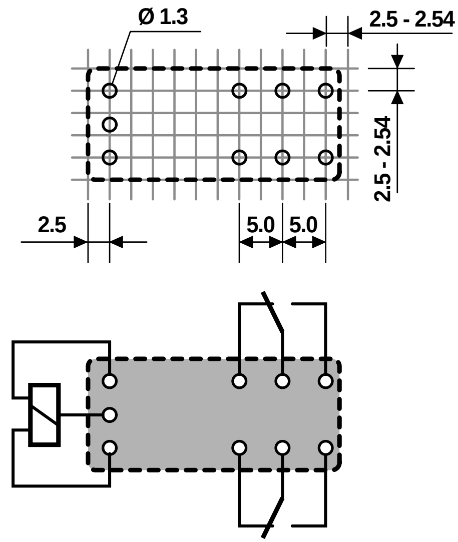
047

Bistable relays are particularly useful in applications where very low power consumption is important. This is because they only use a little bit of power while switching and nothing at all at other times! The switching is quite fast, it lasts typically only about 5 ms. The only disadvantage of bistable relays is that they are not fail-safe. When the power is removed from a normal relay it will return to the de-energised position. In the case of the bistable relay it will remain in the current state.

There are two variations of bistable relays: with one or with two windings. The type with only one winding requires a power reversal circuit, so it has more complex drive requirements. The version with two windings has three connections, one of which is common to both windings. We will use the type with two windings in our example circuit. Each winding requires a separate drive circuit; one drives the relay in one position and the other drives the relay on the other position ('on' and 'off' don't really apply here). The circuit consists of a D flip-flop (IC1), with an inverter and driver stage connected to each of its outputs. In each of these branches a low-current



024030 - 11



024030 - 12

LED provides indication of the current state.

The operation of this straightforward circuit is as follows. The relay winding that is connected to the flip-flop output whose state happens to be a logical one, is in the rest state. The LED in that branch will be off and the output of the corresponding inverter is low. When S1 is switched to the other position, the flip-flop output under consideration will change from a ‘1’ to a ‘0’, the corresponding LED will light and there appears a rising edge on the output of IC1a or IC1b. This rising edge will appear on the input of IC2a or IC2b via capacitor C1 (C2). This IC contains not much more than a number of darlington transistors, so the corresponding transistor receives a positive pulse at its base. It will start to conduct and the relay coil that is attached will be energised.

After about 10 ms the pulse at the input will disappear, because C1 has lost too much of its charge. The relay coil becomes de-energised. This is not a problem because in the meantime (in about 5 ms) the relay has changed over. By selecting a larger or smaller value for C1 the duration of the energising period can be made longer or shorter respectively. IC2 already contains the freewheeling diodes to render the inductive voltage surges from the relay coils harmless.

The indicated relay has a coil resistance of 240 Ω for the 12-V version. The current through the coil is therefore 50 mA. When we switch once per second, for example, the current consumption is only 10/1000 ms or 0.5 mA! The LEDs consume more power! If the power supply is rather weak, the required current pulse is delivered by decoupling capacitor C3. If we permit a 1 V sag of the power supply voltage, the value of C3 needs to be 50 mA × 10 ms/1 = 500 µF.

The relays are made by Schrack and are available in various forms. The RT314F12 has two 12-V windings and can switch up to 16 A. Type RT114F12 also has two 12-V windings and can switch two times 8 A.

(024030-1)

Scanning Slides with an ELS 048

Slide scanners are available in all sorts and sizes, but if you want a reasonable level of quality they are rather expensive. Besides that, the average computer table is already crowded enough. Elsewhere in this issue, under the title ‘Illuminating Film’, there is a description of a converter for powering an electro-luminescent sheet (ELS), which is also referred to as a ‘backlight’ for an LC display. The quite bright, uniform white light produced by an ELS gave us the idea for the following experiment.

We took an ordinary flatbed scanner, a slide and an ELS to illuminate the slide. The result was surprisingly good. Naturally, it is not as convenient as a real slide scanner, but if you occasionally need to scan a slide and you don’t have such high demands in terms of quality, this is certainly a possible solution – particularly if you consider that with some luck such ELS backlights can be obtained at rock-bottom prices on computer fairs!

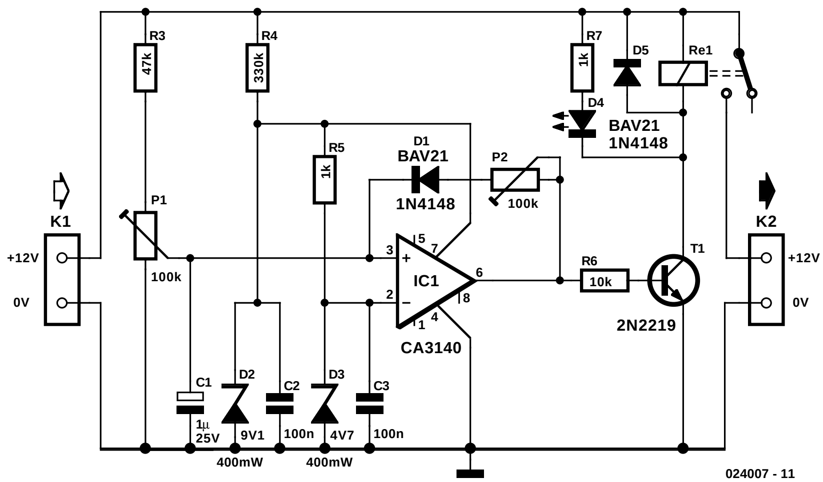
(024112-1)

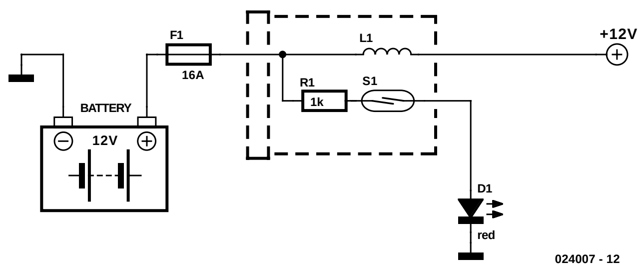
Automatic Fridge Switch for Caravans

049

J. Swart

At last there is another project for caravan owners. They are probably all aware of the problems of a flat battery when they've forgotten to turn off the fridge after the engine has been switched off. When this circuit is installed between the fridge and (caravan) battery, these troubles will be a thing of the past. This simple, but smart, switch reacts to the increase in voltage that occurs when the engine is running. Whereas the normal battery voltage is 12 V, this increases to a minimum of 13.8 V when the alternator charges it. With a suitably configured comparator this voltage difference can easily be detected, and as can be seen, the circuit consists of little more than a 3140 comparator and a relay driver stage for switching the fridge.





P1 sets the voltage at the non-inverting input of the comparator such that the relay will only be powered when the battery voltage is above 13.8 V, so only when the engine is running. The hysteresis introduced by D1/P2 stops the relay from turning off as soon as the engine stops and the battery voltage drops a little. P2 is used to set the exact cut-off point and this preset should be set to a voltage at which the battery has not discharged too much; 11.5 V would be a suitable value. The fridge remains working until the battery voltage drops to this critical level, at which point it will turn off.

It is the intention that the circuit is mounted inside the caravan, between the fridge and the 12 V line coming from the car. This assumes that a 7-pin trailer socket is used, which has a single constant supply on pin 2. When a 13-pin connector is used, the circuit could also be mounted inside the car and switch the battery voltage going to pin 10. The fridge should obviously be powered via this pin too.

Here's a tip: The circuit isn't limited just for use with fridges. The same circuit could for example be used to automatically switch on the car lights whilst the engine is running. This really is a multi-purpose circuit.

For those of you who wish to verify that the circuit operates correctly, the author has designed a LED indicator that lights up when a current greater than 3 A is drawn from the supply. A special property of this circuit is that it introduces virtually no voltage drop in the supply. It consists of little more than a reed switch with several turns of 4 mm diameter wire wound round it (8 turns were found to be sufficient for the prototype). The reed switch is turned on by the magnetic flux created by the coil and switches on a LED that can be mounted on the dashboard. The reed switch and coil would fit perfectly in a 35mm film canister.

(024007-1)

Voltage Inverter with Cascade Stage

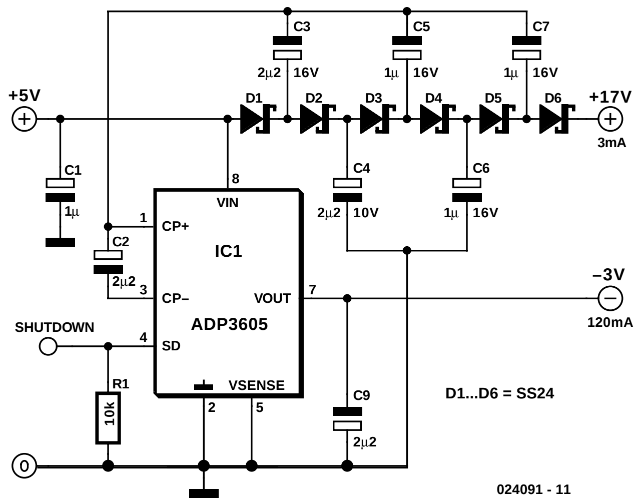
050

The circuit diagram shows a switched-capacitor voltage inverter with +5-V input and –3-V output, along with a supplementary cascade stage to generate a +17-V auxiliary voltage. The capacitor connected to the CP– and CP+ terminals assists in inverting the input voltage. During the first clock phase it is charged to the input voltage, while during the second clock phase its positive terminal is connected to ground while its other terminal is connected to the output. This generates a negative voltage at the output, with an amplitude equal to the input voltage. Using the duty cycle, the IC described here generates a regulated output voltage of –3 V with a current capacity of 120 mA.

The clocked operation makes it possible to connect an additional diode cascade stage for voltage multiplication. This consists of a series of diodes (for instance, type SS24 SMD Schottky diodes) with alternating pump and storage capacitors. The pump capacitors are connected to CP+ and charge when CP+ is at ground potential. When CP+ goes to a high-potential level, the potentials on the upper plates of the pump capacitors are pushed up. Each pump capacitor then discharges into the following storage capacitor (connected to ground) via the intermediate diode. The voltage increases with each pump stage, resulting in a net voltage of around +17 V after three voltage boosts, with a maximum load capacity of 3 mA.

The type ADP3605 IC is available from Analog Devices (www.analog.com/productSelection/pdf/ADP3605_a.pdf) and is housed in an SO8 SMD package. A High level (> +2.4 V) can be applied to the Shutdown input (SD) to disable the converter.

(024091-1)



DC Protection for the IGBT Power Amp

051

E. Potters

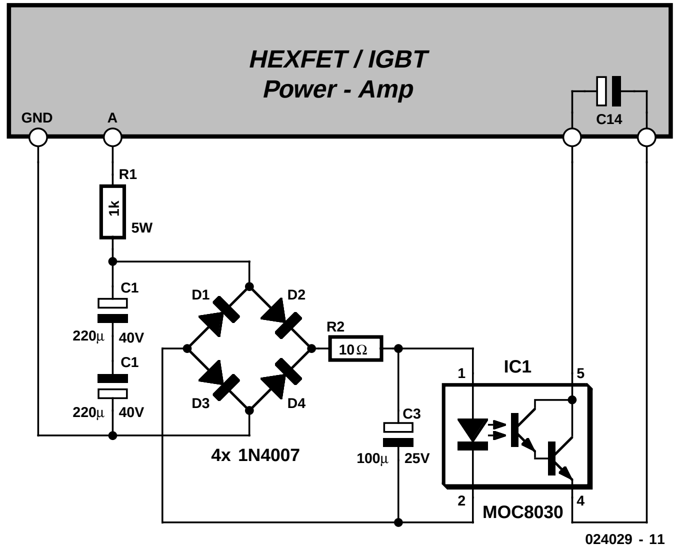
Some time ago, the author built a copy of the IGBT Power Amp, a final amplifier design described in the June 1995 issue of *Elektor Electronics* that has since become a classic. The sound quality provided by the amplifier was more than superb, but it was evident that the output transistors became quite hot during full-power testing (at 140 W). This is not uncommon, of course, but it set an alarm bell ringing, and it was deemed a good idea to at least add DC protection to safeguard the (expensive) amplifier and equally expensive speakers.

The accompanying schematic diagram shows the simplicity the necessary extension, which naturally can also be used with the Hexfet Power AMP described in the November 1993 issue (which is identical in terms of overall design). All that is involved is an optoisolator that monitors output terminal A of the amplifier via a bridge rectifier and series resistor, and whose output is connected in parallel with C14 in the relay control stage. This circuit can be used for all amplifiers up to a DC voltage of 70 V. For higher voltages, the value of R1 must be modified. When a voltage of approximately 2 V_{DC} is present at the input, the phototransistor in IC1 starts to conduct, causing C14 in the amplifier to discharge and disconnect the loudspeaker from the amplifier output by releasing the relay.

If you want to replace the MOC8030 by a different type, be sure to use a Darlington type (or fit an additional transistor) on account of the dynamic range. Also, pay attention to the maximum diode current, which is 80 mA for the MOC8030.

Another incidental point is that the IGBT Power Amp has a tendency to start oscillating if RF1 and RF2 are not low-inductance types or are replaced by other types of low-inductance resistors. In order to eliminate this problem once and for all, the following modification has been developed in the *Elektor Electronics* labs:

– Fit a 27-nF capacitor in parallel with R31 (on the solder side).
– Insert a 20-kΩ resistor between the collector of T8 and ground.
– Change R20 to 1k8.
– Change R17 and R18 to 390 Ω.



– Change R3 and R4 to 33 Ω.

These changes also proved to yield a slight improvement to the original IGBT Power Amp specifications.

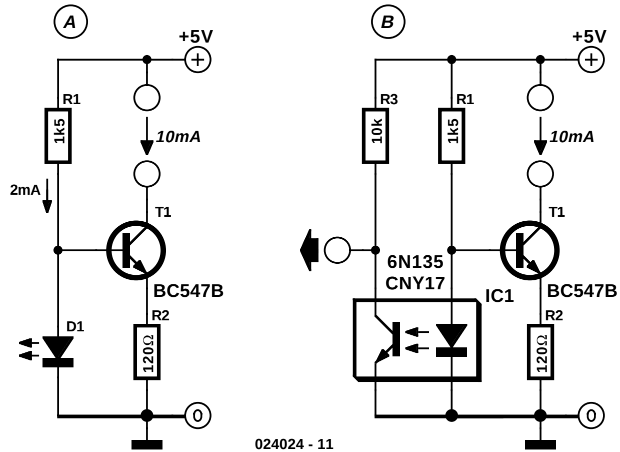
(024029-1)

Current Source with Indicator 052

There's nothing new about a current source consisting of a transistor, a resistor and an LED to provide the reference voltage. However, what many people do not realise is that the LED provides an excellent indication of the proper operation of the circuit.

First let's review how this circuit works. The voltage drop across the LED is approximately 2 V, with practically the same temperature coefficient as that of the transistor. This means that in principle the voltage across the emitter resistor is constant, since the base–emitter voltage is constant (at least for a fixed base current, and that is normally true with a constant collector current, which is what we want to achieve). A constant voltage across a resistance yields a constant current, and up to now everything is clear.

The current through the LED is chosen to nicely illuminate it, which means 1–2 mA in the case of a high-efficiency LED. The transistor also needs a bit of current – if 200 mA flows through the current source and the transistor has a gain of 200 (a 'B' type), this is 50 μA. However, if too little current (or no current) flows through the collector of the transistor, the voltage drop over R2 will decrease. This leads to a lower emitter voltage, and the transistor will attempt to boost the emitter voltage via its base–emitter junction. As a result, the current does not flow through the LED, but instead via the base. There is thus less current left over for the LED, which will quickly become dark. This means that whenever too little current flows through the current source the LED goes out, and this is an excellent *visual* indication of the operation of the current source. An excessively low current flow can be caused by the absence of the supply voltage, a disconnected or broken cable or an excessive load resistance.



A visual indication is nice to have, but we often need a logical indication in order to allow the signal to be further processed. In this case we can replace the LED by the LED of an optocoupler. As long as the LED receives sufficient current, the built-in transistor will conduct (with the output thus being Low). As soon as the current source no longer operates properly, the LED no longer receives any current and the transistor is cut off, so the logic output goes High. The type of optocoupler used is not critical; just about any common type is acceptable.

(024024-1)

Vibration Detector

053

Pradeep G.

This little circuit may act as a vibration-activated burglar alarm. The sensor, which may be secured unobtrusively to a door or a window, is a an inexpensive piezo buzzer. Piezo ceramic material deforms under application of voltage, but the reverse also applies, i.e., a piezo ceramic element will produce a voltage if it is deformed in any way, by acoustic waves (sound) or mechanical vibration.

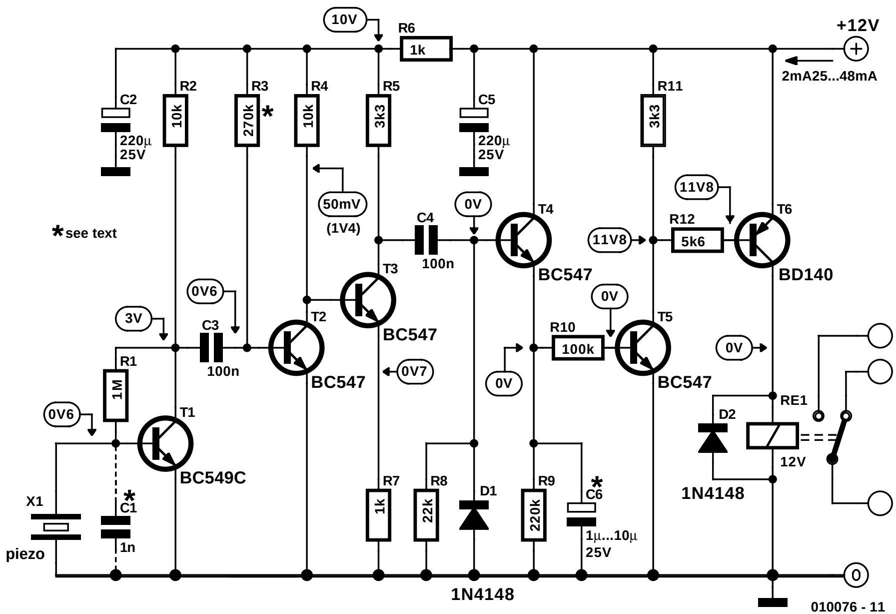
The first amplifier, T1, raises the piezo signal by about 100 times. Transistor T2 acts as a detector with a collector voltage of just 50 mV. Because R3 takes the base of T2 straight to the positive supply line, this transistor will conduct all the time and not add to the amplification. If necessary, more gain can be obtained by connecting the top end of R3 to the collector of T2. The next stage, T3, provides a voltage gain of about 3 times and drives the pulse rectifier, D1. When a sufficiently high pulse level is detected, T4 will rapidly charge C6 which, in turn, will slowly discharge via R9 and the high resistance presented by R10/T5. The value of C6 is subject to experiments because it alone determines the on time of the relay.

The cable between the sensor and the input of the circuit should be shielded and as short as possible. If strong RF fields are a problem, connect a 1-nF ceramic capacitor between the base of T1 and ground.

Finally, 'known' sources of vibration (including sound but also a large relay) should be kept away as far as possible from the sensor because they may cause false triggering of the alarm and/or oscillating behaviour.

Current consumption of the circuit will be of the order of a few milli-amps plus, of course, the relay energizing current.

(010076-1)

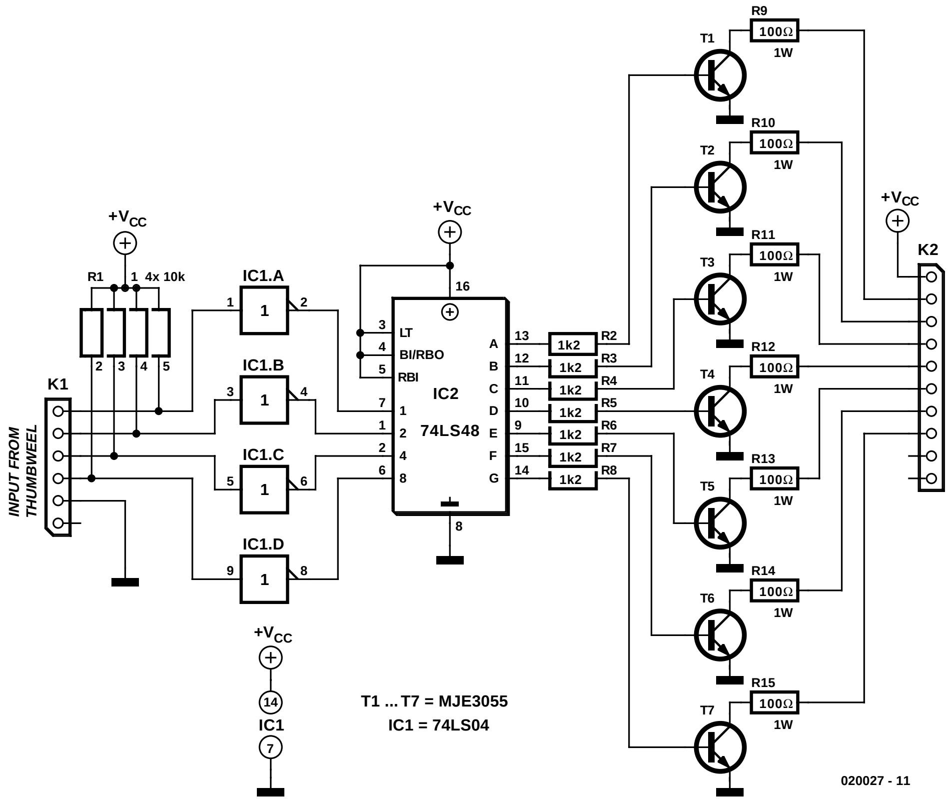


Token Number Display

054

Ketan Mehta

Numerical display systems are (unfortunately) very common in banks, shops and offices where they serve to manage a customer queue or waiting system. Commercially-made systems are very expensive because they are almost invariably microcontroller based. The circuit shown here is cost effective and relatively simple to make. The circuit employs BCD (binary coded decimal) thumbwheel switches are used to set any desired digit on the display. The switches are a cost-effective alternative to a microcontroller or a keypad. The floating lines of the thumbwheel switches are pulled up by 10-kΩ resistors. Four gates from a 7404 hex inverter IC invert the thumbwheel switch lines to create the BCD equivalent of the number selected on the switch. The BCD output is applied to the inputs of BCD to a 7-segment decoder type 74LS48 which is capable of driving a common-cathode (CC) display. Here, however, extra drive current is required for the (large) display so the 7448 outputs are connected to MJE3055 segment drivers. Because of the inverting action of these drivers, a common-anode (CA) 7-segment display has to be used.



The current consumption of the circuit will be negligible compared to that of the common-anode display.

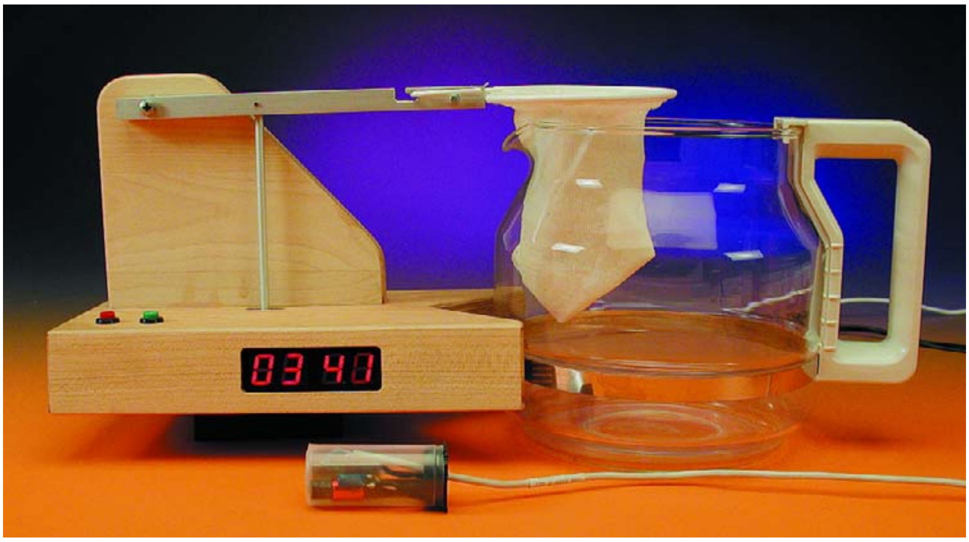
Three modules of this kind are required to display numbers up to 999. Next, please!

(020027-1)

Tea Timer

055

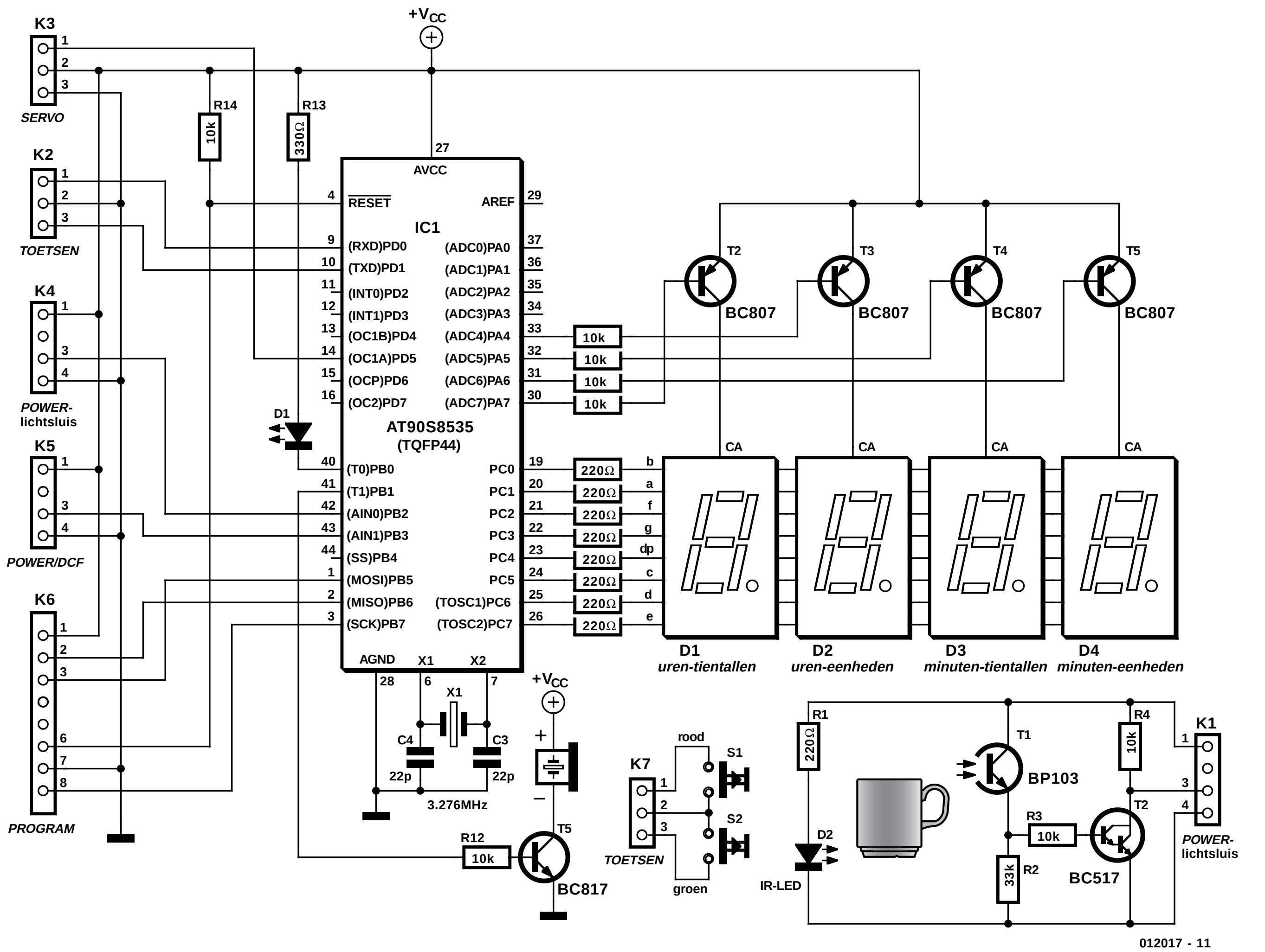
T. Finke



Tea drinkers take note: you are about to see the ultimate device for lifting the tea egg out of the teapot, complete with a microcontroller and DCF (radio time standard) control. Every tea drinker is familiar with the problem: you pour water into the teapot and turn your attention to something else while the tea is steeping. Naturally, you forget about the tea, and when you finally remember it has long since become a bitter muck.

The Tea Timer solves this problem by independently lifting the tea strainer out of the teapot or cup after an adjustable interval. The time is provided by a DCF module, which also displays the exact time of day when no tea is being brewed. However, if you place a teacup next to the Tea Timer, its display changes to show how long the tea strainer should remain in the pot. This time can

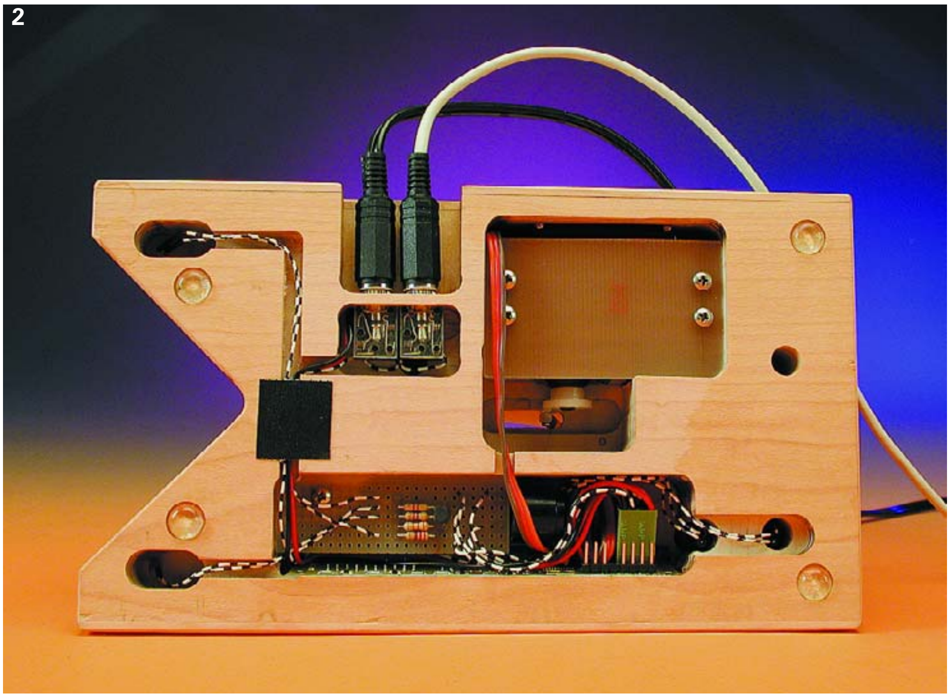
1



be adjusted whenever desired using a pushbutton. Next, you pour water into the pot and press the Start button. The remaining time is displayed, and when the counter reaches zero a servo lifts the teabag out of the tea. After a short pause – after all, the teabag has to drip off – a buzzer sounds to indicate that 'tea's on'.

A glance the circuit diagram in **Figure 1** shows that an AT90S8535 microcontroller (well known to regular *Elektor Electronics* readers) orchestrates the actions of the Tea Timer. The following devices are connected to its ports:

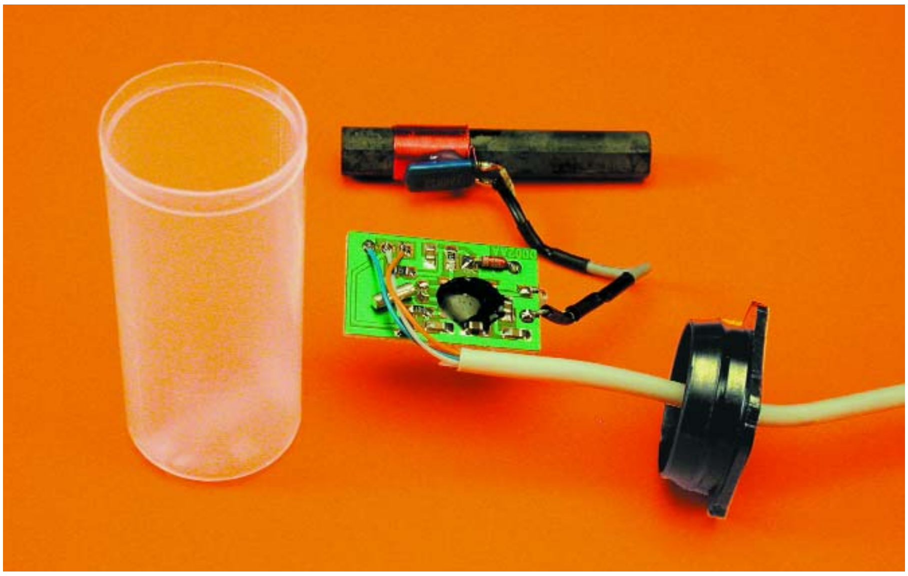
2



- Four multiplexed LED modules with driver transistors for displaying the remaining time (in minutes and seconds) and the time or date (in hours and minutes, minutes and seconds or day and month, selectable using a pushbutton).
- An R/C model servo connected to X3.
- An LED that blinks in sync with the DCF signal after power is applied so the antenna can be properly oriented and then remains on steadily.
- A light-barrier sensor consisting of an IR LED and a phototransistor (almost any IR type can be used), connected to X4.
- A DCF module connected to X5.
- Two pushbuttons connected to X2.
- A programming connector (X6).

If you look at the carefully routed-out bottom of the Tea Timer (**Figure 2**), you can see how the electronics are arranged. The light barrier sensor can be seen at the left, with the light barrier buffer being built on a small piece of prototyping board. The main circuit board (layout available from the *Elektor Electronics* website as a PDF file) with the microcontroller and the four seven-segment displays is fitted at right angles to the light barrier and can barely be seen here; only the programming connector (a pin header) protrudes. The two pushbuttons are fitted to the right of the main circuit board. The R/C servo, which moves the teabag up and down via the linkage, is secured in the large recess with the circuit board segment.

Finally we have the two external connectors (miniature stereo phone sockets) on the right: one is for the DCF module with its ferrite antenna, which is housed in a small, empty IC tin (visible in the foreground of the title picture), and to its left is the power connector. Any mains adaptor that can supply a well-stabilised 5 volts at 300 mA is suitable as a power source. However, additional stabilisation in the form of a fixed-voltage regulator can't do any harm and can certainly be fitted into the housing.



The microcontroller is programmed in C. Both the hex file (for directly programming the microcontroller) and the C source text are available in the Free Downloads section of the *Elektor Electronics* website. The definitions SERVO_O and SERVO_U at the beginning of the code (commented in German), which represent the angle settings of the servo for the 'arm up' and 'arm down' positions, respectively, may need to be adjusted in certain situations. Even if you don't have a compiler, these values can easily be modified in the hex code.

The DCF time standard transmitter can be received within a range of about 1,500 kilometres from Düsseldorf, Germany.

(012017-1)