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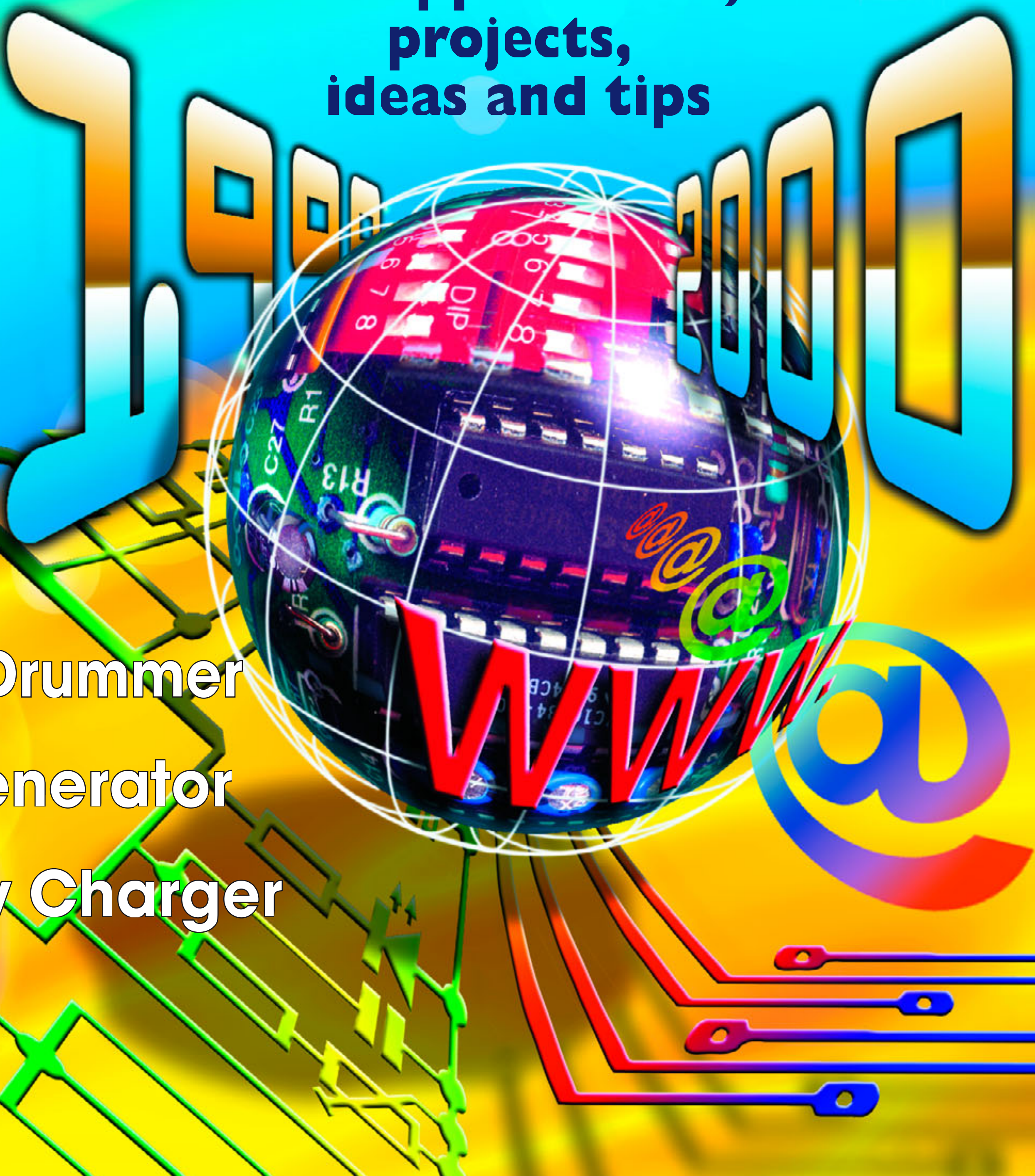

Funky Drummer

CW Generator

Battery Charger

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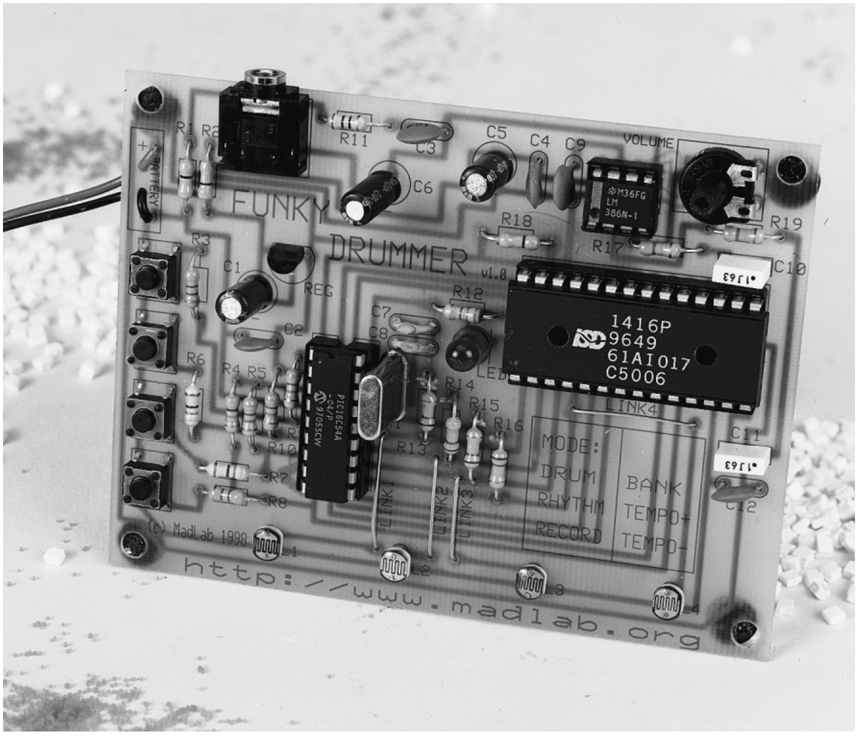
MISCELLANEOUS INFORMATION

funky drummer

a programmable drum machine

This article presents a novel use for a voice recording chip — a programmable drum machine.

Design by MadLab, Edinburgh



The voice recording IC used is the 1416P ChipCorder from Information Storage Devices (ISD). This is one of the best of its kind on the market. It is a complete solution in a single chip. It doesn't need external memory or amplification and can be used with just a microphone, a speaker and a few passive components to make a complete working voice memo recorder. The memory in the chip is non-volatile which means that recordings are retained when power is removed. The technology is E^2PROM memory technology (electrically-erasable programmable read-only memory) but with an interesting twist. Normally an E^2PROM cell stores a single digital bit of information but in this chip the cells are used as analogue storage. The charge in a cell represents the analogue voltage sampled during recording. Signals are not digitised so no analogue-to-digital and no digital-to-analogue circuitry is needed. It's a clever approach that the manufacturer claims is equivalent to digitising at 8-bit resolution.

Digital memories that use E^2PROM technology saturate cells with large amounts of charge to avoid the possibility of reading a cell back as a zero when it should be a one. But using E^2PROM cells to store analogue sound signals 100% accuracy doesn't matter. If the voltage read back is slightly different to the voltage that was stored one wouldn't be able to hear the difference. It would matter greatly if digital information was being stored. Having said this in fact ordinary computer memory is moving in the multi-level direction with devices available from companies such as Intel which store 2 bits per cell, thus doubling the storage capacity of a chip with little increase in the physical die size.

The ChipCorder

The ChipCorder is designed for recording the human voice so it doesn't need to be responsive to a wide range of frequencies. The cut-off filter is at just above 3 kHz which gives about the same bandwidth as a telephone. Nevertheless it works surprisingly well at recording both low frequency sounds such as a bass drum and high frequency sounds like a crash cymbal. The chip contains anti-aliasing and conditioning circuits to improve the sound quality.

The total time available for recording is 16 seconds which doesn't sound like very much but, because the time can be partitioned into small segments, a large number of samples can be stored. The chip is 'randomly addressable' (in segments of 100 ms) which means that an individual sample can be picked out and played in isolation.

The ISD ChipCorder is controlled by a microcontroller, one from the very popular PIC stable. This family of microcontrollers has come to assume a dominant position in the hobbyist constructional world. Deservedly so because they are cheap, robust and easy to program. Support in the form of magazine articles and affordable development tools

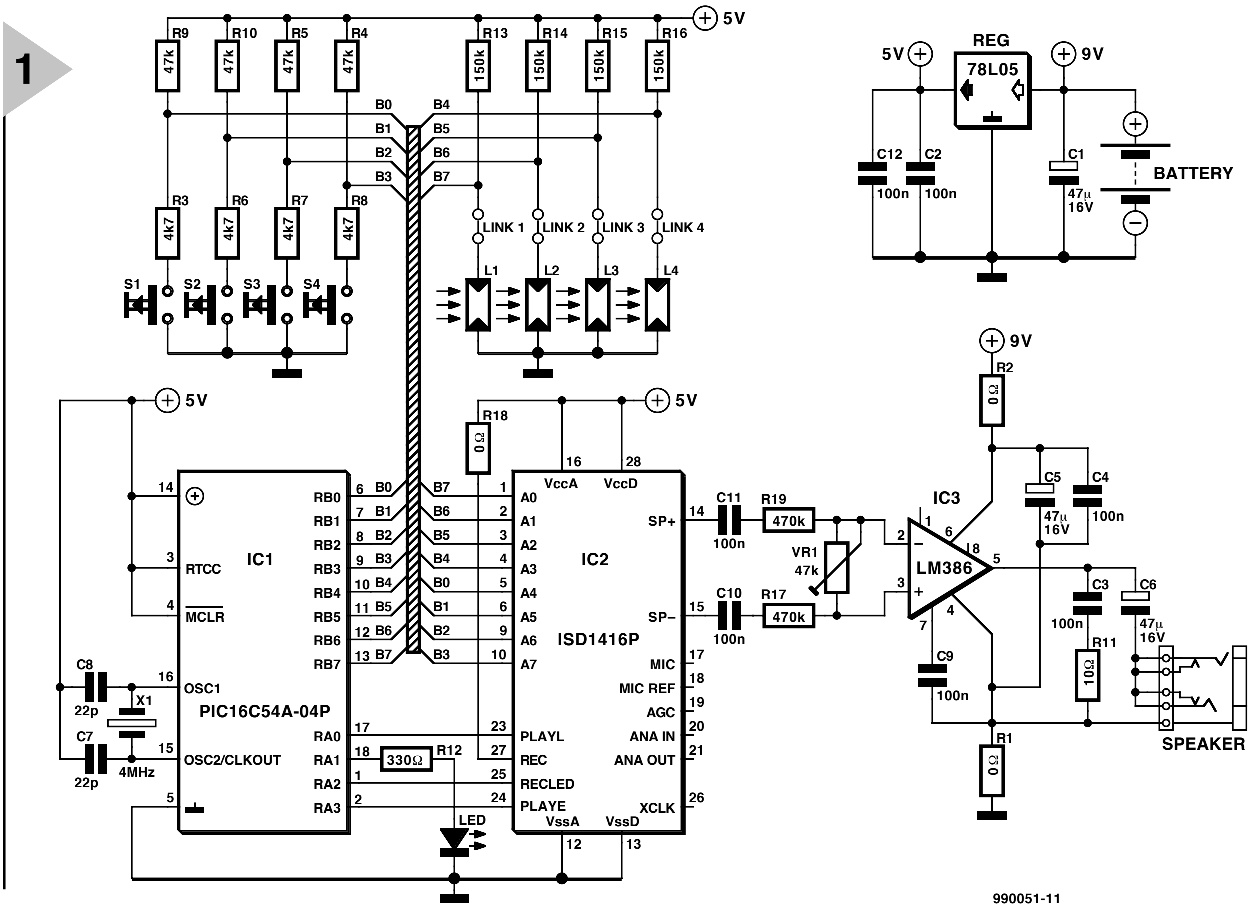


Figure 1. Circuit diagram of the Funky Drummer. The main components are a programmed PIC and a 'Chipcorder' IC.

from independent companies is widely available. This design uses one of the earlier PICs, for the simple reason that it doesn't need a more advanced chip. For development purposes a PIC with *in situ* programming is to be preferred because it is so much easier to re-program in place on the prototype board than to pull the chip and put it in a UV eraser, but once the development is complete a cheaper chip can be used in the final design. All the PICs use the same instruction set (more or less) so to migrate finished software to a different chip is simply a matter of changing a few lines such as the restart vector. In fact a single source code file can be used with conditional assembly of different lines for different processors. If you look at the source code for this project you will see that it was developed on a PIC16C84 which has electrically-erasable program memory.

The features

Funky Drummer has 40 pre-recorded drum sounds, 12 pre-programmed rhythms and the facility to program a rhythm of one's own. The tempo of both the pre-programmed and the user rhythm can be varied. **Table 1** lists the drum sounds and **Table 2** lists the pre-programmed rhythms. There are a few 'fun' samples included such as a chicken, as well as exotic South American percussive sounds like the quijada.

The drums are triggered using 4 touch switches. The drums are divided into banks of 4, and a pushbutton selects between banks.

The pre-programmed rhythms are also triggered by the touch switches. The bank pushbutton selects 4 rhythms at a time.

A single user rhythm can also be recorded. This is volatile and will be lost when the battery is disconnected. A metronome clicks on the beat and an LED flashes while the rhythm is being recorded. Up to 11 drum hits can be programmed in the user rhythm.

The design

To work effectively as a drum machine the switches that trigger the drums must be very responsive to touch. One needs to be able to rapidly tap out a rhythm with one's fingers. Electromechanical switches were ruled out as being too slow and awkward. An optical solution was settled upon using miniature light dependent resistors (LDRs). These are devices whose resistance changes depending on how much light they are exposed to. In light their resistance is around 50 kilohms and in darkness the resistance rises to several megohms.

There are 40 drum sounds but only 4 touch switches to play them. Some means of accessing the drums in banks was needed and this was achieved by using a pushbutton to step through the available drums in banks of 4 at a time. On power-up bank 1 is selected. The first time the pushbutton is pressed bank 2 is selected, and so on up to bank 10, when pressing the pushbutton selects bank 1 again.

Another pushbutton was needed to select between drum, rhythm and record modes. In rhythm mode the bank button selects banks of rhythms. And finally two pushbuttons were added to increase and decrease the tempo.

The ChipCorder has an internal amplifier and can drive an external speaker directly but it was decided to add an extra stage of amplification. This usefully provides a volume control. And after all this is a drum machine and should be loud!

THE SOFTWARE

The sample memory of the ChipCorder can be partitioned into chunks which are multiples of 100 ms in length. The different drum samples are stored at different offsets, at 100 ms boundaries, in the sample memory. The PIC needs to know where each drum sample begins so that it can play it when called upon to do so. These offsets, or addresses, are stored in a lookup table in the PIC's program memory. This is simply a list of addresses for all the drum samples. Some re-ordering of the bits is necessary to match the PIC port pins to the ChipCorder address lines. This is performed by an assembler macro.

The software doesn't need to know how long each sample is because this is handled directly by the ChipCorder. It has a separate array of single-bit memory which it uses to flag the end of each sample. A pulse appears on one of its pins when the end-of-sample bit is encountered and the PIC looks for this signal. The PIC can restart a sample or cancel the playback of one sample and play another depending on the actions of the user.

The pre-programmed drum rhythms are also stored in a lookup table in the microcontroller's program memory. An entry in the table describes a single 'event' in a rhythm and has the form `dddddsss`, where the top 5 bits (`ddddd`) are the drum index and the low 3 bits (`sss`) are the sustain. The drum index is simply the drum number from 1 to 31 (00001 to 11111 in binary), and the sustain is the length of time the drum sound is played for (in other words the time between successive rhythm events). Binary 000 represents a sustain of 1 unit, 001 a sustain of 2 units, and so on. Only the first 31 drum sounds can be used in the pre-programmed rhythms and you may wonder why drum index 0 is not used. The reason is that the special value of all zeroes (00000000) represents the end of the rhythm. When this bit pattern is encountered the software loops back to the start so that the drum rhythm can repeat itself. This technique of packing bits into bytes is very common when writing microcontroller code and allows the maximum performance to be squeezed from the limited memory resources. Of course it takes extra software to extract the packed data from the table but on balance the technique achieves a saving.

Here is a sample rhythm along with a macro that makes the source code more readable. Note that the drums have been given symbolic names. The format d'n' is just the syntax the assembler uses for a decimal constant, and `entry` is another macro that hides the confusing instruction the PIC uses to implement a lookup table.

```
event    macro drum,sustain
   entry  (drum<<3)+(sustain-1)
   endm

   event  BASS2,d'4'        ; reggae
   event  BASS3,d'3'
   event  BASS2,d'1'
   event  CL_HIHAT,d'4'
   event  BASS3,d'4'
   entry  0
```

A particular rhythm is found by stepping through the lookup table counting the number of zero bytes reached. For example, to find the third rhythm the first two rhythms must be stepped over. This means counting two zero bytes then the next byte is the start of the rhythm.

A slightly different format is used for the rhythm that the user can program. This is stored in RAM rather than ROM and the former is in even shorter supply than the latter. In fact there are only 25 bytes of usable RAM for everything so bit packing is absolutely essential. The situation is complicated by the addition of a metronome which clicks while the rhythm is being programmed but is silent afterwards, and a special 'pad' bit pattern which initially fills the buffer and is overwritten by rhythm events. A consequence of this is that only the first 16 drums can be used in the user rhythm. The memory buffer for storing the user rhythm is 15 bytes, and because the metronome clicks always use up 4 bytes this leaves the maximum number of rhythm events at 11.

The touch switches need special handling to stop them 'bouncing', which might cause a drum to repeatedly re-trigger when activated. The touch switches are polled about 60 times a second.

A design feature of the ChipCorder which had to be circumvented was the inbuilt debounce period which is useful when the chip is operated by noisy pushbuttons. This debounce period is not needed when the chip is driven by a microcontroller which generates sharp edges on its control pins but nevertheless is still in effect and cannot be disabled. A delay loop in the software takes account of the debounce period.

The rhythm tempo is controlled by the real-time clock counter built into the PIC. A software subroutine extends this from the 8-bit hardware counter to a 16-bit software counter to give the required timing resolution.

This short description of the software can only cover the major points. If you are interested then study the source code (see Component sources below for how to obtain a listing) to fully understand the workings of the drum machine. This software is a good example of how much functionality can be achieved with even the smallest of microcontrollers — the PIC16C54 has only 512 words of program memory. The art of writing microcontroller code is the art of the minimal, of repeatedly writing and re-writing, and then staring at the code to see how a byte here and a byte there can be saved. It is the antithesis of programming for big machines like a PC where one doesn't think twice about grabbing a memory buffer of a few hundred kilobytes in an application. It is the author's opinion that coding for a microcontroller is more satisfying.

THE CIRCUIT

The regulator provides a reliable 5V for the digital ICs. Capacitors C1 and C2 together smooth the supply for the PIC. C2 has a smaller capacitance than C1 but reacts faster. Similarly C5 and C4 smooth the voltage rail for the op-amp. Capacitor C12 decouples the ChipCorder. Any voltage between 5V and 12V dc can be used to supply the board. Normally a 9V PP3 battery would be used. The board draws about 40mA at maximum volume. The ChipCorder is power efficient and enters a low-power standby state immediately after completing a sample.

The ChipCorder has its own amplifier built in and can drive a speaker directly. But for increased loudness an extra stage of amplification has been used. The amplifier is the circuit suggested by ISD, using a LM386 op-amp. A differential design is used since a single-ended amplifier would give rise to annoying 'pops' at the end of each sample. The signal from the ChipCorder is coupled to the differential amplifier by C10 and C11, along with R17 and R19. VR1 sets the differential gain and acts as a volume control. R11 and C3 are a protection network for the op-amp, and C9 is a bypass capacitor necessary for amplifier stability. C6 ac couples the output of the amplifier to a stereo jack socket with the left and right channels wired together.

The 4 MHz crystal along with C7 and C8 provide the clock for the micro-

User guide

Funky Drummer operates in 3 modes – drum, rhythm and record mode. To change mode first press and hold the **MODE** button (S1) then press one of the other three buttons (S2 to S4). The box on the printed circuit board reminds you of this.

DRUM mode
Funky Drummer is in drum mode when the battery is first connected.
The touch switches (L1 to L4) play drums in banks of 4 according to Table 1.
The **BANK** button (S2) steps through the banks of drums. There are 10 drum banks in total.

RHYTHM mode
Pressing the **MODE** button (S1) then the **RHYTHM** button (S3) puts *Funky Drummer* into rhythm mode.
The touch switches (L1 to L4) play rhythms in banks of 4 according to Table 2.
The **BANK** button (S2) steps through the banks of rhythms. There are 3 rhythm banks in total.
The **TEMPO+** button (S3) increases the tempo and the **TEMPO–** button (S4) decreases the tempo.
The LED flashes briefly at the start of each rhythm.

RECORD mode
Pressing the **MODE** button (S1) then the **RECORD** button (S4) puts *Funky Drummer* into record mode. A metronome starts which clicks and flashes the LED on every beat (4 beats in the bar).
The touch switches (L1 to L4) record drums. The rhythm is layered with each new drum being added to the loop. Up to 11 drum hits can be recorded.
The **BANK** button (S2) steps through the banks of drums. Note that only the first 15 drums can be recorded.
The **TEMPO+** button (S3) increases the tempo and the **TEMPO–** button (S4) decreases the tempo.
Pressing the **MODE** and **RECORD** buttons again stops the metronome click but the recorded rhythm continues until another button is pressed.
Record your rhythm at a slow tempo then speed it up when finished.

Table 1. Drums

Bank	*L1*	*L2*	*L3*	*L4*
1	bass # 1	snare # 1	low tom # 1	closed hihat
2	bass # 2	snare # 2	low tom # 2	open hihat
3	bass # 3	snare # 3	taiko	crash cymbal
4	snare # 4	high tom # 1	high tom # 2	high tom # 3
5	low bongo	high bongo	low conga	high conga
6	low agogo	high agogo	timbale	timpani
7	brush # 1	brush # 2	cabasa	china cymbal
8	triangle	cowbell	clap	snap
9	kalimba	whistle	scratch	gunshot
10	quijada	bubble	chicken	rimshot

Table 2. Rhythms

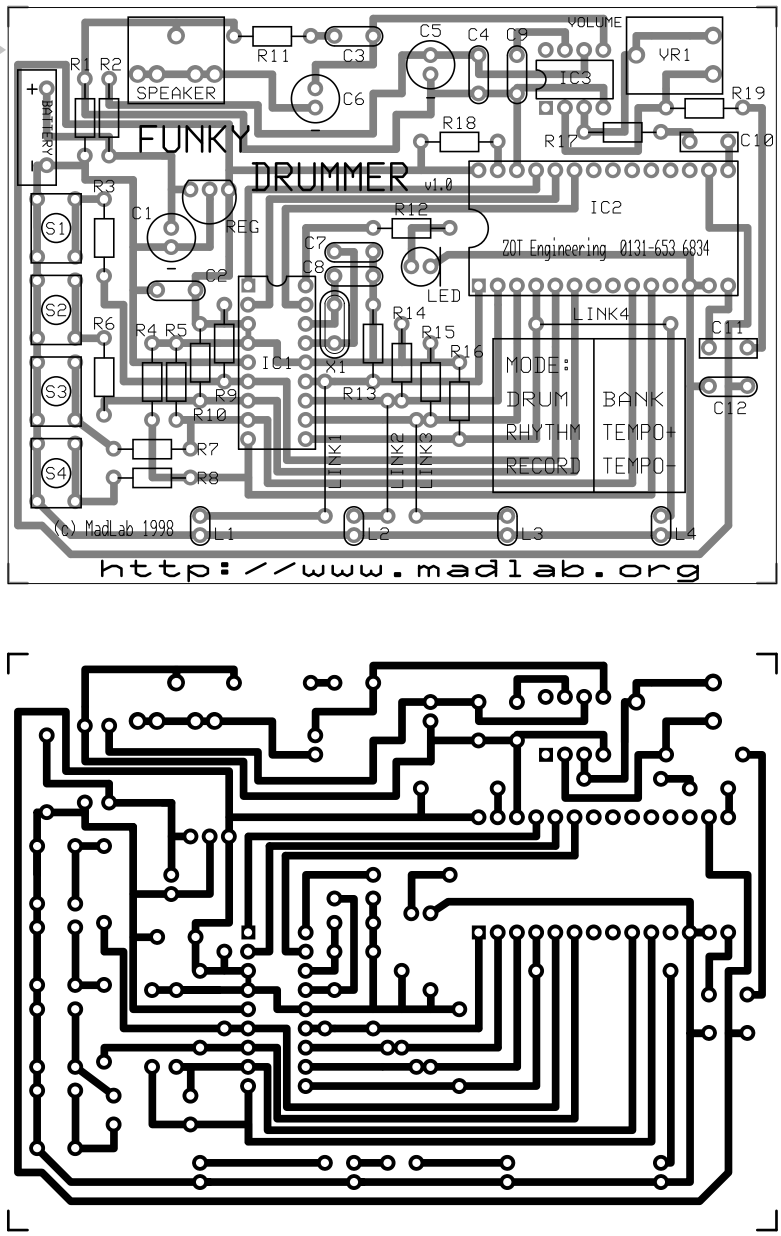
Bank	*L1*	*L2*	*L3*	*L4*
1	8beat # 1	8beat # 2	8beat # 3	8beat # 4
2	jazz	shuffle	reggae	samba
3	disco # 1	disco # 2	elec pop	pattern # 1

controller. Accurate timing is not essential for the software so a simple RC-type oscillator could have been used instead.

Light dependent resistors L1 to L4 work in conjunction with resistors R13 to R16 as potential dividers. As the resistance of the LDRs change, depending on their exposure to light, the voltage at the PIC's pins changes.

The pushbuttons and the ChipCorder address lines share the same pins on the PIC. This can work because the ChipCorder latches the address internally, so as soon as an address has been strobed into the chip the pins are available for polling the pushbuttons. This doubling-up of pins is a very common technique for increasing the effective number of I/O ports on a microcontroller. Resistors R4, R5, R10 and R9

2



COMPONENT LIST

Resistors:
(all 1/4W 5% carbon film)
R1,R2,R18 = 0Ω
R3,R6,R7,R8 = 4kΩ7
R4,R5,R9,R10 = 47kΩ
R11 = 10Ω
R12 = 330Ω
R13,R14,R15,R16 = 150kΩ
R17,R19 = 470kΩ
VR1 = 47kΩ enclosed carbon variable resistor (vertical adjustment) + spindle
L1-L4 = miniature light dependent resistor (see text)

Capacitors:
(electrolytics 2.5mm spacing, others 5mm)
C1,C5,C6 = 47µF, electrolytic 16V
C2,C3,C4,C9,C12 = 100nF ceramic
C7,C8 = 22pF ceramic
C10,C11 = 100nF miniature polyester

Semiconductors:
REG = 78L05 5V regulator
LED = red 5mm LED
IC1 = PIC16C54A-04P (microcontroller, programmed)
IC2 = ISD1416P (ChipCorder)
IC3 = LM386

Miscellaneous:
X1 = 4MHz crystal, HC49/U case
S1-S4 = miniature tactile pushbutton (PCB mounting)
SPEAKER = 3.5mm stereo jack socket (PCB mounting)
LINK1-LINK4 = 3cm wire link
BATTERY = PP3 battery snap
18-pin DIL socket
28-pin DIL socket
8-pin DIL socket
4 x PCB pillars or rubber feet (to fit 4mm hole)
PCB, available from MadLab (see text)
Disk, PIC object code, available from MadLab (see text)

Figure 2. PCB artwork. Ready-made circuit boards for this project are available from MadLab, Edinburgh.

(47k) pull up the pushbuttons to 5V, and resistors R8, R7, R6 and R3 (4.7k) provide loads when the PIC is driving the pins. The ratio of these two resistances (10:1) is chosen such that the PIC senses a low when a pushbutton is pressed.

A design weakness of the ChipCorder (at least as far as this application is concerned which relies on its storage being non-volatile) is that the record pin, which is active low, is next to a pin which is grounded. If these two pins should momentarily short then the chip goes into an erase cycle and overwrites its memory, so be warned. This of course can only happen when the chip is powered up. To minimise the risk of this occurring the record pin is tied to the positive supply rail by a zero ohms resistor. If the two pins should touch then a short across the power rails occurs which will crash the power supply and the chip will no longer be powered up, and so is protected. This seems to be a robust solution to the problem.

CONSTRUCTION

Construction is straightforward. The resistors (R1 to R19) should be soldered first followed by the wire links (LINK1 to LINK4). Identify the resistors by the coloured stripes on the body. The IC sockets (IC1 to IC3) should then be soldered with their notches matching the notches in the symbols on the board. It is not recommended that the chips are soldered directly to the PCB.

Next fit and solder the capacitors. The electrolytic capacitors (C1, C5 and C6) are polarised, the minus sign on the board corresponds to the shorter leg or leg near the stripe on the side of the body. The ceramic and polyester capacitors (C2 to C4, C7 to C12) can be soldered either way around.

The light dependent resistors (L1 to L4) should then be soldered to the board. The LDRs are liable to melt if overheated so be very careful when soldering them. Ensure they are flat on the board.

Solder the variable resistor (VR1) and push the spindle into the hexagonal hole in the top. Solder the regulator (REG) matching its shape to the symbol on the board, and the LED fitting the shorter leg into the hole with the line. Next solder the crystal (X1), the pushbuttons (S1 to S4), and the jack socket (SPEAKER).

The wires for the battery snap have support holes on the board. Feed the wires through the support holes from the track side of the board before soldering them. Red is positive and black is negative.

Don't fit the ICs into their sockets until the procedures in Testing below have been followed. When fitting the ICs you will find the legs need bending a little first. Do this carefully with your fingers. Match the notches in the ICs to the notches in their sockets.

Finally attach the rubber feet to the four corners of the board.

TESTING

Thoroughly examine the circuit board for mistakes before connecting a battery. Check that all the components have been fitted correctly and that there are no dry joints and no solder bridges between tracks.

Power up the board without the ICs in their sockets. Check the voltage at pin 14 of the PIC socket and pins 16 and 28 of the ChipCorder socket. You should see a regulated 5 volts. The voltage at pin 6 of the op-amp socket should be the unregulated supply voltage (9V). The top or bottom of link R1 is a good ground point for taking measurements.

As mentioned above the ChipCorder is liable to wipe its contents if incorrectly connected so double check this part of the board. Check the voltages on pins 27 and 26. Pin 27 should be at 5V and pin 26 should be at 0V.

Examine pins 6, 7, 8 and 9 of the PIC socket. You should see a level change when the pushbuttons are pressed.

Power down the board and insert the LM386 op-amp. Check the output pin 5. The voltage should be half the supply voltage (4.5V).

Power down the board and insert the PIC. Check that the microcontroller is oscillating by looking at pin 15 with a high-impedance oscilloscope. You should see a 4MHz oscillation.

Finally insert the ChipCorder chip. Connect a speaker to the jack socket via a lead with a 3.5mm jack plug, set the volume control to mid point, and connect a battery. The software includes a power-on self test. The LED is flashed briefly and a 'beep' is sounded. If this happens then you can be sure the microcontroller, the ChipCorder and op-amp are all working.

Resistors R1-R16 (150k) are optimal values for average lighting conditions. Depending on the characteristics of the actual LDRs used these resistors may need adjusting. Indeed the characteristics of LDRs seem to be quite variable even within the same batch. Examine the signal at the LDR end of resistors R13 to R16. You should see a voltage of about 0.5V when the associated LDR is uncovered and this should rapidly rise to around 4V when covered. 1.4V is the threshold voltage at which the PIC senses the difference between a 0 and a 1. If the voltage does not rise above this value then decrease the value of these resistors (to 120k or 100k say). Note that it is normal to see a 50Hz ripple on this signal due to room lighting.

Experiment with the lighting conditions to get the best response from the touch switches. You might find that small pieces of opaque tape wrapped around the ends of your fingers improve performance.

CASING

This project is designed to be uncased. If however you wish to case it then any small box of approximate dimensions 15cm by 10cm by 5cm will do. Mount the pcb in the bottom part of the case using spacing pillars at the four corners of the board (fitting 4mm holes). Certain components will need mounting on the exterior of the case so the components used should be panel-mounting rather than pcb-mounting varieties. These components are the LED, the pushbuttons, the touch switches, the jack socket and the volume control. Wires can be run from the front panel components to the solder pads on the PCB. The touch switches can be mounted directly on the top of the case. You could if you wish use pushbuttons (of the push-to-break variety) in place of the LDRs but they wouldn't be as responsive. A small speaker of impedance 8 ohms could also be mounted inside the case, in which case the jack socket wouldn't be required. Finally an on-off switch should be included when mounting in a case, in the positive line from the battery.

COMPONENT SOURCES

Most of the components are standard and are easily obtainable. The more unusual parts can be obtained from (among others) Maplin Electronics. The Maplin order code for the PIC is NR92A, for the miniature pushbuttons is KR89W, and for the miniature light dependent resistors is AZ83E. It is important to use miniature LDRs which can be completely covered by a fingertip. If panel mounted rather than pcb pushbuttons are used then any small push-to-make button would be suitable. The jack socket can also be obtained from Maplin (order code JM20W), as can the variable resistor (DT39N) and spindle (DT47B).

Maplin also sells the ISD1416P ChipCorder. If you purchase this chip from them you will need to record the sound samples into it yourself. This should only be attempted by those people who have the technical skill to build a programmer for themselves (as yet there is no ChipCorder programmer on the hobbyist market but such a device may form the basis of a future article). If you go down this path then you could, of course, record a completely different set of drum sounds.

A suitable speaker is a small cased speaker for use with a Walkman cassette player, or a multimedia speaker for a PC. These types of speakers are quite widely available at reasonable prices. You can use powered speakers for even more volume.

Both complete kits and the individual specialised components are available from MadLab. A professionally-manufactured printed circuit board with tinned tracks and silk-screened legend is available at £4.00, a pre-programmed PIC at £6.00, and a pre-recorded ISD ChipCorder at £8.00. A complete kit of parts including the pcb, ICs and all other components is available at the price of £25.00. All prices are inclusive of P&P. Please make cheques and postal orders payable to MadLab Ltd, and send your order to MadLab, 149 Rose Street, Edinburgh EH2 4LS. Orders will be despatched within 28 days.

The PIC source code is available for perusal on our website at *http://www.madlab.org/pic.html* or, for those people who don't have access to the Internet, on a 3.5" PC-format floppy disk. The disk contains both documented source and object code for the software, as well as all the drum samples in .wav format. This disk is available from the above address for £2.50 inclusive.

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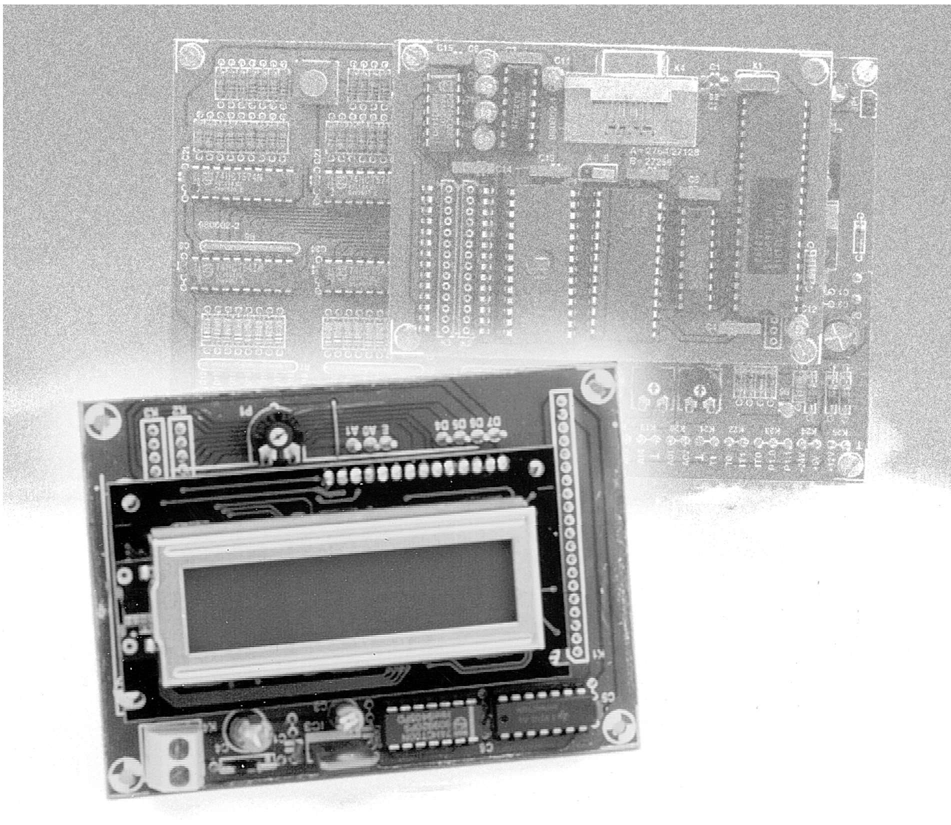
LCD drive

via 8032 BASIC



The 80C32 BASIC control computer published in the February/March 1998 issues of this magazine lends itself to a number of interesting experiments. One of these, described in this article, is its use as direct driver for a liquid crystal display via a 4-bit or 8-bit interface.

Design by A. Köhler

INTRODUCTION

Programmed with the MCS-51 BASIC interpreter, the 80C32 BASIC control computer published in this magazine early last year enables interesting experiments even for those who do not have special knowledge of microcontroller programming.

The single-board computer (SBC) consists of a small main computer board on which the microcontroller is configured, and a larger multifunction extension board to which the main board is fitted. What was not foreseen is a simple, direct connection for a liquid-crystal display (LCD). The present article describes a setup that allows a standard 2×16 character LCD to be connected to the control computer.

The display is driven via the 4-bit interface of the extension board or a discrete 8-bit interface. The latter is no doubt the better solution since only the microcontroller configuration is needed to drive the LCD. Nevertheless, the article gives short BASIC listings for both variants.

4-BIT INTERFACE

Most alphanumeric liquid-crystal displays are based on a member of the HD64780 family of controllers. In most literature on these controllers, the possibility of driving the circuits via four data lines is often not included. Apart from these lines, the control of an LCD also requires three status lines. If a back signal from the display is not needed, it is possible to make do with six control lines.

This small number of lines makes it possible for the LCD unit to be driven via an 8-bit output port. For this purpose, port connections D_{01}–D_{08} (K_{13} to K_{16} on the extension board) are used; note that D_{07} is not used.

Output power driver IC_8 would not be required were it not for the fact that it must support the software for inverting the signals. This is true of the listings for both versions. Listing 1 is for use with the original circuit, whereas with Listing 2 the port lines of IC_8 are replaced by wire bridges. In this case, the LEDs in the port lines are, of course, superfluous.

The programs are annotated liberally, so that a detailed discussion here is not needed.

The control bits (type of display, matrix format, reset, cursor to the left or right, and so on) are set up to line 170 and sent to the display controller via routines 700–780. The bits on the output interface are allocated as shown in the table below.

Even though the display is limited to 2×16 characters, the controller drives 2×40 characters at all times. Since a return line from the display to the SBC is not provided, the software must ensure that after the 2×16 visible characters (program lines 250–300) have been input, the invisible character positions in the memory are filled with space characters. This is effected in program lines 310–350.

Finally, the data bits are sent to the controller in routines 400–600: the four most significant first, the least significant last.

It should be ensured that the busy flag is enabled only after the third output of 03H (line 60).

Note the row of 'wait' loops that make any kind of handshaking unnecessary. These loops are generously proportioned and may be shortened if required.

Power for the interface is derived from the SBC.

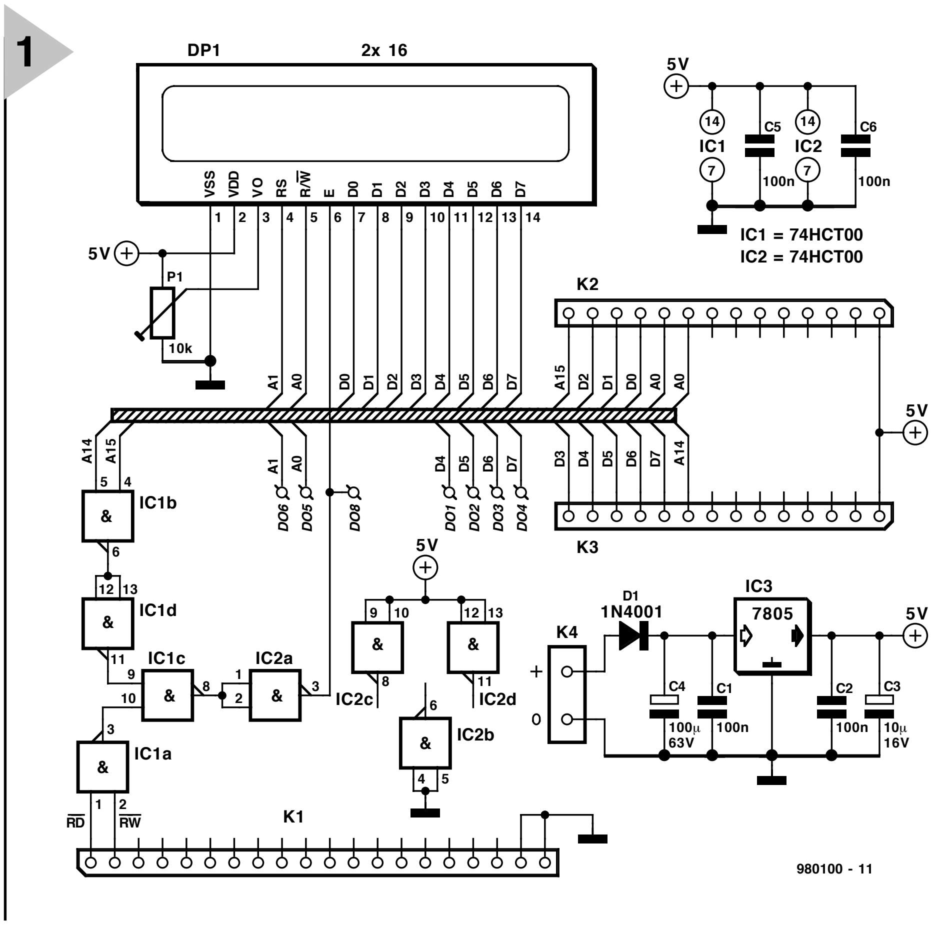


Figure 1. Circuit diagram of the LCD interface. In the 4-bit version, the components associated with regulator IC_3 may be omitted.

Bit	Significance	LCD pin
7 (D_{08})	LCD latch enable(active high)	6
6 (D_{07})	not used	
5 (D_{06})	RS (L= command; H= data)	4
4 (D_{05})	R/$\overline{W}$ (L= write)	5
3 (D_{04})	LCD data bit 7	14
2 (D_{03})	LCD data bit 6	13
1 (D_{02})	LCD data bit 5	12
0 (D_{01})	LCD data bit 4	11

8-BIT INTERFACE

It is, of course, much neater to link the liquid-crystal display directly to the SBC, for which purpose the computer and display interface have the same types of connectors. The controller then receives, apart from the earlier mentioned control signals RS (address A_1) and R/$\overline{W}$ (address A_0), all eight data bits in parallel. Taking a basic address of 0C000H, the address allocation is

0C000H	write instruction
0C001H	read instruction
0C002H	write data
0C003H	read data

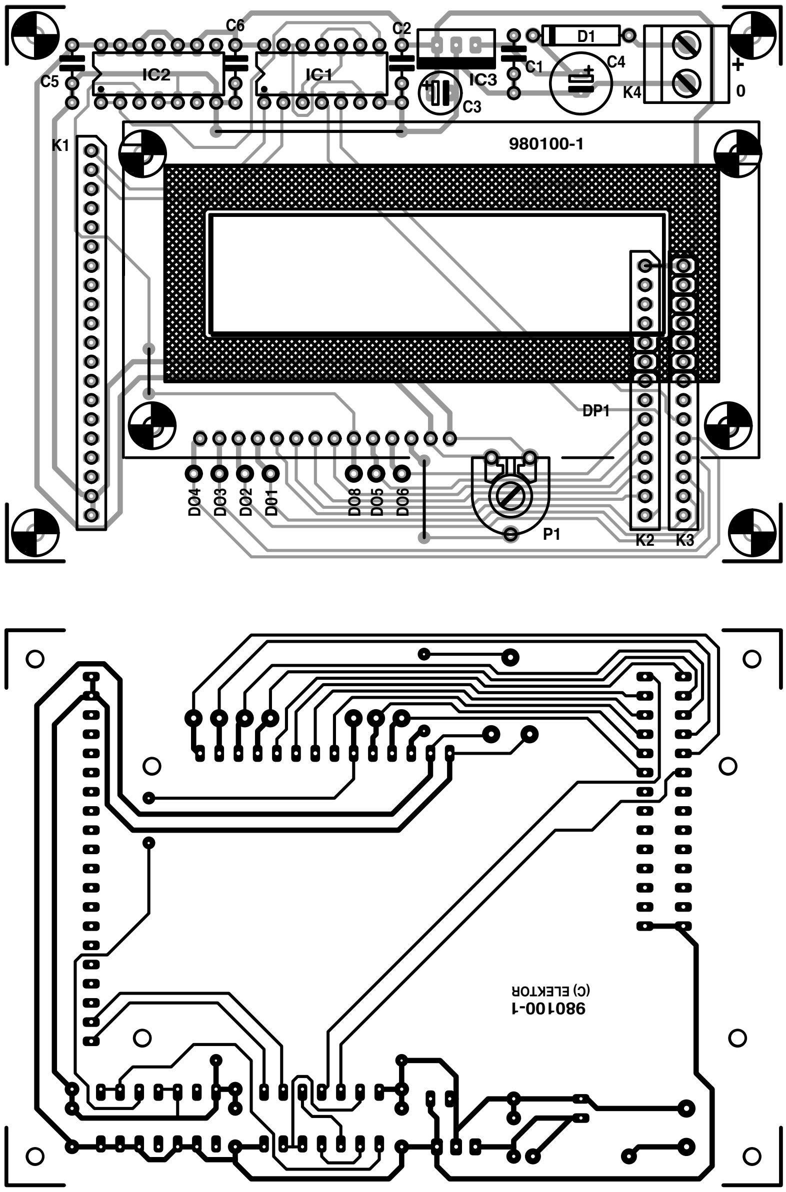
Address 0C00H (enable line at pin 6) is decoded by an AND operation of the $\overline{WR}$ and $\overline{RD}$ signals in the SBC and address lines A_{14} and A_{15}. This arrangement makes the LCD interface multi-addressable, which is particularly useful when other peripheral building blocks are linked to the SBC.

Listing 3 shows that the 8-bit version has clear advantages over the 4-bit version. For instance, there are no wait loops to obstruct the execution of the short, plain program.

Power cannot be taken from the SBC: on the contrary, the controller should now be powered via the LCD interface board. Power is derived from a discrete mains adaptor, whose output is stabilized by IC_3 and smoothed by capacitors C_1–C_4. Diode D_1 protects the circuit against inadvertent incorrect polarity of the supply voltage.

[980100]

2



Parts list
Resistors:
P_1 = 10 kΩ preset potentiometer

Capacitors:
C_1*, C_2, C_5*, C_6* = 0.1 µF
C_3 = 10 µF, 16 V, upright
C_4* = 100 µF, 63 V. upright

Semiconductors:
D_1 = 4001

Integrated circuits:
IC_1*, IC_2* = 74HCT00
IC_3* = 7805

Miscellaneous:
K_1* = 20-way SIL socket
K_2*, K_3* = 14-way SIL socket
K_4 = 2-way terminal strip for board mounting
K_5 = 2¥16 character liquid-crystal display (for instance, Sharp Type LM16A211)

* Not used in 4-bit version

Figure 2. The single-sided printed-circuit board for the LCD interface which is not available ready made. The 8-version is linked directly to the SBC board, for which purpose the same connectors are used as on that controller.

Listing 1

```
5   REM ULN 2803 replaced by wire links
10  STRING 100,20   : REM Memory for string
20  K = 3 : GOSUB 700 : REM Init l
30  FOR Z = 1 TO 4000
40  NEXT Z
50  K = 3 :  GOSUB 700 : REM Init 2
60  K = 3 :  GOSUB 700 : REM Init 3
70  K = 2 :  GOSUB 700 : REM Init.4
80  K = 2 :  GOSUB 700 : REM 4-bit interface
90  K = 8 :  GOSUB 700 : REM 2 lines,
    5*7 matrix
100 K = 0 : GOSUB 700 : REM Clear display
110 K = 1 : GOSUB 700
120 K = 0 : GOSUB 700 : REM Cursor home
130 K = 2 : GOSUB 700
140 K = 0 : GOSUB 700 : REM Increment counter,
    do not shift
150 K = 6 : GOSUB 700
160 K = O : GOSUB 700 : REM Display on,
    cursor on, flash
170 K = 15 : GOSUB 700
180 REM ——————————
250 PRINT " Max. 36 characters may be entered
    up to arrow <"
260 INPUT " Please enter text string to be
    displayed :",$(1)
270 FOR Z = 1 TO 16
280 D=ASC($(1),Z) : REM Individual char's,
    supplied by user
290 GOSUB 400
300 NEXT Z
310 FOR Y = 16 TO 39 : REM Fill LCD controller
    memory
320 D = 32 : REM not having a display function
330 GOSUB 400
340 NEXT Y :REM with dummy characters
350 GOTO 250
360 REM ——————————
```

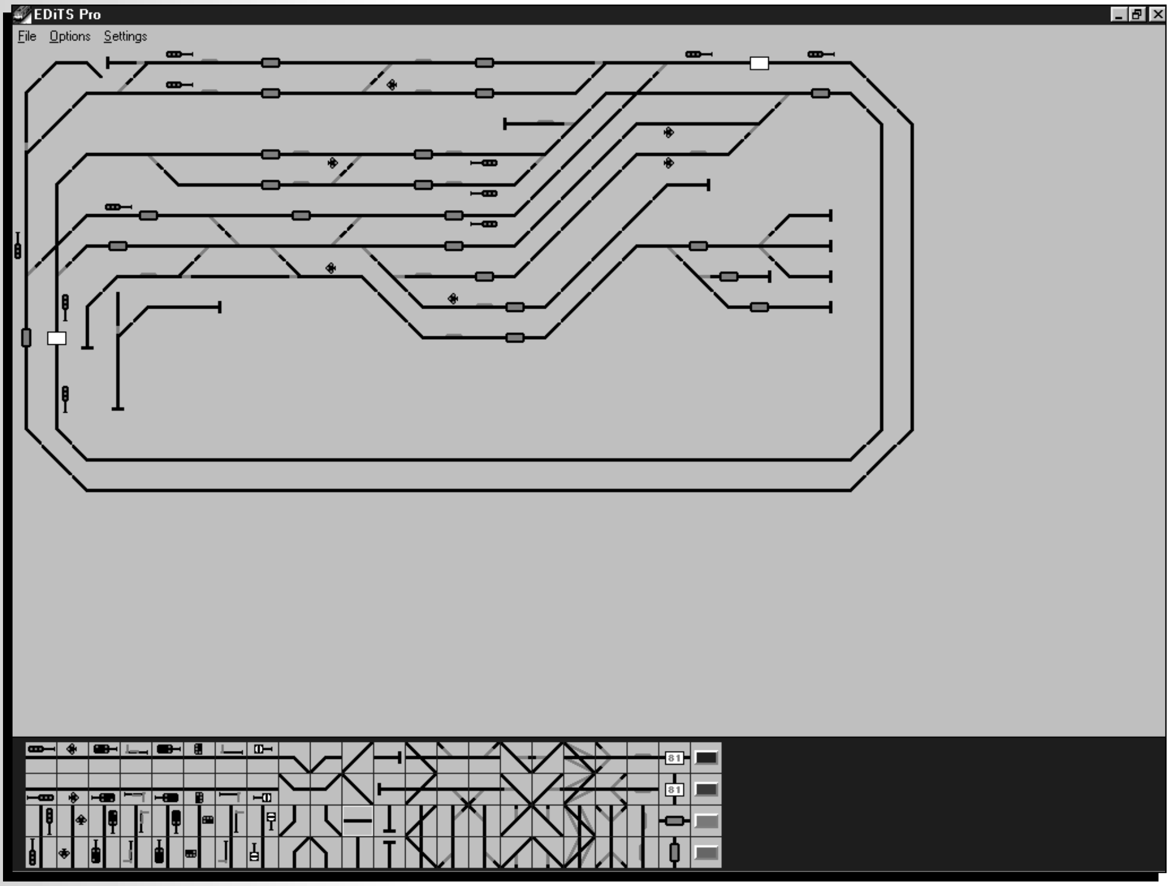
```
400 REM Subroutine for data output
410 L = D.AND.15 : REM Data of low part
420 H = D.AND.240 : REM Data of high part
430 H = H/16 : REM Shift high data
440 H = H.OR.32 : REM Enable data
450 XBY(0C000H) = H
460 H = H.OR.160 : REM Enable latch
470 XBY(0C000H) = H
480 H = H.AND.127 :REM Disable latch
490 XBY(0C000H) = H
500 FOR U = 1 TO 100
510 NEXT U
520 L = L.OR.32 : REM Enable data
530 XBY(0C000H) = L
540 L = L.OR.160 : REM Enable latch
550 XBY(0C000H) = L
560 L = L.AND.127 : Disable latch
570 XBY(0C000H) = L
580 FOR U = 1 TO 100
590 NEXT U
600 RETURN
610 REM ——————————————
700 REM Subroutine for command outputting
710 XBY(0C000H) = K
720 K = K.OR.128 : REM Enable latch
730 XBY(0C000H) = K
740 K = K.AND.127 : REM Disable latch
750 XBY(0C000H) = K
760 FOR U = 1 TO 100
770 NEXT U
780 RETURN
```

```
Listing 2

5   REM Unmodified circuit with ULN2803
7   XBY(0C000H)= 255 : REM Initial state
    because ULN2803 inverts
10  STRING 100,20 : REM Memory for string
20  K = 12 : GOSUB 700 : REM Init 1
30  FOR Z = 1 TO 4000
40  NEXT Z
50  K = 12 : GOSUB 700 : REM Init 2
60  K = 12 : GOSUB 700 : REM Init 3
70  K = 13 : GOSUR 700 : REM Init 4
80  K = 13 : GOSUB 700 : REM 4-bit interface
90  K = 7 : GOSUB 700 : REM 2 lines,
    5*7 matrix
100 K = 15 : GOSUB 700 : REM Clear display
110 K = 14 : GOSUB 700
120 K = 15 : GOSUB 700 : REM Cursor home
130 K = 13 : GOSUB 700
14O K = 15 : GOSUB 700 : REM Increment counter,
    do not shift
150 K = 9  : GOSUB 7O0
160 K = 15 : GOSUB 700 : REM display on,
    cursor on, flash
170 K = 0  : GOSUB 700
180 REM——————————————
250 PRINT." Max. 32 characters may be entered
    up to arrow <"
260 INPUT " Please enter text string to be
    displayed :",$(1)
270 FOR Z = 1 TO 16
280 D=ASC($(1),Z) : REM Individual char's,
    supplied by user
290 D = D.XOR.255 : REM ULN 2803 inverts
300 GOSUB 400
310 NEXT Z
320 FOR Y = 16 TO 39 : REM Fill LCD controller
    memory
330 D = 223 : REM not having a display function
340 GOSUB 400
350 NEXT Y : REM with inverted-spaces
360 GOTO 250
370 REM——————————————
400 REM Subroutine for data output
410 L = D.AND.15 : REM Data of low part
420 H = D.AND.240 : REM Data of high part
430 H = H/16 : REM shift high data
440 H = H.OR.16 : REM Enable writing
450 XBY(0C000H) = H
460 H = H.AND.127 : REM Enable latch
470 XBY(0C000H) = H
480 H = H.OR.128 :REM Disable latch
490 XBY(0C000H) = H
500 FOR U = 1 TO 100
510 NEXT U
520 L = L.OR.16 : REM Enable writing
530 XBY(0C000H) = L
540 L = L.AND.127 : REM Enable latch
550 XBY(0C000H) = L
560 L = L.OR.128 : REM Disable latch
570 XBY(0C000H) = L
580 FOR U = 1 TO 100
590 NEXT U
600 RETURN
610 REM——————————————
700 REM Subroutine for command outputting
710 K = K.OR.48 : REM Enable command and
    writing
720 XBY(0C000H) = K
730 K = K.AND.127 : REM Enable latch
740 XBY(0C000H) = K
750 K = K.OR.128 : REM Disable latch
760 XBY(0C000H) = K
770 FOR U = 1 TO 100
780 NEXT U
790 RETURN
```

```
Listing 3 (8-bit interface)

10  STRING 100,20   : REM Memory for string
20  XBY(0C000H)=56  : REM 8-bit interface,
    2 lines, 5*7 matrix
30  XBY(0C000H)=15  : REM Display on,
    cursor on, flashing on
40  XBY(0C000H)=1   : REM Clear display
50  PRINT " Max. 16 characters may be entered
    up to arrow <"
60  INPUT " Please enter text string to be
    displayed :",$(1)
70  FOR Z = 1 TO 16
80  A=ASC($(1),Z) : REM individual char's,
    supplied by user
90  XBY(0C002H)=A : REM Transmit them!
100 NEXT Z
110 FOR H = 16 TO 39 : REM Fill LCD controller
    memory
120 XBY(0C002H)=32 : not having a display
    function
130 NEXT H : REM with dummy characters
140 GOTO 50
```

PC-controlled model railway: EEDTS Pro

Part 2: the control software



Although the model railway may be controlled manually, it is more convenient to drive it via a personal computer (PC). For this purpose, a special EEDTS Pro program has been developed for use under Windows. It provides the necessary communication between the controller and the railway track via the PC. This article gives a detailed description of the software. Moreover, elsewhere in this issue there is a project for a booster amplifier suitable for use with the EEDTS Pro model railway.

Design by S van de Vries

INTRODUCTION

Not only is the software, available through our Readers' Services under Order No. 986027, user-friendly, but the designer has also tried to make it give as realistic a picture of a model railway on the monitor screen as possible.

The operator can thus sit facing the screen like a real station master and control the entire track and all that is on it. All functions are available at the click of a mouse.

The program, written in Visual BASIC, is suitable for use with Windows 3.1 or higher, and requires a minimum memory of 8 Mbyte. It is available on diskette in four languages (Dutch, English, French, and German).

GO!

After starting with setup.exe, the installation instructions on the screen guide the operator.

Start the program via the Windows start menu, where the setup program has created its own menu. First, there is a copyright notice on the screen, which disappears automatically after a short time.

After the user has acquainted him/herself with the contents of the text, the text on the screen may be shortened by clicking on the text with the left-hand mouse button. Note, however, that the software can be used only when an EEDTS Pro unit is connected to the system.

The program assumes that the controller is linked to the COM1 port. If this is not so, another communication port may be chosen via the menu 'Settings→Communication'.

LAYING THE TRACK

Once the program is operational, the menu item 'File' may be opened in the usual manner with the mouse. There then appears a sub-menu containing 'New'. 'Load', 'Save', 'Delete', and 'Close'. There is complete control over the saving of screen data.

When 'New' is selected, fresh data may be defined. At the bottom of the screen there is an overview of the railway components familiar to any model railway enthusiast. Any of these may be selected rapidly and efficiently with a click of the mouse. Should a component be placed in the wrong position, this is quickly rectified with the right-hand mouse button. An element may also be moved by clicking on it with the mouse (left-hand button) and dragging it to the wanted position.

In general, the components are divided into four groups: passive, active, return, and detect functions. The return and detect functions, which are found on the screen in the penultimate column, have a fourfold function:

- starting a track
- terminating a track
- placing the starting point of a subsidiary track
- signalling that a track is busy.

The detect button – the white squares in the penultimate column which contain a number (81) – show the number of the train that has passed the relevant point last, provided that the locomotive is fitted with a super engine decoder (see Part 1 – June 1999).

Since detection can take place only in combination with a contact rail, locomotives without a super engine decoder are also detected, but these are indicated by the address ().

USERS

Users are items such as turnouts (points; US: switches) and signals, that are driven by a suitable decoder. There are three types of user:

1. users with one stable condition, such as a uncoupling ramp, and those that are controlled with a yellow or green knob.

2. users that have two stable conditions, such as turnouts or two-way signals, and those that are controlled with a red or blue knob.

3. users that have three stable conditions, such as three-way signals and three-way turnouts.

The coloured knobs in the last column (blue, red, yellow, and green) are not included in the track layout. They may be placed in random positions for special functions, such as switching the station lights on and off via a relevant decoder.

The blue and red knobs function like switches, whereas the yellow and green ones function like push buttons. The latter two are active only when the left-hand button on the mouse is pressed.

All users are controlled via a suitable decoder, which may be EEDTS Pro signals or turnout decoders, or relevant Märklin or Viessmann types. The address of all these decoders is set with a dual in-line package (DIP) IC switch. Each decoder enables up to eight electromagnets to be controlled.

To indicate to the program which user is associated with which symbol on the screen, actuate 'Decoder addresses' via 'Options' and click with the mouse on the relevant symbol.

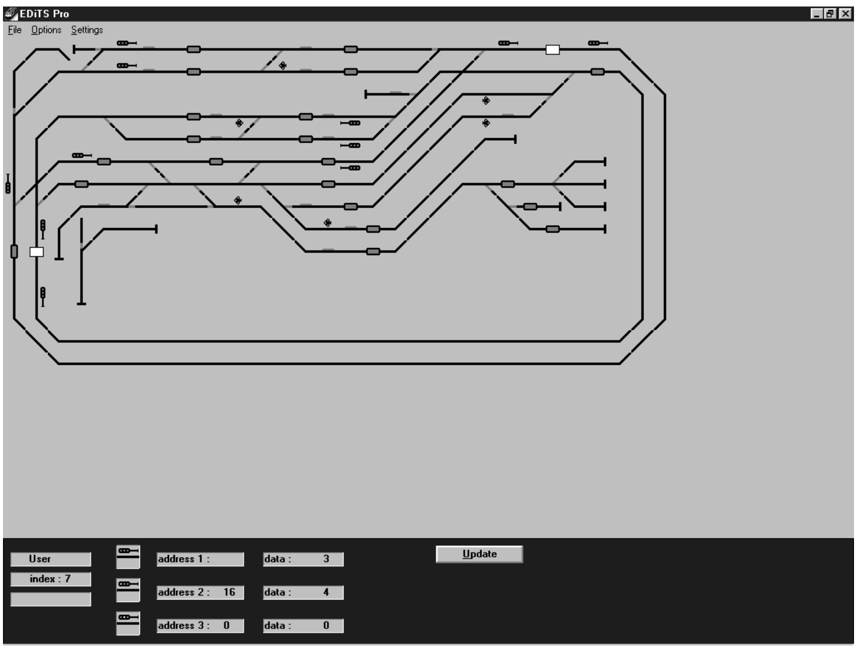
The dark red box shows all states of a symbol and in it may be stated which decoder address and data output are are associated with a particular function.

If only two positions of a three-way signals set are used, the non-used position should be indicated by a 0 decoder address and data output. This converts the three-way signals set into one with two stable conditions. When the 'Update' is actuated, the information is saved.

When all address and data fields are 0, the program assumes that there is no turnout or signal decoder for the symbols.

SIGNALLING

The primary function of the return knobs – grey rectangular symbols – is to signal track occupation. For this purpose, there must be a connection between the relevant symbol and the return signaller. EEDTS Pro and Märklin units may be used together on a track, but do not forget to connect the

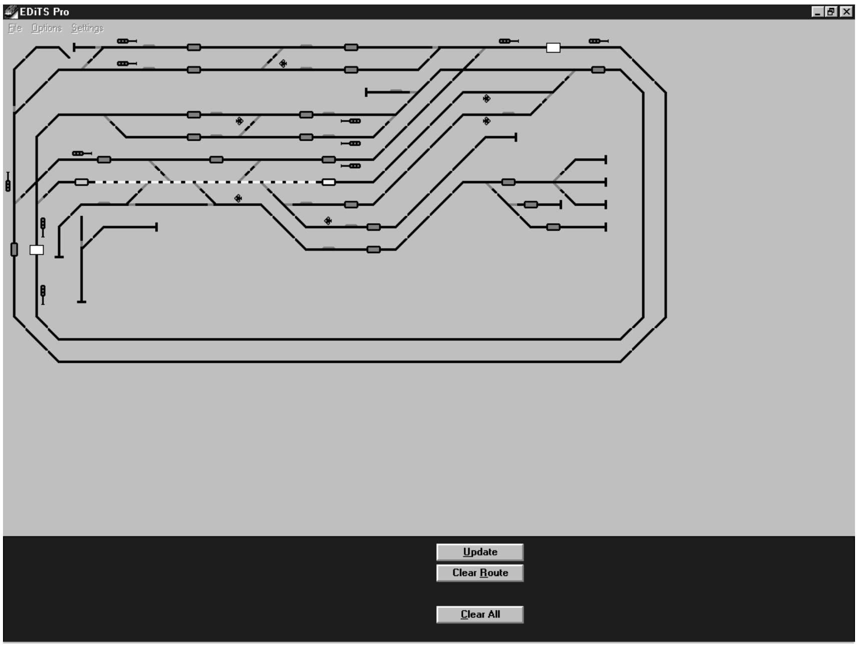


sixth wire of the Märklin units (see Part 1 – June 1999).

When the left-hand mouse button is clicked on a return knob, address and data information is needed. The address follows from the sequence in which the decoders are linked to the controller. That nearest to the controller is number one, the next one, number two, and so on. The controller can accommodate up to 32 decoders. If Märklin S88 decoders are used, it must be borne in mind that these use two sequential addresses. Inputs 9–16 are really 1–8 of the next higher address.

TRAIN DETECTION

The train detector module – white rectangular icon –is a detector inserted into a chain of return signallers. After the mouse has been clicked on it, only the address has to be input. More data is not needed, since all eight data bits are used to give the address of the engine decoder.



SECURE TRACKS

Secure tracks are defined as those between two return knobs or between two train detectors. Point the mouse at the return or train detector knob that marks the start of a section of track and press the left-hand button, whereupon the icon should turn green. Then point the mouse at the icon that marks the end of the relevant section of track and press the left-hand button, whereupon the icon should turn yellow. By repeating this process at all intermediate points along a track, a secure section will be defined. This is important because, as will be seen later, the program needs these secure sections of track.

The position of turnouts and signals may be altered by repeatedly clicking with the left-hand button of the mouse on the relevant symbol. If a wrong symbol is selected, this can be corrected with the right-hand button of the mouse.

A secure section of track forms a chain of interlinked symbols, but it remains possible, for instance, for safety reasons, to select a signal outside the section. This signal, which is allowed to show only the 'stop' signal, automatically assumes this condition when the relevant secure section is selected.

If a secure section is to be removed, it is selected by clicking with the left-hand mouse button at the start and end of it, and then disabling the individual segments with the aid of the right-hand button. Then, actuate 'Update', whereupon the entire section is removed.

When a secure section of track has been saved, it is no longer possible to return to option 'Build control section'. The only way to alter the track is by erasing all secure sections first.

AUXILIARY PROGRAM

Automatic processing of a train service is possible by an additional module that may be programmed with the aid of mouse movements. The program may institute virtual stations, train service schedules and automatic control of track sections. It also provides protection against lateral or head-on collisions.

The setup of the program is that the train determines its execution. The programming rules are, therefore, coupled to the return or detection knobs that are to be actuated by the train. This often also requires protection with a 'do not proceed ' signal. to prevent a train from entering an incompletely arranged section of track or a busy section. The relevant signal set must be placed behind the stretch of detect section associated with the return or detect knob. At rest, it is in the 'stop' position. An approaching train has to wait until a section of track becomes accessible to which operation of the signal is coupled. It is useful to position this signal at a reasonable distance from the contact rail used to prevent the train having to wait for the program to be executed.

In the programming mode, return or detect knobs are selected first, after which the associated program lines are composed with the left-hand mouse button. When that button is clicked, the detect knob becomes red and the program screen opens automatically.

Once this is done, a start may be made with defining the action, that is, the selecting of a secure section of track, or setting a user to one of its positions. In case of a secure section, click with the left-hand mouse button on the start of the section – usually the detect knob – and then on the desired end of the section. The red icon then gets a green core and the end stop becomes yellow. The section between these points, which must be saved under option 'tracks', then becomes visible.

If a user is to be actuated, click on the relevant symbol with the left-hand mouse button. By clicking on it a few times, it is set to the wanted condition. Any wanted interval preceding the action may also be input.

The next action, for instance, a subsidiary section, may be defined on the next line once 'Add line' has been actuated.

There is also a level function: at the first program line, 'level' has a value of one. This value is retained until the operator selects a higher one. When the relevant knob is actuated, level is raised by one, whereupon the program lines for this level may be defined. They form a first alternative route.

In 'Operational' mode – when the program is executed – the software selects this alternative if the program lines defined at level 1 temporarily cannot be carried out.

The relevant lines are marked non-executable when in one of the lines a section is defined that crosses another one. It may also be that the end of the section is occupied.

The level function thus makes it possible to define a set of alternative routes. This arrangement allows varied traffic at normal stations, and enables virtual stations to be programmed in a simple manner.

If none of the alternatives is possible, no actions are carried out, that is, the train is (temporarily) at standstill. As soon as the situation changes to the extent that one of the alternatives becomes possible, the relevant lines are executed at once.

If no program lines are associated with the selected knob, the lines are shown empty on the screen. Each line carries the 'nx' index number of the relevant button – this nx index number is uniquely allocated by the programmer to a return or detect knob. The number may be called up in menu item 'Decoder addresses'.

A delay in combination with the action 'Secure section' is sensible only if the section is coupled to a signal set contained within the section. When the section is set up with delay, the signal goes to 'stop' to prevent the train continuing on its journey.

Sections that are actuated by program lines become accessible to other traffic when the train has reached the end of the relevant section: a return or detect knob.

To ensure automatic progression of trains, it is advisable to include a program line in each level that sets the signal immediately preceding the program knob to condition 'safe'.

If program lines are associated with a detect knob, it becomes possible to define secure sections that are coupled to a specific engine (loc address). In the case of detect knobs, loc address 0 indicates a locomotive without super engine decoder. The program lines and levels for this locomotive must be programmed first.

When all lines have been input, actuating 'Update' is sufficient to link these lines permanently to the selected knob. If there is an error in the program, the relevant knob must be actuated with the left-hand mouse button. All program lines up to that to be altered are then removed with 'Delete line'. When this is done, reinput the deleted lines and actuate 'Update'.

PROGRAMMING THE CONTROLS

A window may be opened via the option 'Soft controls'. Its lower section shows 20 shift controls. There are also four buttons with which a bank of 20 controls may be selected. In total there are, therefore, 80 controls to be defined. When the left-hand mouse button is clicked on the icon with the red arrow present on each control, a configuration screen is opened. The soft controls are used in the operational mode to vary the speed of trains.

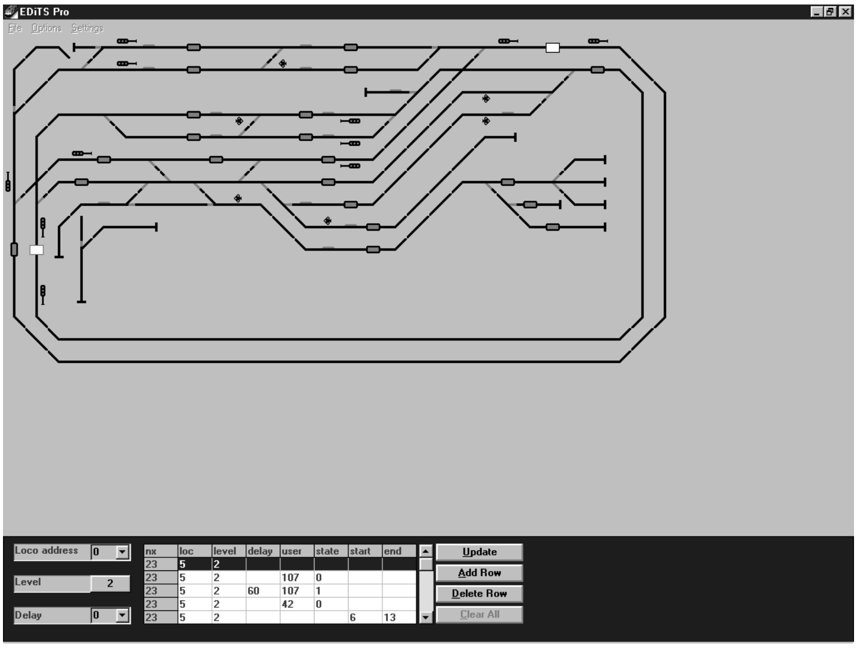
Two types of engine decoder may be controlled: normal or extended. Normal refers to standard loc decoders with just one additional functions or decoders without an additional function, such as delta decoders. Extended refers to engine decoders with more – up to four – functions, such as the super engine decoder which is planned for publication in a forthcoming issue of this magazine.

The address of the decoder is input into the address field. A short text must be put into the field 'description' to identify the relevant locomotive.

Next, icons may be placed behind the function keys. Point the mouse at the relevant icon and drag this to the wanted box. When the mouse button is released, the icon is saved in that position. Unused functions must be left empty.

OPERATION

When 'Operational' is actuated, trains may be controlled, signals and turnouts set, secure sections of track set up manually or the program may be enabled.



Controlling trains

Clicking on a control – arrow up, arrow down, reverse, or direction function – actuates it. From then on, the icons of the control – as they are input during the programming of the control – can be seen between the 10th and 11th line. The written description of the relevant engine or train can be seen under the buttons.

If all that is needed is setting or resetting of a function, point the mouse at the relevant shift control and click on it with the left-hand button. The speed of the train may be set with the vertical arrows on the control.

If the direction of travel is to be altered, the reverse button must be actuated with the left-hand mouse button. This is, however, possible only when the speed of the engine has been set to 0 with the shift control.

When a super engine decoder or a Märklin decoder with four functions is used, the direction of travel is known. An arrow pointing to the right indicates forward, an arrow to the left indicates reversing.

The functions of an active shift control may be actuated and deactuated with the left-hand mouse button. When the left-hand mouse button is clicked on the relevant icon, the picture changes to indicate that the status has changed.

Shunting
An option that is very useful for shunting trains is the converting from soft control to manual control. This is done by clicking with the right-hand mouse button on the reversing knob of the relevant soft control. The control of the train is then assumed by the manual control and the relevant shift control on the screen becomes invisible.

The control may be reverted to the soft control by again clicking on the relevant reversing knob with the right-hand mouse button. The shift control then becomes visible again on the screen.

It is worthwhile noting that all settings of the soft control are transferred to the manual control and that any changes in the setting – reversing, functions, old/new format – are also transferred from the manual to the soft control.

Control of turnouts, signals and uncoupling ramps
When the left-hand button of the mouse is clicked on a turnout or signals symbol, the status of the associated turnout or signal set changes, provided that it is not part of an active secure section of track. The status of three-way turnouts or signal sets is changed by repeatedly clicking on the relevant symbol with the left-hand mouse button.

To prevent that data of intermediate conditions (in case of a Type 3 three-way user) is transferred by the program to the decoder, some time delay has been built in. Owing to this delay, the operator is able to select the correct position on the screen. During the delay time, the symbol may be repeatedly clicked on.

Since many three-way turnouts are briefly in position straight on when they are moved from the left-hand road to the right-hand road, this condition is indicated to the decoder beforehand.

A similar arrangement applies to three-way signal sets. If these are moved from 'safe' to 'proceed at reduced speed', condition 'stop' is briefly selected.

It is not necessary to use turnouts with switch-off since the time they are energized is variable – see options. This is not the case with uncoupling ramps: these are energized as long as the left-hand mouse button is pressed.

Secure track sections
Secure track sections are set by clicking with the left-hand mouse button first on the (start) return knob and then on the (end) return knob. Again, the start knob goes green and the end knob, yellow.

Subsidiary secure sections are set by clicking again with the left-hand mouse button on the end return knob. This then becomes the start of the subsidiary section, while the end of this section is set by clicking with the left-hand mouse button on the wanted return knob.

This arrangement allows a train to traverse a railway yard starting from a green knob. The route is via a number of yellow knobs to the yellow end stop.

ENABLING A PROGRAM

When a program or part of it has been set up, a start may be made with its execution. There is a program knob at the bottom right of the window on the screen. When the mouse is clicked on this knob, the program starts. This means that, as soon as the train passes a return knob or monitor knob that is linked to a program, program lines will be executed. Clicking on a knob always makes it go dark red. If program lines are actuated, the colour changes from light red to dark red and vice versa twice a second.

When the program is being executed, manual control remains possible. It is, however, important that the operator realizes that the software can claim an unused section of track. If the program is to be interrupted for some time, click once more on the program knob. As soon as all trains are at a standstill, the situation is stable. The screen data can then be saved and be reenabled later when the process continues from the 'frozen' status.

When the program is started after a knob has been actuated – the train is on a contact rail –the trigger may be carried out by clicking with the right-hand mouse button on the knob.

When a secure track section is built manually or by the program, traffic is conducted according to a fixed procedure. First, all signals on the secure section are set to 'stop', followed by the turnouts being set to the wanted position, and finally, the signals being set to 'proceed'. This procedure ensures maximum safety on the section. When the train has passed the end stop of the section, the section is open to other traffic again.

A secure section can be opened manually to other traffic by clicking at the end stop with the right-hand mouse button.

Manual control of turnouts and signal sets is possible only if these are not part of a secure section of track. When the left-hand mouse button is clicked, all positions are traversed sequentially.

SETTINGS

The first choice from the menu 'Settings' refers to the communications port. The default setting is COM1. The menu allows an alternative, if available, to be selected.

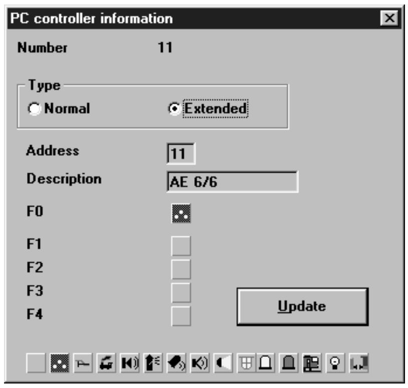
'Actuation time' is a second choice in this menu. This option makes it possible to set the time an electromagnet is energized between 0.2 s and 2 s.

The manual controls have fixed addresses: 2, 6, 8, 19, 24, 26, 60, and 72. If desired, each control may be given a new address. Such a new address is, however, superseded by a hard reset of the microcontroller, unless the option 'permanent' is selected.

If hand controls are to be disabled, they are allocated address 0.

The addresses allocated to the manual controls are saved, together with certain other properties of the screen data. When the relevant file is opened anew, the controls are programmed accordingly.

In 'Loc decoder' the properties of a locomotive with a super engine decoder may be laid down. This function is available only when the program is in the 'Operational' mode. During programming, address 79 is used. If super engine decoders are



used, it is imperative to keep this address free. Also, during programming, it is essential to place only the locomotive to b e programmed on the track to prevent several locomotives being program-med simultaneously.

The address, the maximum speed, the rate of acceleration and deceleration, the brightness of the headlights, F0, and the flash frequency of F4 of the decoder are to be set.

Finally, the desired language must be chosen from Dutch, English, French or German.

[980085-2]

CW generator

aid for radio amateurs

The generator described can accept texts of up to 64 characters long and make this audible in the form of morse signals. This action can be repeated automatically with variable intervals – an aspect that is bound to be of interest to many radio amateurs.

Design by G. Baars

INTRODUCTION

Transmitting radio amateurs are obliged under International Law to give their call sign at least once every ten minutes. This is to ensure that calling stations can be identified at all times and also to prevent abuse of frequencies allocated to radio amateurs. This requirement is monitored conscientiously by the relevant inspection service, which has the authority to reprimand and, if the offence is repeated, to apply sanctions.

This legal requirement soon gave rise to timers and other automatic warning appliances to alert the operator to transmit the call sign. The generator described in this article is one such automatic device. With the aid of a number of DIP switches, it permits a line of text not exceeding 64 characters to be loaded into its memory, which is then transmitted in morse code at intervals that can be set between 0 s and 15 s or between 0 m and 15 m. The keying speed can also be varied.

The unit is provided with an audio output, a key output, and a push-to-talk output, PTT. It is sufficiently compact to allow its integration into existing equipment.

This short description makes it clear that the unit may be used as a stan-

Table 1.		
DIP switch	Programming mode	Run mode
sw1	data0	rep0
sw2	data1	rep1
sw3	data2	rep2
sw4	data3	rep3
sw5	data4	sec/min
sw6	char/digit	wpm0
sw7	store	wpm1
sw8	run/prog	run/prog
(sw1 = S1(1); sw2 = S1(2); … sw8 = S1(8))		

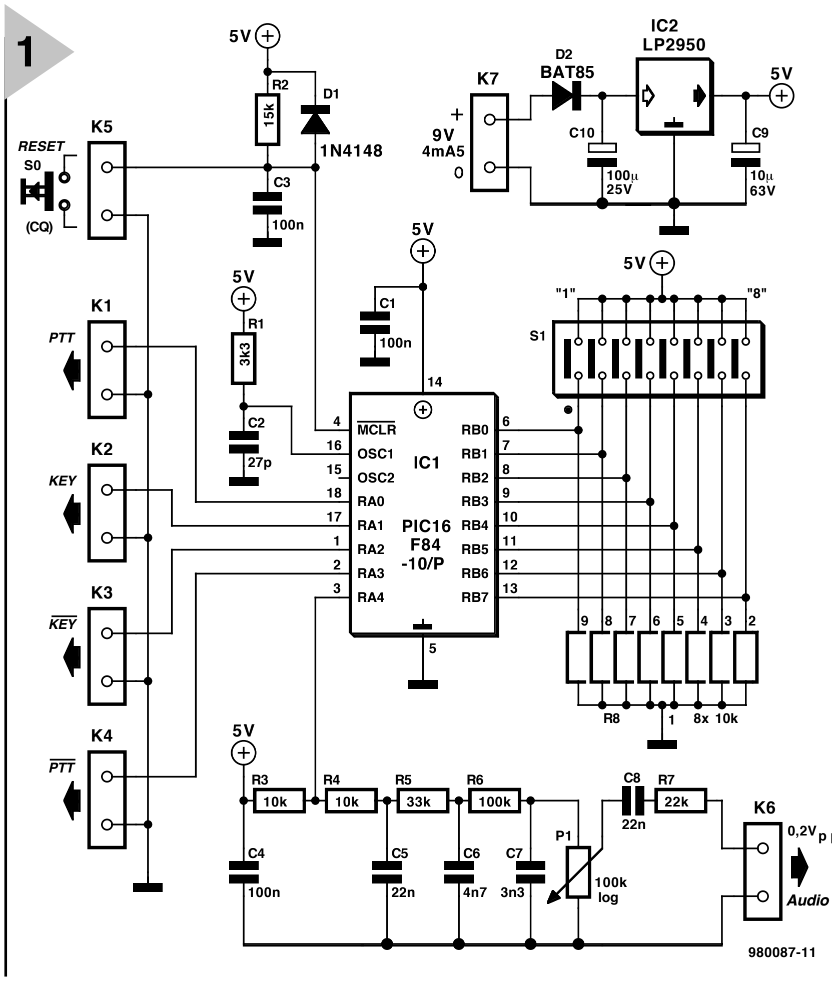


Figure 1. The circuit of the CW generator is based on a programmed PIC processor.

dard call generator, a CQ generator, a beacon, or as a morse test generator. With a bit of a push, it may also be used to learn the morse code.

FUNCTIONAL DESCRIPTION

The circuit in the diagram in **Figure 1** shows that the design is straightforward. It consists of a programmed PIC processor, IC1, octal DIP switch, S_1, output filter R_4–R_6-C_5–C_7, and a power supply regulator, IC_2.

The unit is linked to the outside world via five terminals, K_1–K_5, made from PCB pins. A sixth, K_6 also made from PCB pins, delivers the audible morse signal at a frequency of 1000 Hz.

Key terminals K_2 output the morse characters in the shape of high logic levels when push-to-talk terminals K_1 are high during transmissions.

The inverse signals of those at K_2 and K_1 are also available: at K_3 and K_4 respectively.

If desired, a simple push-button switch may be linked to terminals K_5 to serve as a reset switch. This is not really necessary, since the generator may be reset by switching the supply voltage off and on again.

The actual operation of the unit is performed almost wholly by processor IC_1. This is loaded with a simple program whose execution is carried out according to the setting of the DIP switches. The function of these switches is shown in **Table** 1. In the table, 'rep' means repetition interval and 'wpm' means words per minute.

Programming mode

Switch $S_{1(8)}$ enables selecting the *programming mode* or the *run mode*. This selection must always be made before the generator is switched on, or before a reset as the case may be.

In the programming mode, $S_{1(1–5)}$ are used to input data. The setting of $S_{1(6)}$ determines whether these data are letters or numerals. When this switch is on, switches $S_{1(1–5)}$ input the alphabet plus space and slash. When $S_{1(6)}$ is off, switches $S_{1(1–5)}$ input numerals 0–9. This is shown in **Table** 3 and will be reverted to shortly.

Switch $S_{1(7)}$ serves to store the relevant characters into an EEPROM. This is done by setting it from on to off or vice versa.

Run mode

When $S_{1(8)}$ is on, the run mode of the other switches is selected. Switches $S_{1(1–4)}$ enable the repetition interval of the input text to be set. Switch $S_{1(5)}$ determines whether this time is in seconds (switch on) or in minutes (switch off). The interval may be set between 0 s and 15 s or between 0 m and 15 m.

Switch $S_{1(5)}$ also has another functions. When switches $S_{1(1–4)}$ are all off, and $S_{1(5)}$ is also off, the input text is transmitted once after the supply is switched on or after a reset. When $S_{1(5)}$ is on, the input text is transmitted continuously. **Table 2** shows the process for the various settings of

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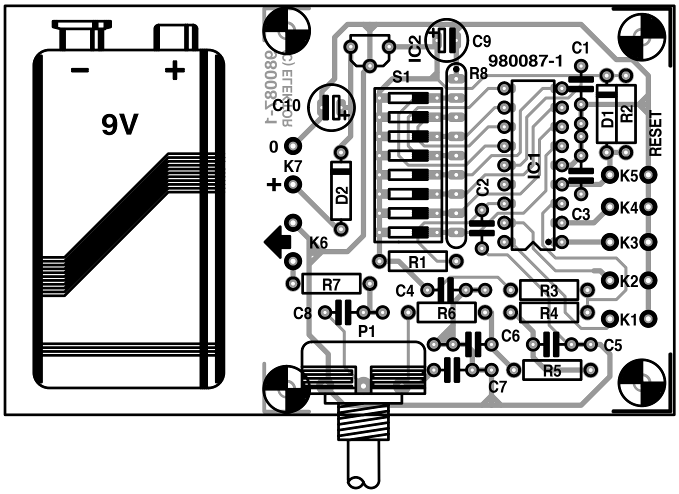

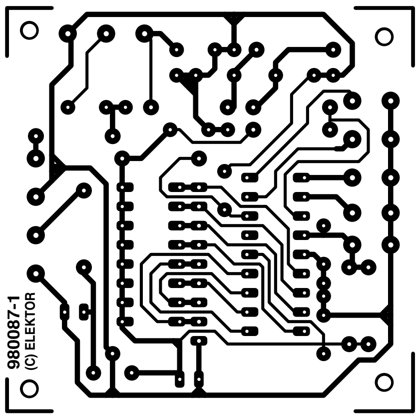

Figure 2. Printed-circuit board for the CW generator.

Parts list

Resistors:
R_1 = 3.3 kΩ
R_2 = 15 kΩ
R_3, R_4 = 10 kΩ
R_5 = 33 kΩ
R_6 = 100 kΩ
R_7 = 22 kΩ
R_8 = resistor array, 8×10 kΩ

Capacitors:
C_1, C_3, C_4 = 0.1 μF
C_2 = 27 pF
C_5, C_8 = 0.022 μF
C_6 = 0.0047 μF
C_7 = 0.0033 μF
C_9 = 10 μF, 63 V, radial
C_{10} = 100 μF, 25 V, radial

Semiconductors:
D_1 = 1N4148
D_2 = BAT85

Integrated circuits:
IC_1 = PIC16F84 *
IC_2 = LP2950CZ5.0 (National Semiconductor
* Available programmed under Order No. 986512 – see Readers' Services toward the end of this issue.

Miscellaneous:
K_1–K_7 = PCB pins
S_0 = push-button switch
S_1 = octal DIP switch
Enclosure as and if required
PCB Order No. 980087 – see Readers' Services toward the end of this issue.

switches $S_{1(1–5)}$.

The keying speed is set with switches $S_{1(6)}$ and $S_{1(7)}$. When both these switches are off, the speed is 10 w.p.m.; when $S_{1(6)}$ is on and $S_{1(7)}$ is off, the speed is 15 w.p.m., when $S_{1(6)}$ is off and $S_{1(7)}$ is on, the speed is 20 w.p.m. and when both switches are on, the speed is 25 w.p.m.

PROGRAMMING

The wanted text is input by first setting switch $S_{1(8)}$ to off before the supply is switched on or the circuit is reset. Each subsequent programming step consists of setting $S_{1(6)}$ as relevant and switches $S_{1(1–5)}$ according to Table 3. After each character has been input, switch $S_{1(7)}$ from off to on or vice versa to store the character in memory. When the entire text has been input in this manner, set switch $S_{1(8)}$ to on, followed by setting $S_{1(7)}$ from off to on or vice versa as the case may. Note that in Table 3 the character 0 indicates a space which has a standard duration of seven dots.

EXAMPLE

Assume that radio amateur PA0XYZ wants to use the unit as an automatic call generator. He/she sets $S_{1(8)}$ to off, switches the supply on, or presses the reset button. This is followed by the following programming steps:

sw1	*sw2*	*sw3*	*sw4*	*sw5*	*sw6*	*sw7*
off	*off*	*off*	*off*	*on*	*on*	→
on	*off*	*off*	*off*	*off*	*on*	←
off	*off*	*off*	*off*	*off*	*off*	→
off	*off*	*off*	*on*	*on*	*on*	←
on	*off*	*off*	*on*	*on*	*on*	→
off	*on*	*off*	*on*	*on*	*on*	←
NOTE. ←→ = change from "on" to "off" or vice versa						
(sw1 = S1(1); sw2 = S1(2); … sw7 = S1(7)						

The programming is terminated by setting $S_{1(8)}$ to on and switching $S_{1(7)}$ from on to off or vice versa as the case may be.

Since the call is to be repeated every 10 minutes, the operator must set the timer for this interval. Also, a keying speed of 25 w.p.m. is desired. The whole process is programmed by setting the various switches as follows:

After this has been done, the generator must be reset or the supply voltage switched on. Any changes in the settings of the switches during the run mode become effective only after a reset.

CONSTRUCTION

The generator is best built on the printed-circuit board shown in **Fig-**

sw1	*sw2*	*sw3*	*sw4*	*sw5*	*sw6*	*sw7*
off	*on*	*off*	*on*	*off*	*on*	*on*
10				*min.*	*25 wpm*	
(sw1 = S1(1); sw2 = S1(2); … sw7 = S1(7)						

Table 2.

sw1	sw2	sw3	sw4	sw5	Interval
0	0	0	0	0	Send once
1	0	0	0	0	1 minute(s)
0	1	0	0	0	2
1	1	0	0	0	3
0	0	1	0	0	4
1	0	1	0	0	5
0	1	1	0	0	6
1	1	1	0	0	7
0	0	0	1	0	8
1	0	0	1	0	9
0	1	0	1	0	10
1	1	0	1	0	11
0	0	1	1	0	12
1	0	1	1	0	13
0	1	1	1	0	14
1	1	1	1	0	15
0	0	0	0	1	Send continuously
1	0	0	0	1	1 seconde(s)
0	1	0	0	1	2
1	1	0	0	1	3
0	0	1	0	1	4
1	0	1	0	1	5
0	1	1	0	1	6
1	1	1	0	1	7
0	0	0	1	1	8
1	0	0	1	1	9
0	1	0	1	1	10
1	1	0	1	1	11
0	0	1	1	1	12
1	0	1	1	1	13
0	1	1	1	1	14
1	1	1	1	1	15

(sw1 = S1(1); sw2 = S1(2); ... sw5 = S1(5)

Table 3. Programming table

sw1	sw2	sw3	sw4	sw5	character (sw6= 1)	numeral (sw6= 0)	decimal
0	0	0	0	0	" "	"0"	0
1	0	0	0	0	"A"	"1"	1
0	1	0	0	0	"B"	"2"	2
1	1	0	0	0	"C"	"3"	3
0	0	1	0	0	"D"	"4"	4
1	0	1	0	0	"E"	"5"	5
0	1	1	0	0	"F"	"6"	6
1	1	1	0	0	"G"	"7"	7
0	0	0	1	0	"H"	"8"	8
1	0	0	1	0	"I"	"9"	9
0	1	0	1	0	"J"		10
1	1	0	1	0	"K"		11
0	0	1	1	0	"L"		12
1	0	1	1	0	"M"		13
0	1	1	1	0	"N"		14
1	1	1	1	0	"O"		15
0	0	0	0	1	"P"		16
1	0	0	0	1	"Q"		17
0	1	0	0	1	"R"		18
1	1	0	0	1	"S"		19
0	0	1	0	1	"T"		20
1	0	1	0	1	"U"		21
0	1	1	0	1	"V"		22
1	1	1	0	1	"W"		23
0	0	0	1	1	"X"		24
1	0	0	1	1	"Y"		25
0	1	0	1	1	"Z"		26
1	1	0	1	1	"/"		27

(sw1 = S1(1); sw2 = S1(2); ... sw5 = S1(5))

ure 2. If this is obtained, together with the programmed processor, via the Readers' Services (see toward the end of this issue), the construction of the generator with reference to the circuit diagram and the parts list becomes very easy: most constructors should be able to finish it in well under an hour.

The board is small so that is can easily be integrated into an existing transmitter or transceiver. Alternatively, it may be built into a small discrete case to become a stand-alone unit—see photograph.

Since the generator draws a current of not greater than 4.5 mA, it may be powered by a 9 V (PP3) battery connected to K_7. There is space for this battery on the board. Voltage regulator IC_2 ensures a stable 5 V supply line.

There are no calibrations needed; the only potentiometer, P_1, varies the loudness of the 1000 Hz output tone.

The repetition intervals and keying speeds mentioned in the text are based on a clock frequency of 4 MHz This frequency is determined approximately by R_1 and C_1. If it is to be 4 MHz accurately, replace R_1 by a 5 kΩ preset potentiometer to enable the frequency to be set.

USAGE

When the unit is to be used as a CQ transmitter, the key output may be used to drive a relay that bridges the morse key. Using the earlier example, the text "CQCQDEPA0XYZ" may then programmed. The DIP switches are to be set so that after each and every reset this text is transmitted once. In this way a call may be made simply by pressing the reset button.

The unit may also be used for direction finding exercises. In this case, the push-to-talk terminals should be used to energize a relay via a transistor to switch on the transmitter. The audio output is linked to the input of a microphone preamplifier. The text may consist of numerals 0 and 5 for programming long and short signals. A real text may, of course, also be used. A good repetition interval would be one minute.

When the unit is used as automatic call generator, the audio output signal should be mixed with the speech modulation. This should be done so that the morse signals are clearly audible without drowning out the speech. Setting the loudness with P_1 is facilitated by temporarily setting the timing to 0, resulting in the continuous transmitting of the signal. The correct position of P_1 is readily arrived at with the use of a suitable receiver or the help of a fellow amateur.

To obtain a peak output voltage of 50 mV, it may be necessary to alter the value of resistor R_7 to about ×10 the load across terminals K_6.

Finally, if the unit is used solely as call generator, the key and push-to-talk terminals are not needed and may be left open.

[980087]

battery charger

reliable, yet inexpensive

Charging NiCd batteries does not necessarily require a complex design. The charger described in this article shows that a reliable unit with built-in timer can be constructed for a relatively small outlay.

INTRODUCTION

Over the years many techniques have been developed for fast, accurate and reliable charging of NiCd batteries. One of the best of these is still the 14-hour method at one tenth of the battery capacity. The present design contains a adjustable current source and a timer which, after normal charging has taken place for 14 hours, switches the charger to trickle charging. Since the current source is adjustable, the charger may be used with a wide variety of NiCd batteries.

DESIGN

The circuit of the charger is shown in **Figure 1**. The peak value of the input alternating voltage must be equal to the requisite charging voltage. This alternating voltage is rectified by bridge B_1, smoothed by capacitor C_9 and applied to regulator IC_5. When this voltage is present, diode D_4 lights.

The alternating voltage is also applied to the clock input of IC_1 via resistor R_1. This means that IC_1 is controlled at a frequency of 50 Hz. A signal at a frequency of $50/2^7$ is output at pin 4 (Q_6) and applied to pin 14 (CLK) of IC_2, where it is divided by 10. This signal is output at pin 7 ((Q_3) and applied to the clock input, pin 10, of IC_4.

The signal is divided by 2^{12} in IC_4, resulting in output Q_{11} (pin 1) of this IC being actuated after 14 hours and 33 minutes (52,428 seconds). Diode D_1 places the output at pin 1 at the clock input, which means that the clock signal cannot alter the counter state.

The battery is charged during this 14 hour plus period by charging circuit which is a discrete design.

Design by R. Lucassen

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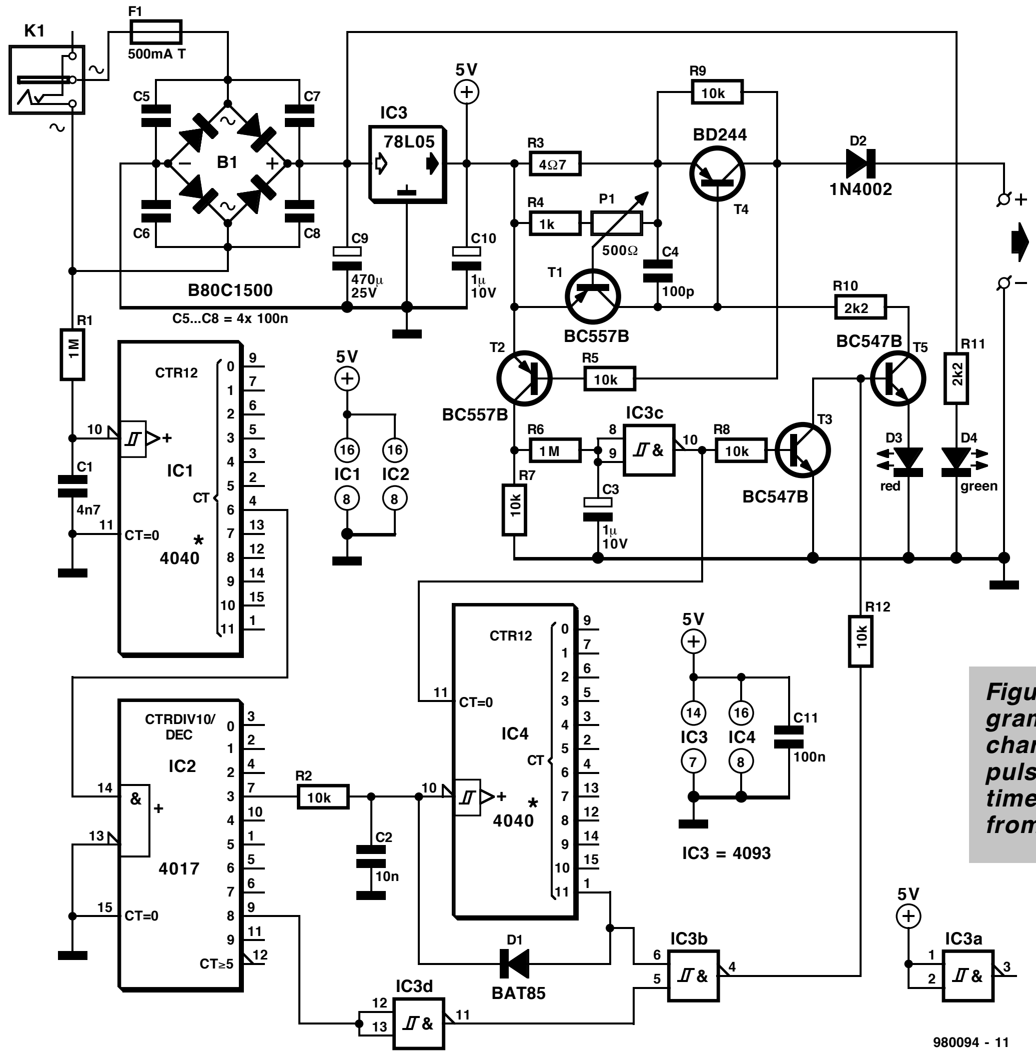

Figure 1. Circuit diagram of the battery charger. The clock pulses controlling the timer are taken direct from the mains voltage.

The adjustable current source is fed with an unregulated voltage. Transistor T_1 is arranged as a variable zener diode. The position of P_1 determines the level of voltage dropped across T_1. This voltage is also applied across resistor R_3. The drop across this resistor, and its value, determine the current flowing from the current source via T_4.

Transistor T_2 functions as a detector. When there is no battery across terminals PC_1 and PC_2, this transistor will be switched off since the potentials at its base and emitter are identical. When a battery is connected across the output terminals, T_2 comes on, whereupon capacitor C_3 is charged via R_6.

After charging has taken place for one second, the output of IC_{3c} goes low. Counter IC_4 is then enabled and transistor T_3 is off. The one second delay time ensures that contact bounce and other interference do not affect the charging process.

Since the output of IC_{3b} is high (output Q_{11} of IC_4 is low after a reset), T_5 comes on. The current source is enabled and charging commences, indicated by the lighting of D_3.

At the termination of the charging process, output Q_{11} of IC_4 goes high, whereupon trickle charging begins. A good level of the trickle-charging current is one tenth of the normal charging current. It is clear that the current source should be modulated to approximate this level. In the present design this is effected by pulse-width modulation.

During normal charging, output Q_{11} of IC_4 is low. Irrespective of the signal at pin 5 of IC_{3b}, the output of IC3b is high. Only when the maximum counter state has been reached does the level at pin 5 determine the level at the output.

Circuit IC_2 is a decade scaler, whose output Q_8 is high for only one tenth of the normal charging period. Circuit IC_{3d} inverts the output so that IC_{3b} ensures that T_5 is on for only one tenth of the normal charging period.

The level of current used for charging is set with P_1. With component values as indicated, the output current may be set between 150 mA (wiper at C_4) and 225 mA (wiper at R_4).

If the unit is used for charging AA batteries, the value of R_3 must be adapted as relevant. With the wiper of P_1 at the centre of its travel, and with R_3= 4.7 Ω, the charging current is 180 mA. AA batteries, which have a capacity of 600–700 MaH, need a charging current of 60–70 mA. If the value of R_3 is trebled to 15 Ω, the current is reduced to 60 mA. The setting range is then 50–75 mA.

CONSTRUCTION

The charger is best built on the printed-circuit board shown in **Figure 2**. Construction should not present undue difficulties: all components, including P_1, are to be placed on the board. If the charger is to be used for one type of battery only, P_1 may be a preset type.

Transistor T_4 is located at the edge of the board so that if a heat sink is deemed necessary, this is easily pun into place.

Start by placing the wire links and three PCB pins for mounting P_1, followed by the passive components and the IC sockets. When construction is complete and the work has been checked thoroughly, insert the ICs into the relevant sockets.

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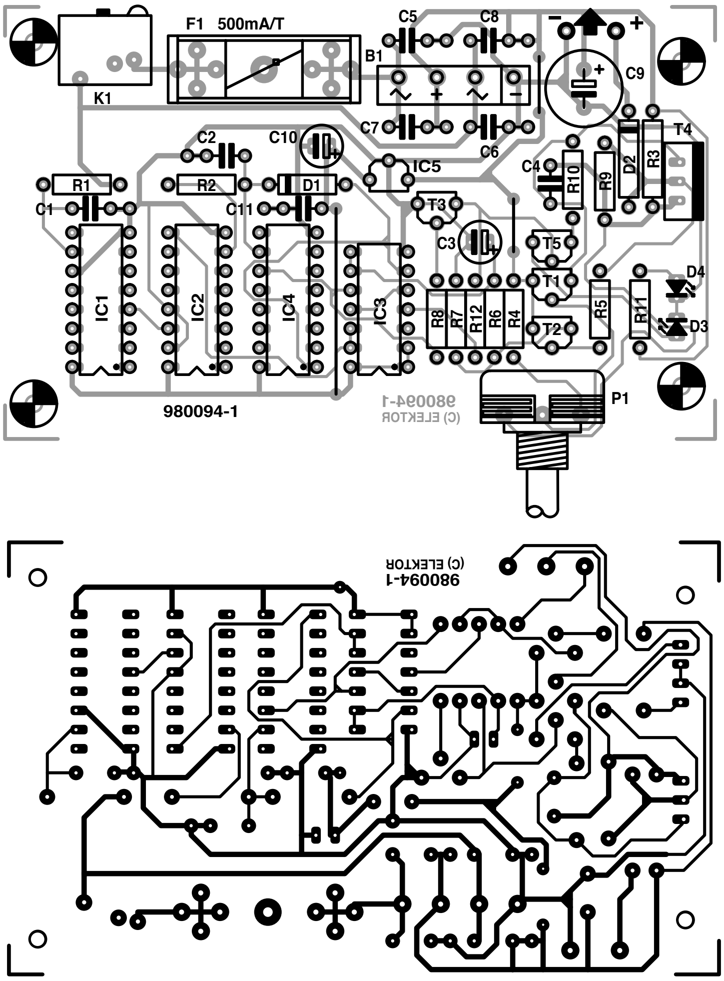


Figure 2. Printed-circuit board for the battery charger.

Parts list

Resistors:

R_1, R_6 = 1 MΩ
R_2, R_5, R_7–R_9, R_{12} = 10 kΩ
R_3 = 4.7 Ω (but see text)
R_4 = 1 kΩ
R_{10}, R_{11} = 2.2 kΩ
P_1 = 500 Ω

Capacitors:

C_1 = 0.0047 μF
C_2 = 0.01 μF
C_3, C_{10} = 1 μF, 10 V, radial
C_4 = 100 pF
C_5–C_8, C_{11} = 0.1 μF
C_9 = 470 μF, 25 V, radial

Semiconductors:

D_1 = BAT85
D_2 = 1N4002
D_3 = LED, 3 mm, red, high efficiency
D_4 = LED, 3 mm, green, high efficiency
T_1, T_2 = BC557B
T_3, T_5 = BC547B
T_4 = BD244

Integrated circuits:

IC_1, IC_4 = 4040
IC_2 = 4017
IC_3 = 4093
IC_5 = 78L05

Miscellaneous:

K_1 = mains adaptor plug for board mounting
B_1 = B80C1500
F_1 = fuse holder with 500 mAT fuse, for board mounting
PCB pins as required
PCB Order No. 980094

FINAL NOTES

Since IC_1 is clocked directly by the alternating voltage, it is imperative that this circuit has a Schmitt trigger clock input. Normal logic inputs often cannot handle the leading edge of such a signal correctly and generate additional clock pulses.

The mains adaptor must be an alternating voltage type. Is this difficult or impossible to find, use a direct voltage type and remove the rectifier and smoothing capacitor from it.

The output voltage of the adaptor depends on the type of batteries to be charged. A good choice is an output voltage equal to 1.2–1.45 times the direct voltage for the particular battery. If, for instance, the battery voltage is 7.2 V (as found in electric tools), the alternating voltage output of the adaptor should be 8.7 V, rounded up to 9 V.

If a direct voltage adaptor is used, the timer function cannot be used.

When construction is complete, insert a multimeter set to the 200–500 mA d.c. range, between the charger and the battery to be charged. During charging, adjust P_1 until the correct charging current flows. Leave the multimeter in place until charging is complete. If at the end of the normal charging period the current drops a little, a slightly higher supply voltage must be used.

When the adaptor is inserted into the mains outlet, D_4 lights. When the battery is connected to the output terminals of the charger, both LEDs light and the charging cycle commences. After a good 14 hours, the red LED goes out, whereupon trickle charging begins. The yellow LED remains on for as long as the charger is connected to the mains. Trickle-charging can go on indefinitely and does not harm the battery.

[980094]

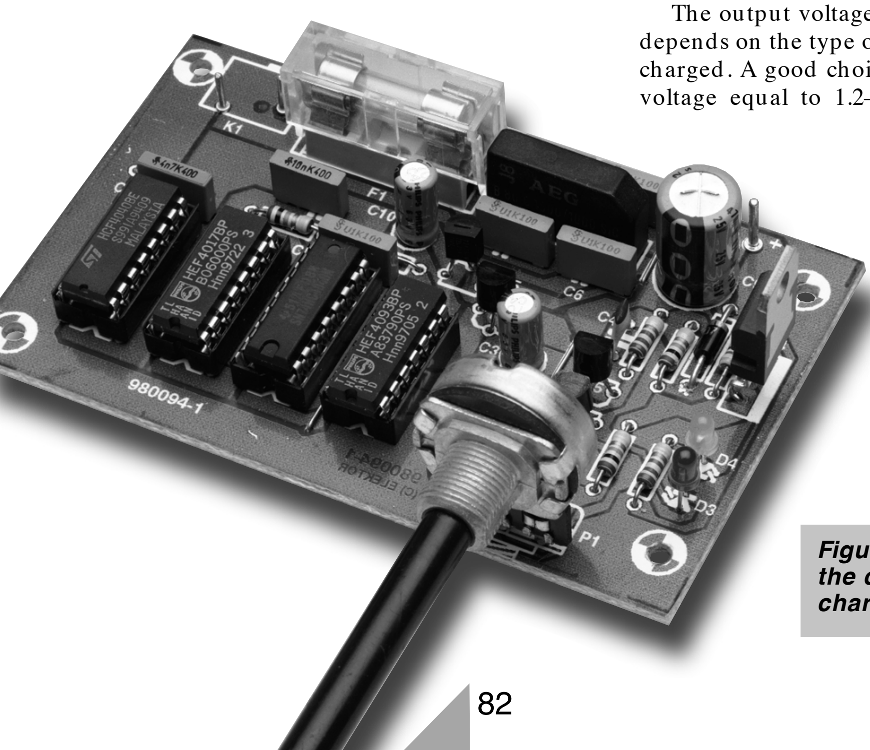


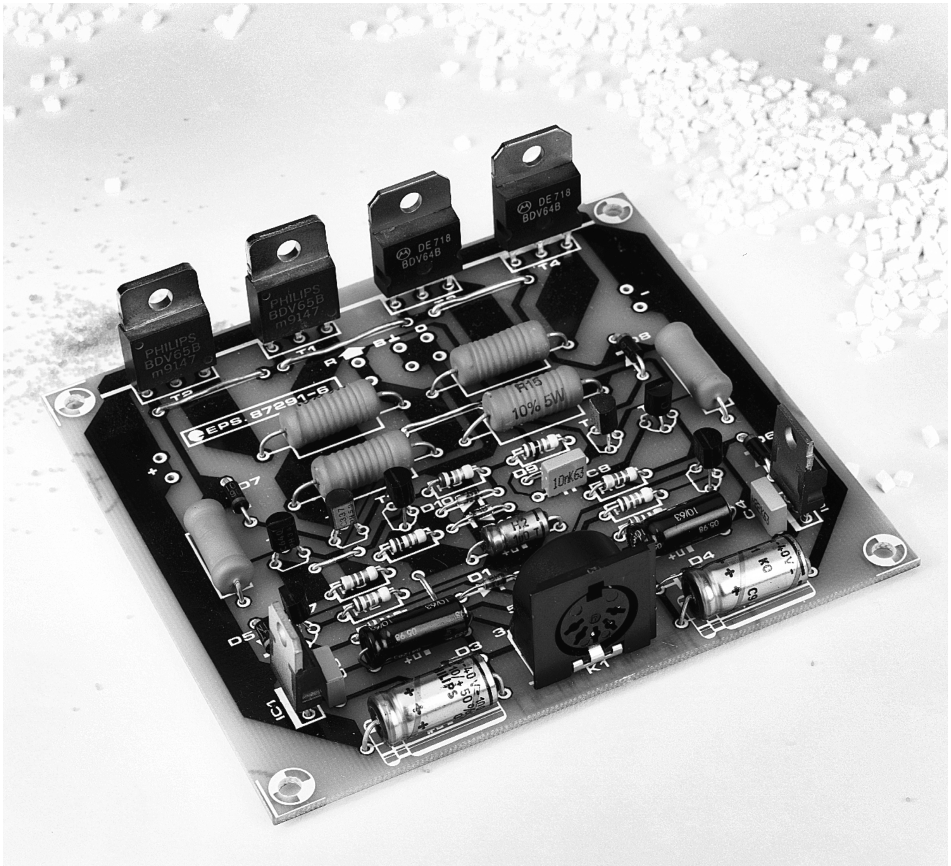
Figure 3. Photograph of the completed prototype charger.

PC-controlled model railway: EEDTS Pro

the booster amplifier

The controller of a model railway is the generic term for the device used to vary the supply to the track, and thus to the locomotives, so that control of their movement is possible. It may take many forms, and may or may not contain a booster amplifier. The booster amplifier described in this article is an updated version of the one originally published in the September 1989 issue of this magazine

Design by L. Lemmens



INTRODUCTION

The booster amplifier described in this article is an updated version of the 'booster unit' described in an article published ten years ago. However, the update is minimal and consists of replacing the original Type BDV64 and BDV65 power transistors by the currently more readily available Types BDW83 and BDW84.

DESCRIPTION

Since the switching pattern of the track voltage contains control data, it is important that the booster amplifier provides a clean output signal. Much attention has, therefore, been paid to the switching speed. The use of emitter follower output stages enable higher switching speeds since the transistors, T_1–T_4 (see **Figure 9**), operate on the linear part of their characteristic. This means that the switching speeds are not affected by saturation effects.

The bases of the emitter followers are switched by drivers T_5 and T_6 between + 20 V and –20 V. These voltages are provided by IC_1-D_3 and IC_2-D_4 respectively. The final output voltage is the difference between the base voltage and the sum of the base-emitter potential (about 1.5 V) of the output transistors and the drop across the emitter resistors (maximum 0.6 V).

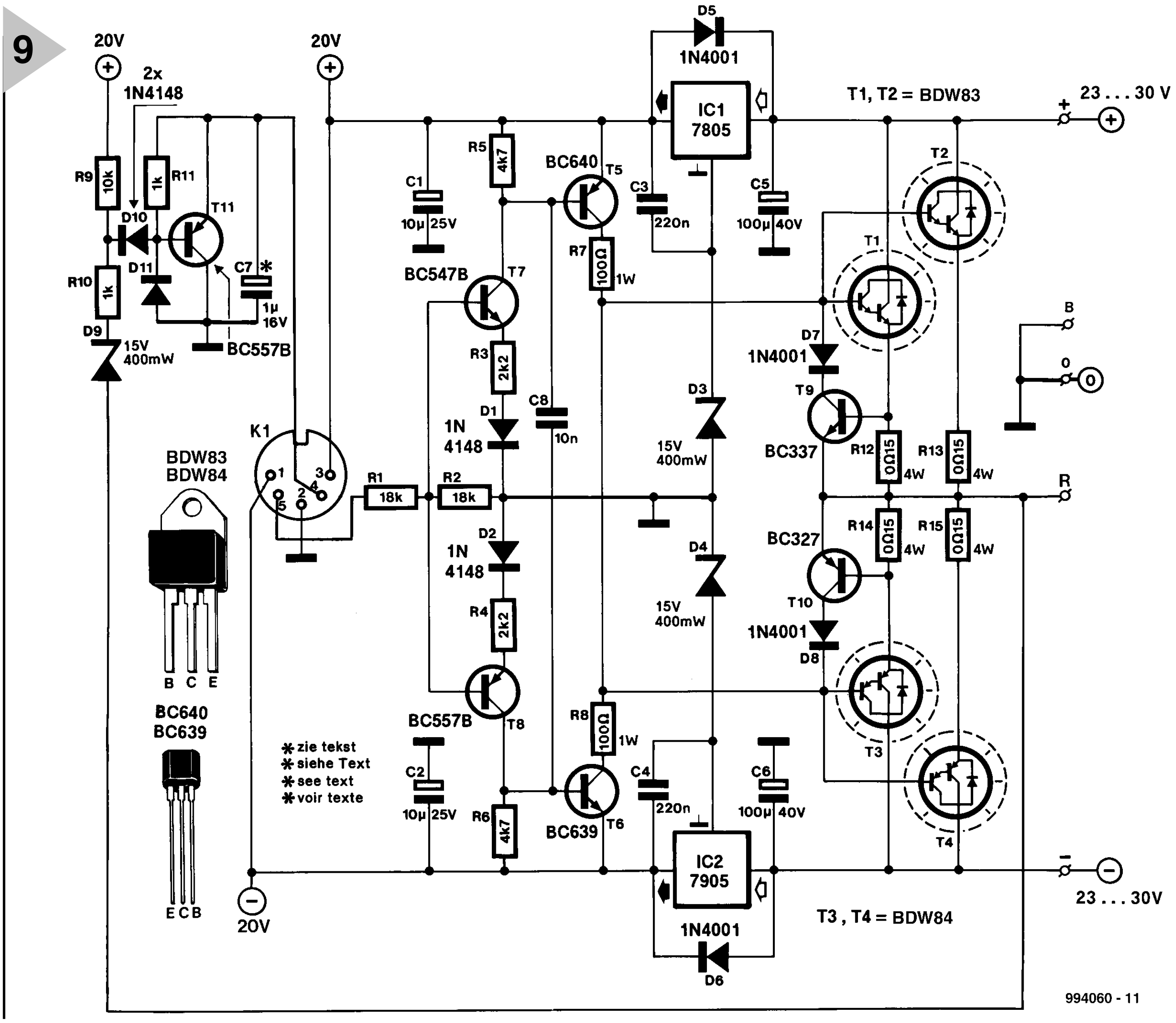


Figure 9. Circuit diagram of the booster amplifier. Power transistors T1–T4 have been replaced by current types BDW83 and BDW84.

In practice, the output voltage is a reasonably constant ± 18 V.

The emitter followers ensure better bandwidth and regulation with complex loads than would be obtained with feedback.

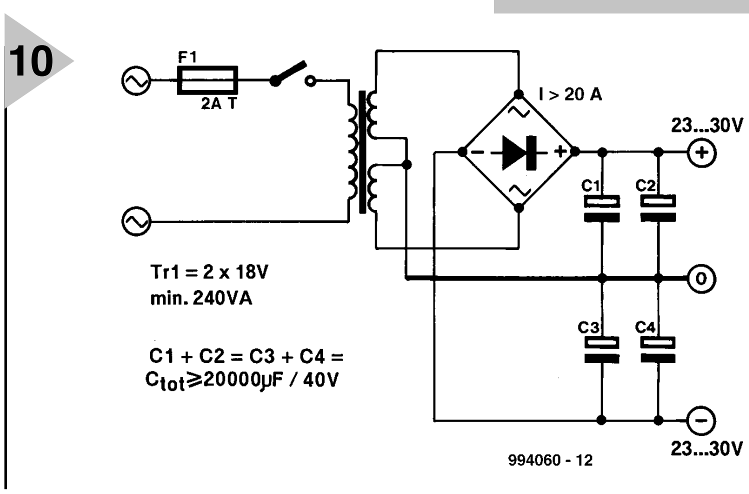
Emitter resistors R_{12}–R_{15} ensure an equal division of the current to T_1-T_2 on the one hand and T_3-T_4 on the other.

Resistors R_{12} and R_{14} serve to measure the current in aid of short-circuit protection transistors T_9 and T_{10}. When the emitter current of T_1 or T_3 tends to become excessive, the drop across R_{12} or R_{14} rises sufficiently to switch on T_9 or T_{10}. This results in a reduction in the base current of the output transistors and, consequently, in their collector and emitter currents.

The input stage is formed by T_7 and T_8, and is configured in a manner that makes a balanced input signal essential. When the input (pin 5 of K_1) is 0 V or not connected, all transistors are off and the output presents a high impedance, that is, there is no voltage supplied to the track. When the input voltage is between + 5 V and + 20 V, transistors T_1, T_2, T_5, and T_7, are on and the output is switched to + 18 V. With the input voltage between –5 V and –20 V, transistors T_3, T_4, T_6, and T_8, are on and the output is switched to –18 V.

All transistors, except T_5 and T_6, operate on the linear part of their characteristics. Transistors T_5 and T_6 are switched in the saturation region

Figure 10. Circuit diagram of a suitable power supply for the booster amplifier; other designs are, of course, possible.



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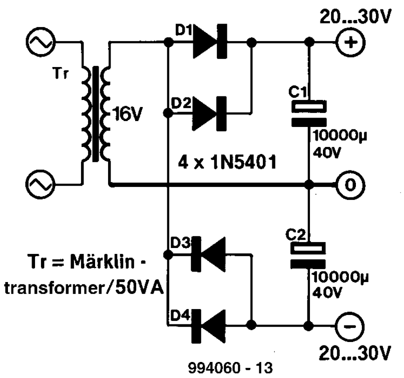


Figure 11. Alternative power supply for use where a suitable mains transformer is already available. See reservations about this in the text.

because switching transistors for voltages of 50 V or more are not available. Nevertheless, capacitor C_8 ensures that these transistors switch at a sufficiently high speed.

OVERLOAD

The circuit around T_{11} serves to indicate an overload condition. Note that only the negative output voltage is monitored, which is sufficient since the

12

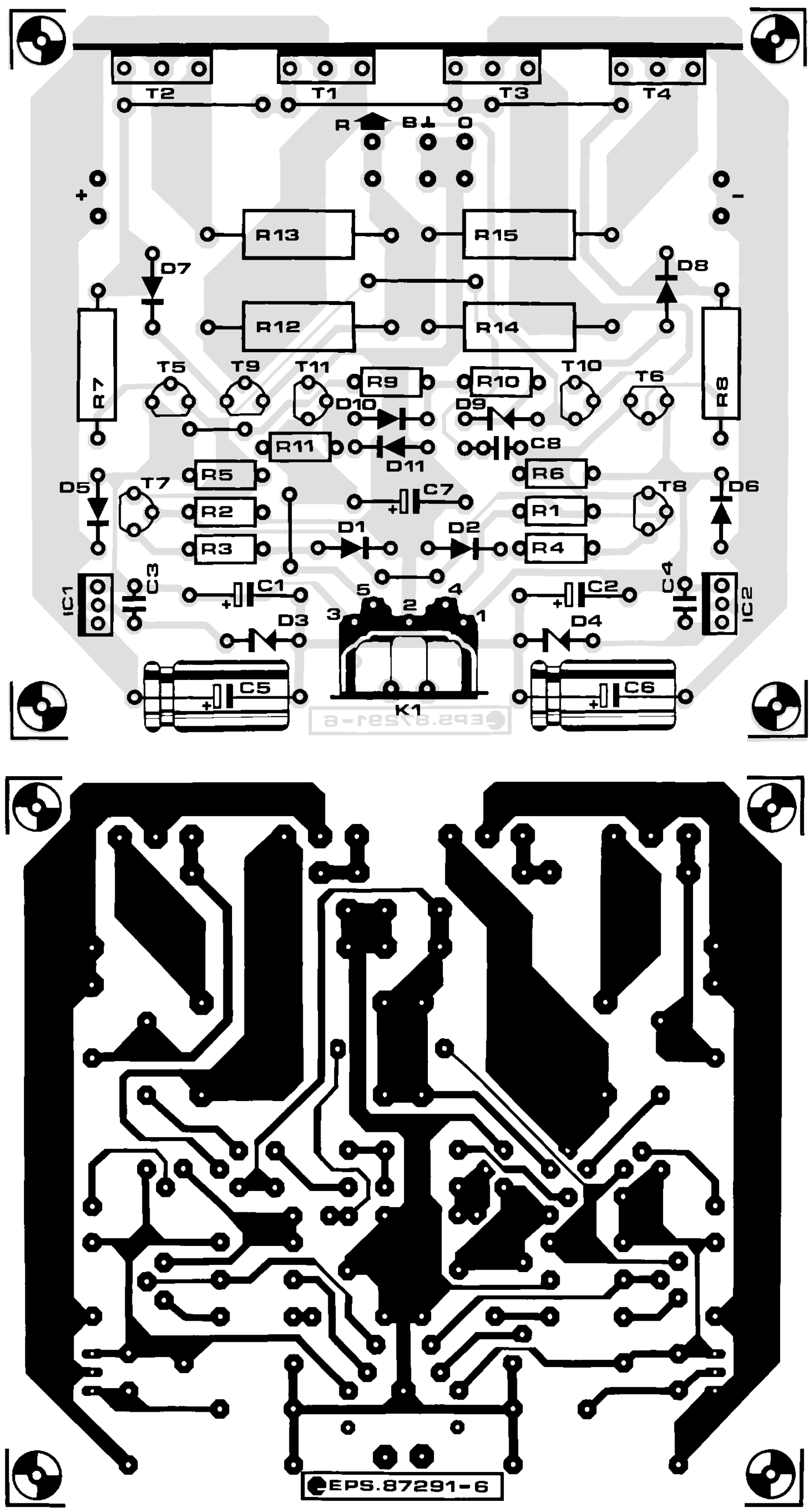


Figure 12. The printed-circuit board for the booster amplifier is available ready made – see Readers' Services towards the end of this issue.

Parts list

Resistors:
R_1, R_2 = 18 kΩ
R_3, R_4 = 2.2 kΩ
R_5, R_6 = 4.7 kΩ
R_7, R_8 = 100 Ω, 1 W
R_9 = 10 kΩ
R_{10}, R_{11} = 1.0 kΩ
R_{12}–R_{15} = 150 mΩ, 4 W

Capacitors:
C_1, C_2 = 10 µF, 25 V
C_3, C_4 = 0.022 µF
C_5, C_6 = 100 µF, 40 V
C_7 = 68 µF, 16 V
C_8 = 0.01 µF

Semiconductors:
D_1, D_2, D_{10}, D_{11} = 1N4148
D_3, D_4, D_9 = zener 15 V, 400 mW
D_5–D_8 = 1N4001
T_1, T_2 = BDW83 (Philips)
T_3, T_4 = BDW84 (Philips)
T_5 = BC640
T_6 = BC639
T_7 = BC547B
T_8, T_{11} = BC557B
T_9 = BC337
T_{10} = BC327

Integrated circuits:
IC_1 = 7805
IC_2 = 7905

Miscellaneous:
K_1 = 5-way DIN socket (180°) for PCB mounting – but see text
5 off car-type space terminals for PCB mounting
Insulation material for T_1–T_4 and their heat sink
Heat sink 0.8 K W^{-1}
PCB Order No. 87291 (see Readers Services towards the end of this issue)

Parts for recommended power supply
(not on booster board!)
Mains transformer, 2×18 V, 300 VA
4 off smoothing capacitors of 10,000–15,000 µF, 40 V
Heavy-duty bridge rectifier
Fuse holder with 2 A slow fuse for board mounting

load on the negative supply line is slightly higher than that on the positive line. For instance, the turnout (points or switches) decoders work with half-wave rectifiers and, therefore, load only the negative line. Moreover, when there are no data being transmitted, the output voltage is negative.

When the booster amplifier is overloaded, T_9 and T_{10} limit the current in the first instance. The output voltage then drops significantly and this causes a rise in the potential across the output transistors and, consequently, in the dissipation. If this situation is allowed to persist, there is a danger of the booster amplifier being thermally overloaded, which presents a real risk of fire.

Therefore, if the output voltage drops below 15 V, owing to the zener voltage of D_9, T_{11} switches off. The signal at pin 5 of K_1 goes low, which results in the removal of the drive to the controller..

Capacitor C_7 enables the overload action to be delayed so that the system is not disabled at every momentary short circuit.

CONSTRUCTION

If the printed-circuit board in **Figure 12** is used, construction of the booster amplifier should not present any undue problems. Fit the wire links first: those close to the output transistors should be of 1 mm dia. wire.

Mount resistors R_{12}–R_{15} well away from the board, because they become pretty hot during operation.

The board has provision for a 5-pin DIN connector, but if the controller is to be used in a stationary position, which is normally the case, the respective wires may be soldered directly to the board.

Circuits IC_1 and IC_2 do not need a heat sink, but transistors T_1–T_4 do: this should be rated at 0.8 K W^{-1}.and be used with good-quality insulating washers and spacers, and liberal use of heat conducting paste.

IMPORTANT

If the booster amplifier is to be used with the controller described in last month's issue, it must be linked to this via the interface described in that issue.

POWER SUPPLY

The circuit diagram of a suitable power supply is shown in **Figure 10**. The mains transformer should preferably be a toroidal type approved to Class I. This means that the mains cable must have three cores, one of which is to be connected to the protective earth of the mains supply. All metal parts that can be touched (incl. the heat sink) must be connected to this earth.

The rectifier must be a heavy-duty type and needs a heat sink: it may be mounted on that used in the booster amplifier (T_1–T_4).

Connect the two secondary windings of the transformer in series and fit and solder the rectifier and the buffer capacitors.

If a suitable transformer is already available, this may be used to build a power supply as shown in **Figure 11**. Note, however, that such a setup will normally not be able to provide more than about a quarter of the power of the design in Figure 11.

Finally, do not connect transistors in parallel to increase the total available current: such a setup can be a risky undertaking.

(994060)

software debugging tools for 80C166

Hitex Telemon 166 debugger specially adapted for Elektor

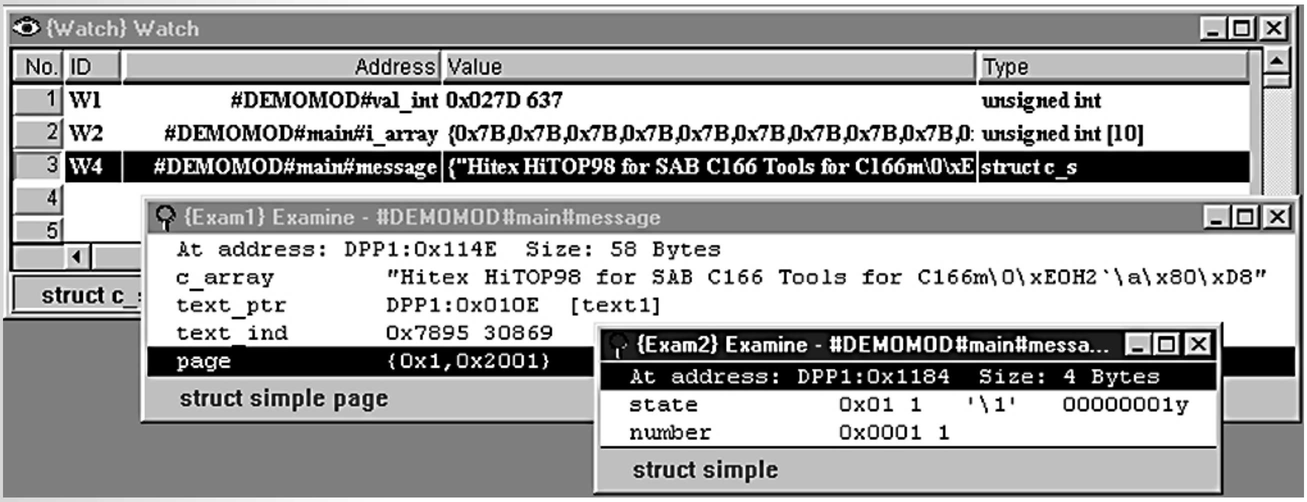


Figure 1. Watching and examining variables.

A strategic partner of chip manufacturer Siemens and a leading supplier of development tools for the 16-bit 80C166 microcontroller family, Germany-based Hitex System Development have adapted their target code debugger *telemon 166* to the requirements of the *Elektor Electronics* 80C166 evaluation system published in the March and April 1999 magazines. This modified version of *telemon 166* is now available on diskette.

By U. Beier,
Hitex System Development, Germany

Comprising powerful CPUs for embedded systems, the 16-bit microcontroller family identified as 'C166' has achieved a strong foothold in the microcontroller market. The C166 is often found in automotive control applications (engine management, power steering, etc.), but also in hard disk control systems. The architectural similarities with the ageing and widely used 8-bit 8051/C500 controller family often cause developers to upgrade to the C166 once the limits of 8-bit programming are acutely felt.

HOW DOES TELEMON 166 WORK?

A target-code (or 'remote') debugger like *telemon 166* consists of a monitor core and a debugger shell. It requires a fully functional piece of hardware using the C166 controller with RAM, Flash or EPROM memory. This hardware should offer PC connectivity using a communication channel.

Running on the target system, the monitor core is often considered the operating system of the debugger. The HiTOP debugger runs as a Windows application on your PC and employs an RS232 interface to communicate with the COMx port on the PC.

In the case of the *Elektor Electronics* hardware, the monitor core is stored in an EPROM pair (H and L) and up and running the moment the hardware is switched on. By connecting the hardware to the PC (via an RS232 cable), and then launching the HiTOP Debugger on the PC you are get a 'window' with a view on all that's happening inside the controller and its memory.

Once that has been done you are in a position to develop a program for the microcontroller, download it into the target system and then either launch it or execute it in single-step mode.

To make sure you, the user, remains in full control, the program has to be stored in the RAM memory on the controller board. So, a couple of important pints should be observed when working with such a debugger.

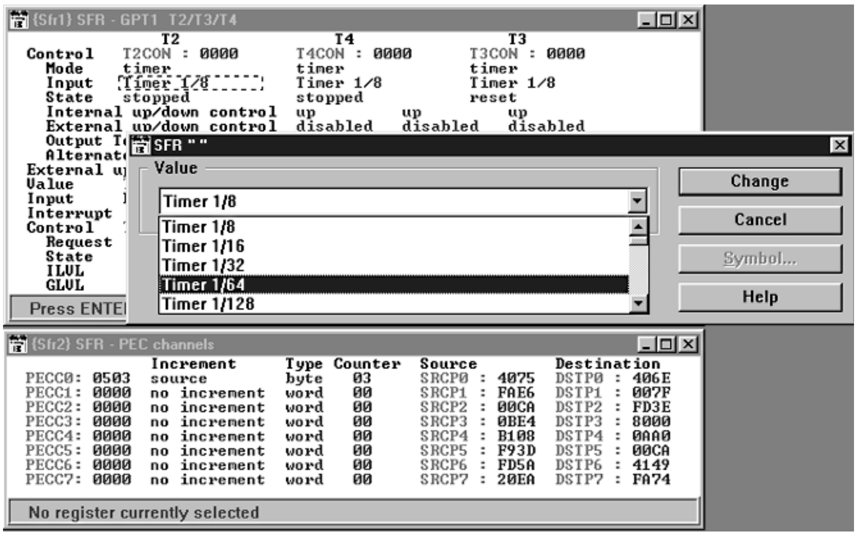


Figure 2. Watching what happens to the Special Function Registers.

Windows on windows

Obviously, embedded systems based on powerful 16-bit controllers with a full complement of complex peripherals tied to an extensive interrupt structure are easily made to enter a state when nothing seems to work anymore. Up to a certain level, such erroneous states may be analysed using a tool like *telemon 166*.

Using a couple of practical examples described below you will get to know the functions of HiTOP.

Instruction window

Once HiTOP is up and running, three windows are opened for you (Instruction, List and Register).
The Instruction window shows the disassembled contents of the memory range pointed to by the program counter. This window allows you to view your assembly-code program after it has been downloaded. You can choose to execute the program step by step, set breakpoints or view and modify variables.

If you are using a 'Keil' or 'Tasking' assembler, you can use full symbolic debugging under HiTOP.

Register window

The current contents of the standard registers inside the microcontroller are always displayed in this window. On each program start, the modified registers are highlighted by a colour. In this way, you can immediately see the effects certain instructions have had on a register.

List window

The List window shows lines of 'C' source code when the controller is being programmed in a higher programming language. In this window, too, the program may be executed step by step and variables may be inspected.

Memory window

HiTOP allows you to open as many Memory windows as you like. These windows may display different memory ranges. The memory contents may be shown in different notations (byte, word, dword, integer, long, float, double). These memories may also be edited using the local functions Fill, Move, Test and Compare.

Watch window

In the Watch window, a number of individual objects (simple or complex

The software: ***telemon 166 for the Elektor 80C166 board***

The availability of the HiTOP 'telemon 166' debugger from Hitex, adapted for the Elektor 80C166 development system means that you, the user, have an alternative to the software described in the April 1999 magazine. Recapping, this software also consist of a PC program and a monitor program stored in pair of EPROMs. Arguably the larger number of possibilities offered by the Hitex software means that the program is a bit more difficult to control. Even if this may seem obvious, the software mentioned in the April 1999 magazine can not be used with the HiTOP PC program. If the HiTOP debugger shell is employed on the PC, the two EPROMs on the 80C166 board should contain the monitor core provided by HiTOP telemon 166. The 80C166 board should be populated as follows:

Segment 0	*64 kByte RAM*
Segment 1	*64 kByte EPROM containing the telemon 166 monitor, v1.0, KHD 80C166 (low and high)*
Segment 2	*64 kByte RAM*
Segmant 3	*optional 16 or 32 kByte EEPROM*

SIO-1 (UART) as the serial port

A short description of adaptations on the Elektor C166 board, plus a memory allocation overview may be found in the file x:\hitopwin\telemon\monitor\README.TXT.

The adapted debugger software HiTOP (Windows version) and the code for the HiTOP-compatible monitor EPROMs may be found on two diskettes, order code ***996015A+ B****, available through our Readers Services. The EPROMs are also available ready-programmed under order code* ***996512-A+ B****. For price and ordering information, see the Readers Services pages towards the end of this issue.*

variables) may be displayed ij the proper format. With complex variables, for example, structures or arrays, these can be resolved in so-called 'Examine' windows (see **Figure 1**).

User SFR windows
It is widely known that the members of the 'C166' controller family have extensive on-chip peripheral circuitry. These circuits may be activated by suitable programming of the *Special Function Register*, or 'SFR'. To be able to do so, you normally have to study the processor manual in great detail, because these control registers consists of sub-registers whose bit contents determines a particular function.

By means of the SFR window offered by HiTOP, the user is not only able to view the control registers contents in plain language but also change it as required. In this way, you no longer have to thumb through the processor manual to locate the SFR names, functions and meanings (see **Figure 2**).

HiTOP however also allows you to define your own windows, as well as assign texts to variables. This is shown in the illustration 'make your own windows in HiTOP'.

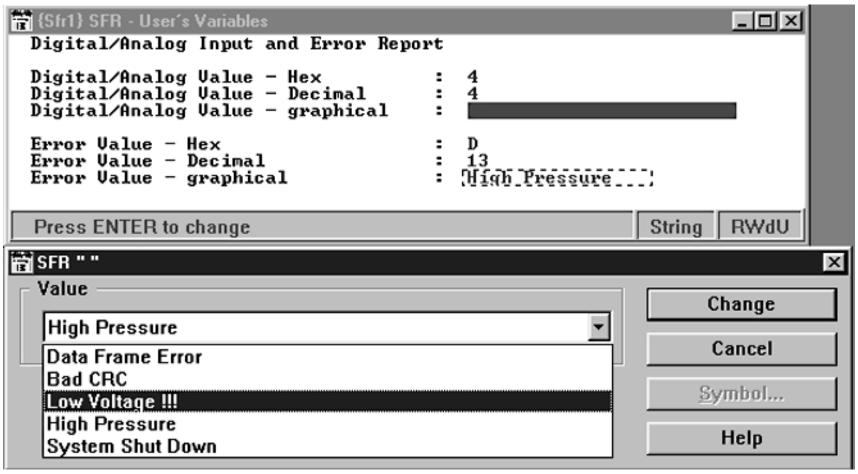


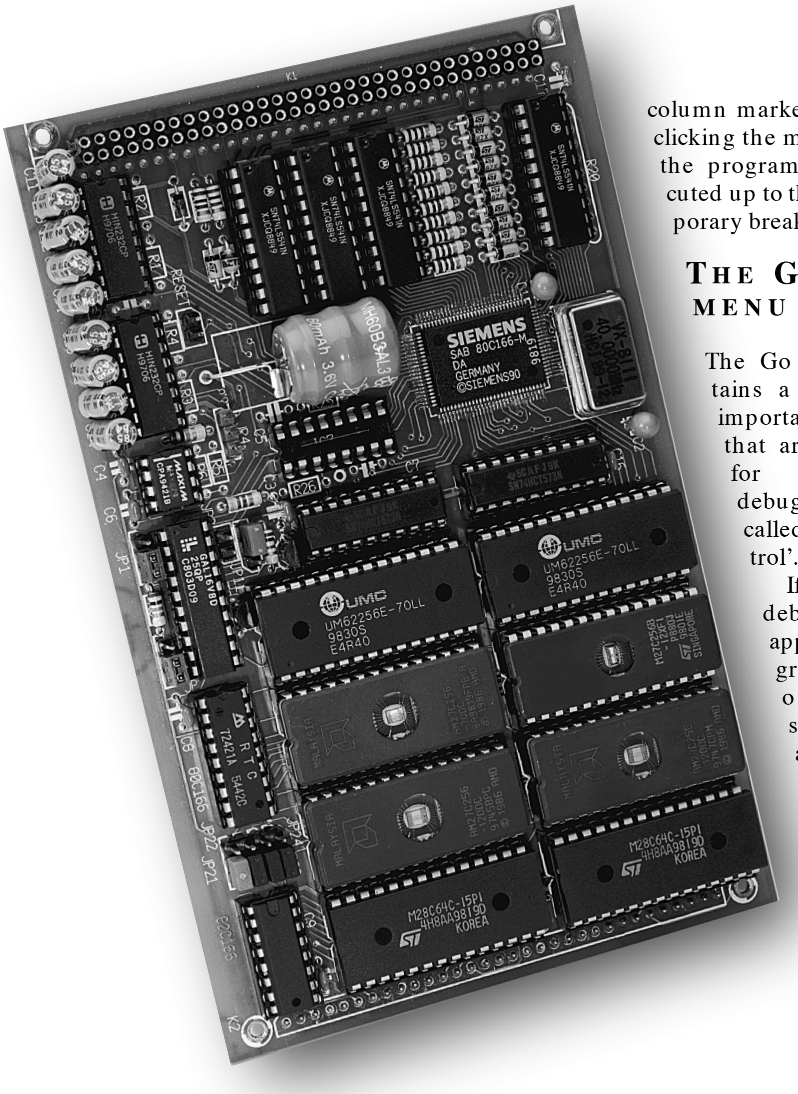
Figure 3 Create your own windows in HiTOP.

Such windows are easily created with the aid of script that describes their structure. An example of a script for a DIY window is shown below

Stack window
The stack window shows the complete stack range of the processor, with the amount of stack space used so far marked in colour.

Breakpoints
HiTOP offers a very convenient way of setting and clearing breakpoints. To do so, you simply open an 'Instruction' or 'List' window. Left-clicking in the 'BP' column at the relevant line then sets a breakpoint. When the cursor is in the

```
; ========================================================================
; WINDOW 1 "System Status and Error Report"
; ========================================================================

REGION: BASE "#DEMOMOD#l", LENGTH 0x1                    ;Definition of Variables (as Symbol)
-l_hex    0x00,   1,    RW,   HEX,    UPD_RUN            ;Hex representation
-l_dec    0x00,   1,    RW,   DEC,    UPD_RUN            ;Decimal representation
-l_txt    0x00,   1,    RW,   ENUM,   UPD_RUN            ;Text representation
= 0: "➲"
= 1: "➲➲➲"
= 2: "➲➲➲➲➲➲"
= 3: "➲➲➲➲➲➲➲➲➲➲➲➲"
= 4: "➲➲➲➲➲➲➲➲➲➲➲➲➲➲➲➲➲➲➲➲➲➲➲➲"                       ;quasi-graphic representation

ENDREGION


REGION: BASE "#DEMOMOD#m", LENGTH 0x1                    ;one more variable
-m_hex    0x00,   1,    RW,   HEX,    UPD_RUN
-m_dec    0x00,   1,    RW,   DEC,    UPD_RUN
-m_txt    0x00,   1,    RW,   ENUM,   UPD_RUN
= 10: "Data Frame Error"
= 11: "Bad CRC"
= 12: "Low Voltage !!!"
= 13: "High Pressure"
= 14: "System Shut Down"
ENDREGION

WINDOW 1 "User´s Variables"                              ;Definition of window layout
l"Digital/Analog Input and Error Report"l
ll
l"Digital/Analog Value - Hex         :"[-l_hex#]l
l"Digital/Analog Value - Decimal     :"[-l_dec#]l
l"Digital/Analog Value - graphical   :"[-l_txt########################]l
ll
l"Error Value - Hex                  :"[-m_hex#]l
l"Error Value - Decimal              :"[-m_dec##]l
l"Error Value - graphical            :"[-m_txt################]l

ENDWINDOW
```



column marked 'PC', left-clicking the mouse causes the program to be executed up to this line (temporary breakpoint).

The Go menu

The Go menu contains a number of important functions that are necessary for comfortable debugging. This is called 'Run-Control'.

If you want to debug your application program, you obviously should be able to start it. After all, you want to see the response of the program to the hardware. If the program does not respond the way it should, you should be n a position to execute it step by step and so examine the effects of individual instructions.

Conclusion

The *telemon 166* debugging system represents a luxurious developing tool which is also available as a freely configurable system (it may be adapted to just about any C166/167 hardware system). In conjunction with the 'COMBOX' extension it is even possible to employ other communication channels between PC and hardware than just the RS232 link. Examples include a 2-wire link via two port pins with interrupt capacity, CAN or a synchronous interface. If you are interested in exploring these possibilities, go to http://www.hitex.com for further information.

(990028-3)

Construction Guidelines

Elektor Electronics (Publishing) does not provide **parts and components other than** PCBs, fornt panel foils and software on diskette or IC (not necessarily for all projects). Components are usually available form a number of retailers – see the adverts in the magazine.

Large and small values of components are indicated by means of one of the following prefixes :

E (exa) = 10^{18}	a (atto) = 10^{-18}
P (peta) = 10^{15}	f (femto) = 10^{-15}
T (tera) = 10^{12}	p (pico) = 10^{-12}
G (giga) = 10^{9}	n (nano) = 10^{-9}
M (mega) = 10^{6}	μ (micro) = 10^{-6}
k (kilo) = 10^{3}	m (milli) = 10^{-3}
h (hecto) = 10^{2}	c (centi) = 10^{-2}
da (deca) = 10^{1}	d (deci) = 10^{-1}

In some circuit diagrams, to avoid confusion, but contrary to IEC and BS recommandations, the value of components is given by substituting the relevant prefix for the decimal point. For example,

3k9 = 3.9 kΩ   4μ7 = 4.7 μF

Unless otherwise indicated, the tolerance of resistors is ± 5% and their rating is ⅓–½ watt. The working voltage of capacitors is ≥ 50 V.

In **populating a PCB**, always start with the smallest passive components, that is, wire bridges, resistors and small capacitors; and then IC sockets, relays, electrolytic and other large capacitors, and connectors. Vulnerable semiconductors and ICS should be done last.

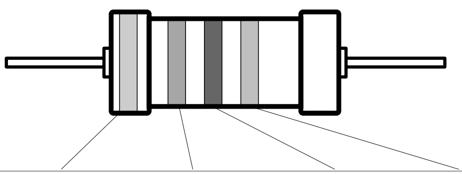
Soldering. Use a 15–30 W soldering iron with a fine tip and tin with a resin core (60/40) Insert the terminals of components in the board, bend them slightly, cut them short, and solder: wait 1–2 seconds for the tin to flow smoothly and remove the iron. Do not overheat, particularly when soldering ICS and semiconductors. Unsoldering is best done with a suction iron or special unsoldering braid.

Faultfinding. If the circuit does not work, carefully compare the populated board with the published component layout and parts list. Are all the components in the correct position? Has correct polarity been observed? Have the powerlines been reversed? Are all solder joints sound? Have any wire bridges been forgotten?

If voltage levels have been given on the circuit diagram, do those measured on the board match them – note that deviations up to ± 10% from the specified values are acceptable.

Possible corrections to published projects are published from time to time in this magazine. Also, the readers letters column often contains useful comments/additions to the published projects.

The value of a resistor is indicated by a **colour code** as follows.

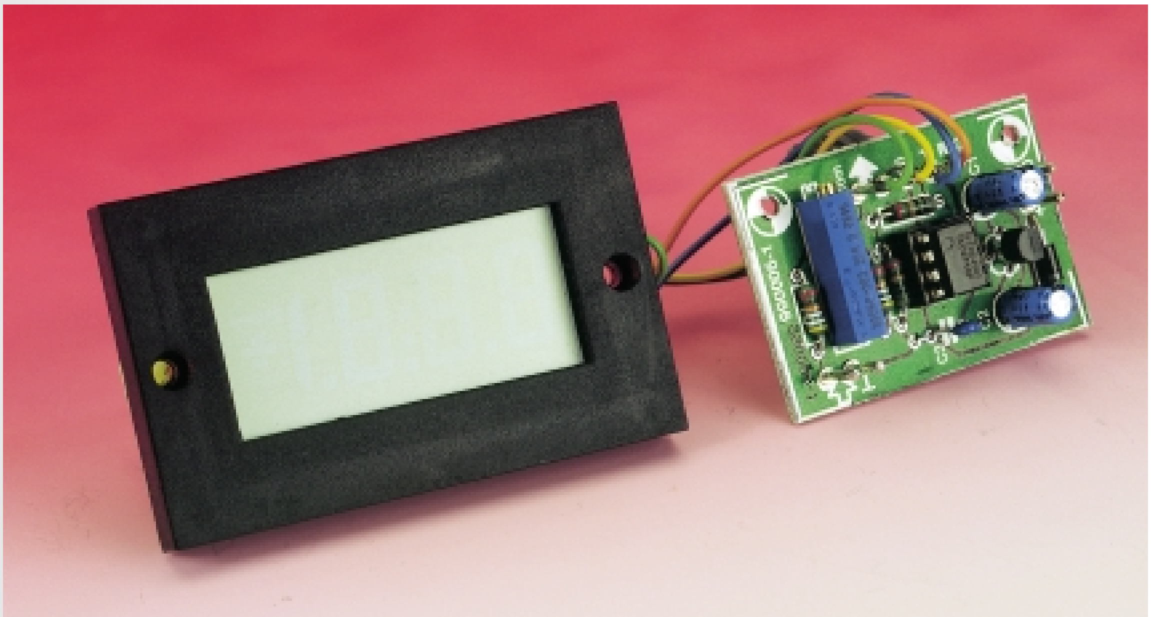


color	1st digit	2nd digit	mult. factor	tolerance
black	–	0	–	–
brown	1	1	$\times10^{1}$	±1%
red	2	2	$\times10^{2}$	±2%
orange	3	3	$\times10^{3}$	–
yellow	4	4	$\times10^{4}$	–
green	5	5	$\times10^{5}$	±0,5%
blue	6	6	$\times10^{6}$	–
violet	7	7	–	–
grey	8	8	–	–
white	9	9	–	–
gold	–	–	$\times10^{-1}$	±5%
silver	–	–	$\times10^{-2}$	±10%
none	–	–	–	±20%

Examples:
brown-red-brown-gold = 120 Ω, 5%
yellow-violet-orange-gold = 47 kΩ, 5%

power for panel meter

without auxiliary battery



Most meter modules using a liquid-crystal display (LCD) and some using a light-emitting-diode (LED) display need a power source that is isolated from the measurand. In practice, this normally means that a separate battery has to be used. This is cumbersome and can be avoided with the circuit described in this article.

Design by G. Lindner

INTRODUCTION

It is an annoying fact that when it is desired to fit a digital panel meter to a certain equipment, the power for this often cannot be drawn from the supply for that equipment. This is not always so, but it certainly is in the case of meters based on the popular ICL7106 and ICL7107. This means that a separate supply has to be provided for the meter whose earth (common return) is isolated from that of the equipment supply.

A simple solution to this problem is the present simple auxiliary circuit, which is a variant of the d.c shifter used in the 'capacitance meter' published in our November 1994 issue. The circuit can be used with any digital voltage module based on an ICL7106. It is based on the shifting of the reference level of the input signal.

DESIGN CONSIDERATIONS

The reason that the earth (common return) of the meter must be isolated from that of the measurand (quantity to be measured) is clear from **Figure 1**. In this, the meter is is treated as a black box with two inputs for the supply lines and two for the measurand. The terminal 'low in' is at the potential of the supply lines less 2.8 V. This means that if the meter and the signal source are to be linked to the same earth, the value of the measurand has to be raised by U_S–2.8 (V).

This is achieved with the aid of the popular non-inverting adder circuit in **Figure 2**. In this, the operational amplifier (op amp) will try to equalize the

Figure 1. The potential at the 'low in' terminal of the meter is U_S–2.8 V, which means that that at the 'high in' terminal must be raised by an identical value.

levels at its two inputs. When $R_2/R_1 = R_4/R_3 = 1$, the output voltage will assume a level of $U_O = U_a + U_b$. The measurand is linked to terminal *a*. When output U_O is linked to the 'high in' terminal of the meter and input U_b to terminal 'low in', the desired shift is achieved, whereupon the return lines of the power supply and measurand can be connected to the same earth.

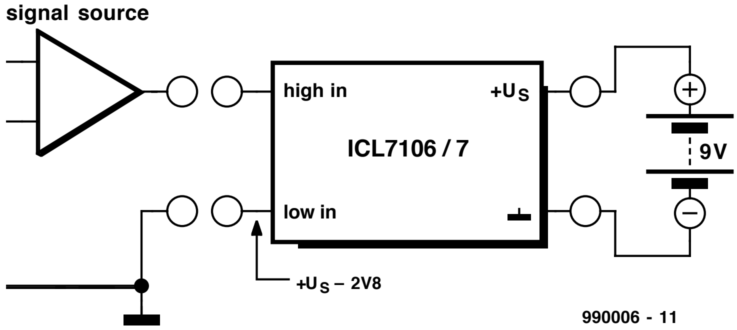
CIRCUIT DESCRIPTION

The diagram of the auxiliary circuit is shown in **Figure 3**, which is basically the same as that in Figure 2, with the meter terminals and a preset potentiometer, P_1, added.

The preset is essential, since it cannot be assumed that the transfer ratio of the input signal is 1:1. This is because in practice all sorts of deviation occur owing to tolerances, the output impedance of the signal source, and the offset of the op amp. All these can be compensated with P_1, provided that the output impedance of the signal source ≤ 2.5 kΩ. If this is not so (which in practice will be seldom), the value of R_1 has to be altered slightly. Note that the compensation provided with P_1 is dependent on the supply voltage. This dependency is such that the meter indication varies over a wide range in direct proportion to supply voltage fluctuations. This is because the offset of the op amp is also compensated; if there were no offset, the meter indication would be independent of the supply voltage. All this is of not much importance, however, as long as the supply voltage is properly regulated.

Figure 3. The diagram of the auxiliary circuit complete with regulator. The regulator is essential since the compensation set with P_1 is dependent on the supply voltage.

1



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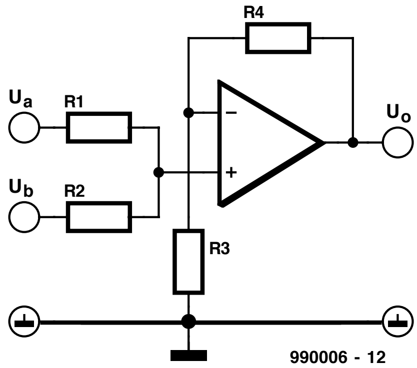
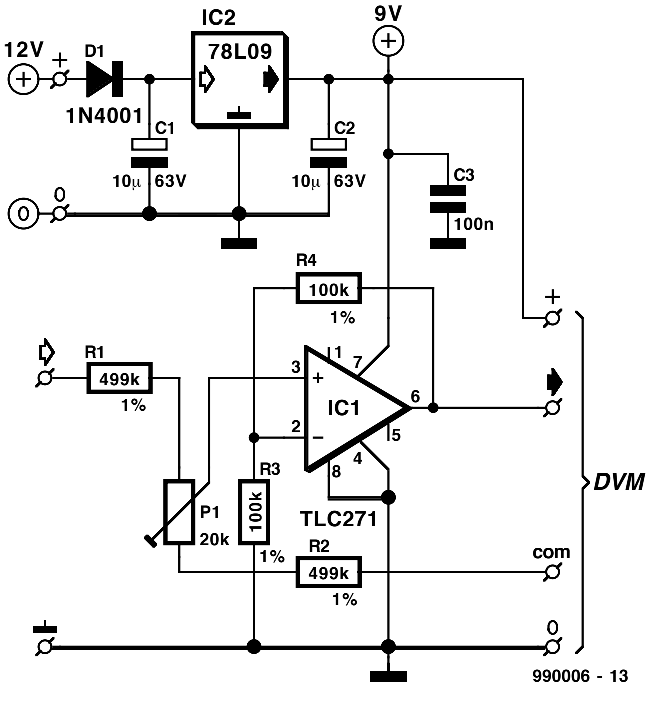


Figure 2. This circuit ensures that the 'low in' signal is added to the signal from the source.

3



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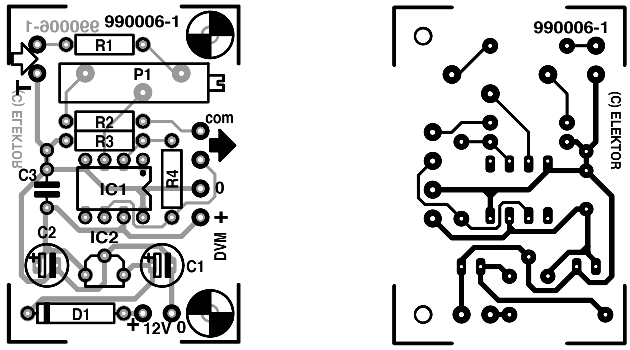


Figure 4. Printed-circuit board for the auxiliary circuit (not available ready made).

Parts list

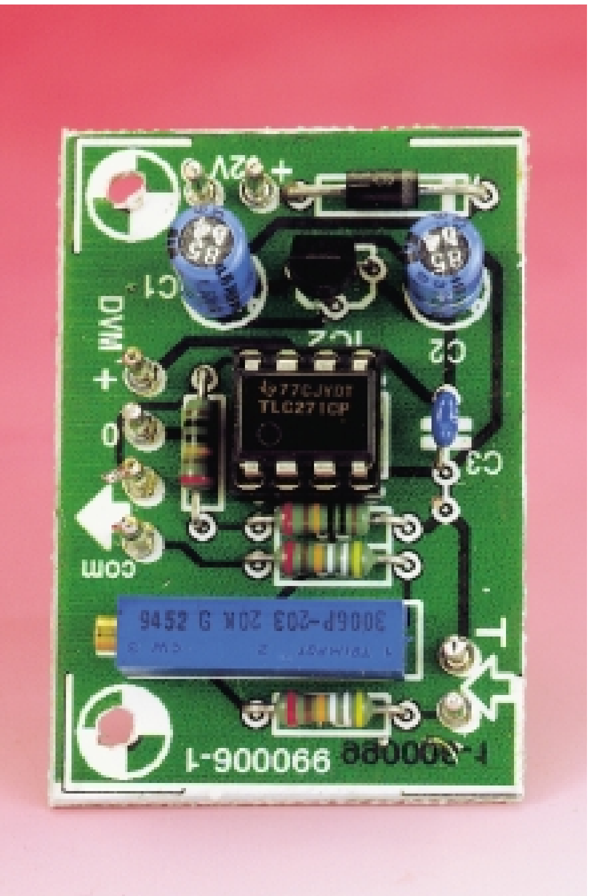
Resistors:
R_1, R_2 = 499 kΩ, 1%
R_3, R_4 = 100 kΩ, 1%
P_1 = multiturn 20 kΩ preset potentiometer, horizontal model

Capacitors:
C_1, C_2 = 10 μF, 63 V, radial
C_3 = 0.1 μF, ceramic

Semiconductors:
D_1 = 1N4001

Integrated circuits:
IC_1 = TLC271CP
IC_2 = 78L09

Miscellaneous:
Meter module based on ICL7106



Since the current drawn by the ICL7106 is tiny, this stabilization may be effected simply with a zener diode and series resistor. However, to avoid any risks, the circuit in Figure 3 uses a popular three-pin regulator. Diode D_1 protects the circuit against inadvertent wrong polarity of the input voltage.

CONSTRUCTION

The circuit is best built on the printed-circuit board in **Figure 4**, which is, however, not available ready-made.

The size of the board enables the circuit to be built into most equipment, and in many cases to be made into 'a sandwich' with the meter.

If there is a suitable supply (9–15 V) available in the signal source, regulator IC_2 may be replaced by a wire bridge.

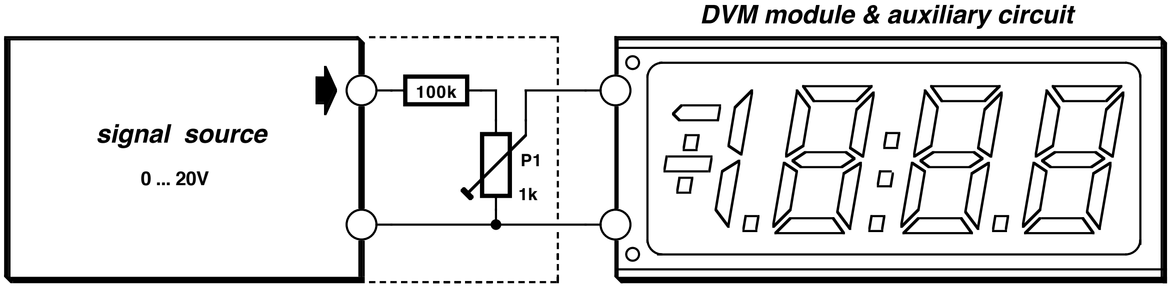
SETTING UP

- Link the auxiliary circuit to the meter and connect the combination to the output of the signal source.
- Set the output voltage of the signal source to 0 V.
- Adjust P_1 until the meter reads exactly 0 V: all deviations are then nullified.
- Set the signal source to the highest possible output and adjust its meter output until the meter displays the correct level. It is assumed that the signal source has an integral potential divider for this purpose; if it has not, it has be added – see **Figure 5**. The values of the resistors must be chosen so that at maximum output of the signal source the maximum input potential of the meter (200 mV) is not exceeded.
- Since the output impedance of the signal source varies slightly when the potential divider is set, it needs to be checked whether the compensation set with P_1 is still correct. This means setting the output of the signal source to 0 V again and readjusting P_1.
- Repeat the setting up procedure a couple of times until a satisfactory result is obtained.

[990006]

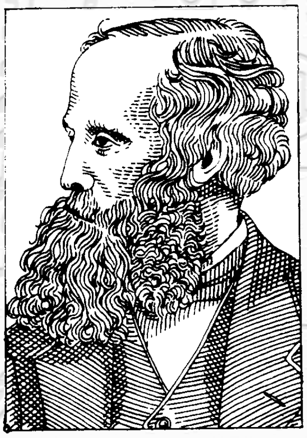
Figure 5. A potential divider enables the output of the signal source to be equated with the correct meter reading.

5



WHEN ELECTRONICS WAS YOUNG (6A)

In 1837, the first electric motor was developed (and patented) in the USA by Thomas Davenport. A few years later, in 1839, the magnetohydrodynamic battery was proposed by Michael Faraday in the UK; the photovoltaic effect was described in France by Alexandre Edmond Becquerel (1820–91), and the fuel cell was invented by Sir William Robert Grove (1811–96) in the UK.



James Clerk Maxwell (1831...1879)

In 1843, the Scottish inventor Alexander Bain patented what has become known as facsimile reproduction (fax), and in 1845–47 the German physicist Gustav Robert Kirchoff (1824–87) published the two famous laws that are named after him. In 1847, George Boole (1815–64) published his first ideas on symbolic logic, although his major work, Investigation of the Laws of Thought was not published until 1854. The kind of symbolic algebra that Boole developed led to Boolean algebras, which are, of course, of great significance in modern algebra and computing.

In 1852, thin film technology was introduced by Sir William Robert Grove. In 1860, professor T J Wray gave a public demonstration of the mercury arc lamp on the Hungerford Bridge in London, and in Germany, the physicist Johann Philipp Reis (1834–74) developed the first microphone. Unfortunately, this microphone was considered a toy and quickly forgotten.

Another important contribution to electrical technology came from the French physicist Robert Louis Gaston Planté (1834–89), who in 1859 developed the lead-acid cell, which was the world's first practical rechargeable or secondary battery. In fact, the lead-acid battery is even today the most widely used rechargeable battery in the world.

In the same year, Michael Faraday discovered that silver sulphide possesses a high negative temperature coefficient. This discovery forms the basis of what are now termed thermistors, that is, temperature-sensitive non-linear resistors. The name thermistor was coined by the Bell Telephone Laboratories of the USA during their research into materials for these components. Also in that year, one of the century's foremost experimentalists, the English physicist James Prescott Joule (1818–89) described magnetostriction, a phenomenon in which the mechanical dimension of a magnetic material is altered as the magnetization is varied.

Perhaps the most able theoretician of the 19th century, the Scottish physicist James Clerk Maxwell (1831–79), started his monumental research on electromagnetism in the late 1850s. This laid the foundations for the work of the German physicist Heinrich Rudolph Hertz (1857–94) in discovering radio waves. Maxwell's 'equations' (1864) form fundamental laws of theoretical physics that govern the behaviour of electromagnetic (radio; television) waves in all practical situations. The equations are used to analyse the propagation of radio waves in free space, at all sorts of boundary, and in all guided-wave structures or transmission lines. His field equations are mathematical formulations of the laws of Gauss, Faraday and Ampère from which the theory of electromagnetic waves can be derived. The Maxwell bridge can be used for the measurement of capacitance and inductance. Maxwell's Rule states that every part of an electric circuit is acted upon by a force tending to move in such a direction as to enclose the maximum magnetic flux.

CORRECTIONS & updates

Eye pattern meter
PC Topics Supplement, March 1999, p. 13. (992002)
The moving coil meter shown in Figure 3 should have a sensitivity of 100-200 µA f.s.d.

Electronics Freeware
May 1999, PC Topics Supplement, p. 4 (990011-1)
The correct url for Digital Works is

http://www-scm.tees.ac.uk/users/d.j.barker/digital/digital.htm

Battery capacity measurement by PC
PC Topics Supplement, December 1998, p. 14-16. (982093)
With reference to the circuit diagram, a number of logic gates in IC4 have been transposed to improve the PCB layout. Functionally, this is of no consequence.
However, one track on the board is missing: that between pin 2 and pin 8 of IC1 (ADC0804). If this link is added, C1 is effectively connected and the circuit will work as described.

Sealed lead-acid battery charger
May 1999, p. 26-31. (990037-1)
In Table 2 (Component Values), the two formulas for R6 should read

0.45 / I [ohms].

D9 is missing from the parts list. As indicated in the circuit diagram, this diode is a type 1N5401. If the charger always supplies currents smaller than about 1 A, diode D9 may also be an 1N4001 or similar.

General Coverage Receiver
January & February 1999 (980084).
In the preselector section, the upper varicap diode, D14, has no dc path. A suggested method of improving the behaviour of the varicap (without modifying the PCB) is to replace capacitor C83 (220pF) with a wire link.

Flash Designs – address information
April 1999, New Products, p. 73.
In the New Products section, the address and telephone number of Flash Designs should be changed to read

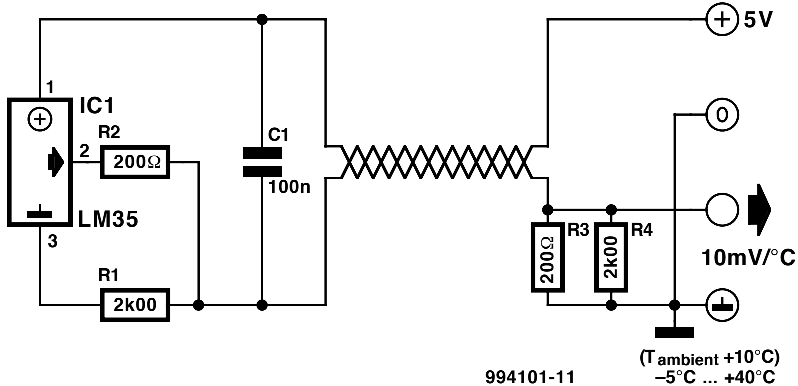
Flash Designs, Ltd.,
North Parade House,
North Parade,
Bath BA2 4AL.
Tel. (01225) 448630.

We extend our apologies to Flash Designs and our readers for any inconvenience caused by the incorrect address information.

Electronic Spirit-Level
July/August 1998, p. 36 (984038).
In the circuit diagram, all LEDs (D2 through D10) should be reversed. The PCB layout is all right.

two-wire temperature sensor

001



A National Semiconductor application

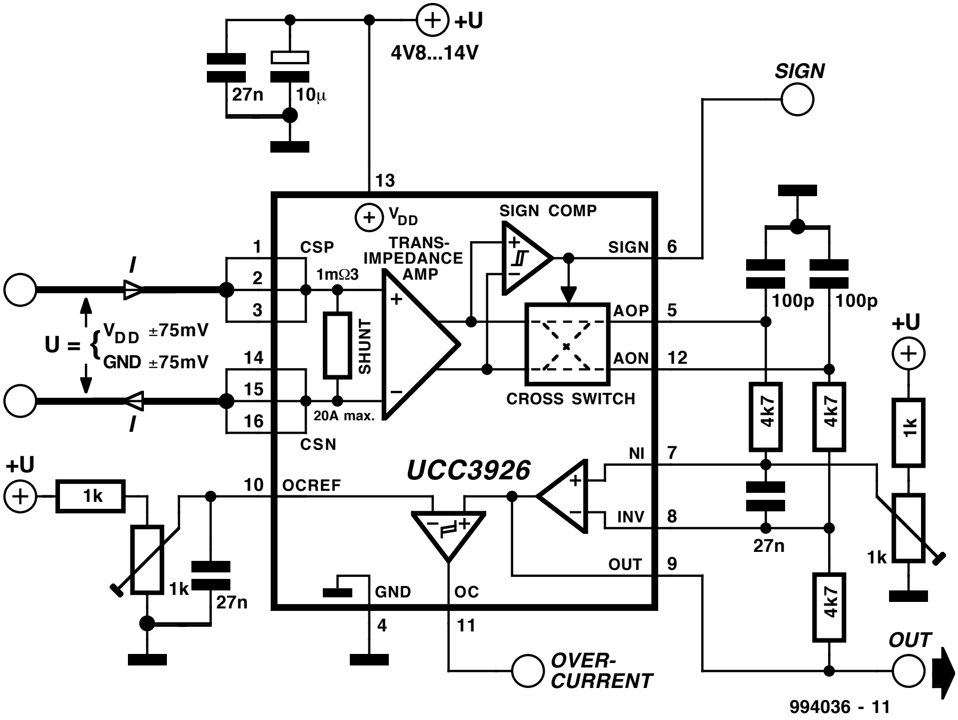
The Type LM35 temperature sensor from National Semiconductor is very popular for two reasons: it produces an output voltage that is directly proportional to the measured temperature in degrees Celsius, and it enables temperatures below zero to be measured. A drawback of the device is, however, that in its standard application circuit it needs to be connected to the actual measuring circuit via a three-wire link. This drawback is neatly negated by the present circuit.

When the LM35 is connected as shown, a two-wire link for the measurement range of –5 °C to + 40 °C becomes possible. Actually, the circuit shown is a temperature-dependent current source, since it uses the variation of the quiescent current with changes in temperature. The values of resistors R_3 and R_4 are calculated to give an output voltage of 10 mV $°C^{-1}$. Where good accuracy is desirable or necessary, 1% resistors should be used. In this context, note that a loss resistance in the link between sensor and measuring circuit may cause a measurement error of about 1 °C for every 5 ohms of resistance. Capacitor C_1 eliminates undesired interference and noise signals.

At an ambient temperature of 25 °C, the circuit draws a current of about 2 mA.

[994101]

±20 A current monitor 002



G. Kleine

The Type UCC3926 current sensor IC from Unitrode is ideally suited for use as a current monitor. It contains a 1.3 mΩ current shunt and can handle currents up to ± 20 A. The common-mode voltage for the shunt is GND ± 75 mV or V_{DD} ± 75 mV, so that the current can be monitored either in the positive supply rail or in the negative supply line of a load. The supply voltage, V_{DD}, may lie between 4.8 V and 14 V.

The potential across the shunt is applied to an internal chopper-stabilized transimpedance amplifier, which converts it into a differential voltage at pins 5 and 12 at a level of 500 mV when the current is 15 A. The differential voltage is applied via a low-pass filter to an operational amplifier, which has unity gain and converts the voltage into a unipolar potential.

An offset voltage is superimposed on to the unipolar potential via a 1 kΩ multi-turn potentiometer to provide a preset voltage at the OUT pin. This means that the voltage level at the OUT pin is typically 500 mV plus the offset direct voltage when the current through the shunt is 15 A.

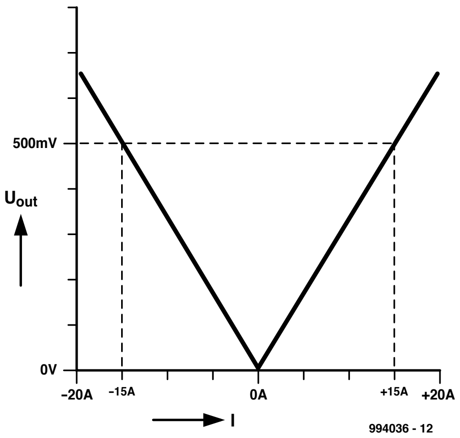
The polarity of the output voltage is determined by the SIGN comparator, which sets the internal cross switch to such a position that the differential voltage between pins 5 and 12 is always positive.

The polarity may be checked at pin 6: if the level at that pin is high, the polarity is correct, that is, the current flows through the shunt from pins 1, 2, 3 to pins 14, 15, 16.

A signal to show up an overvoltage may be generated with the aid of an internal comparator. For this purpose, an overcurrent reference may be applied to pin 10 via the 1 kΩ, 10-turn potentiometer. The digital signal at pin 11 is high when there is an overcurrent.

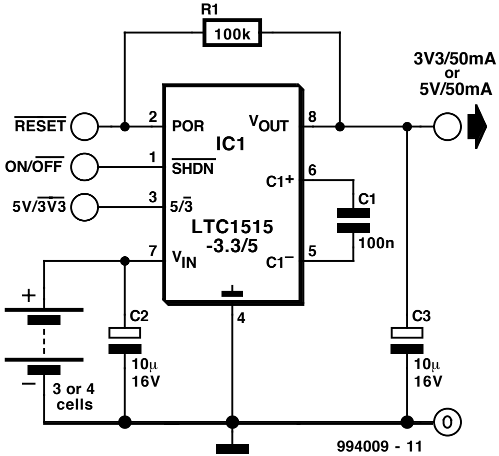
Further information from http://www.unitrode.com

[994036]



buck-boost converter without magnetics

003



A Linear Technology application

One of the problems that designers of portable equipment face is generating a regulated voltage whose level lies between those of a fully charged and a discharged battery. As an example, when a 3.3 V output is generated from a 3-cell battery, the regulator input voltage changes from about 4.5 V at full charge to about 2.7 V when the battery is discharged. At full charge, the regulator must step down the input voltage, and when the battery voltage drops below 3.3 V, the regulator must step up the voltage. The same problem occurs when a 5 V output is required from a 4-cell input voltage that varies from about 3.6 V to 6 V. Normally, a flyback or SEPIC configuration is required to solve this problem.

The LTC1515 switched-capacitor DC/DC converter can provide this buck-boost function for load currents up to 50 mA with only three external capacitors. The circuit shown will provide a 3.3 V output from a 3-cell battery or a 5 V output from a 4-cell input. Connecting the 5/3 pin to V_{IN} will program the output to 5 V, whereas grounding the 5/3 pin programs the output to 3.3 V.

The absence of bulky magnetics provides another benefit: this circuit requires only 0.07 in^2 (0.45 cm^2) of board space in those applications where components can be mounted on both sides of the board.

The addition of resistor R_1 provides a power-on reset flag that goes high 200 ms after the output reaches 93.5% of its programmed value. The $\overline{SHDN}$ pin allows the output to be turned on or off with a 3 V logic signal.

[994009]

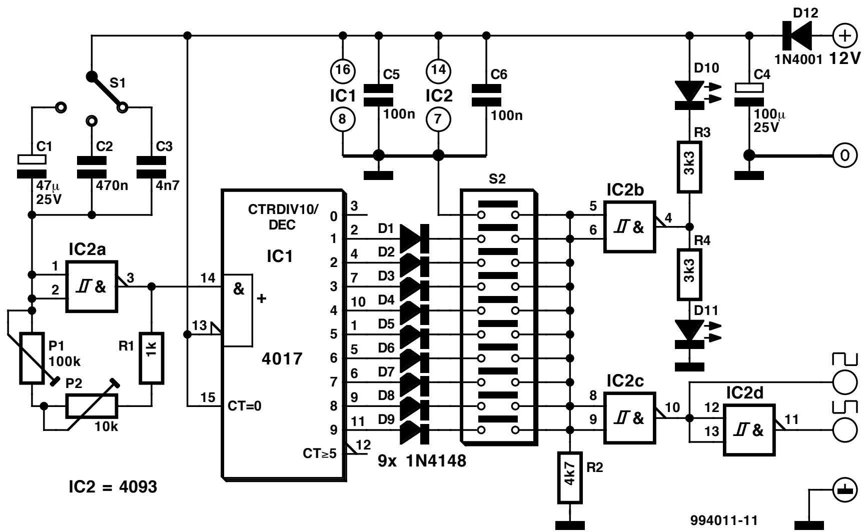
multi-decade pulse generator with selectable duty cycle

004

Design: K.-H. Lorenz

Many pulse generators with adjustable duty cycle have a significant drawback, in that the pulse repetition rate also changes when the duty cycle is adjusted. The circuit shown here avoids this problem. It uses a square wave generator consisting of IC2a and an RC network. Range switch S1 selects one of three RC combinations that control the pulse repetition rate. With the indicated values of C1, C2, C3 and P1, P2 and R1, there are three frequency ranges:

I) 0.1 Hz to 10 Hz
II) 10 Hz to 1 kHz
III) 1 kHz to 100 kHz



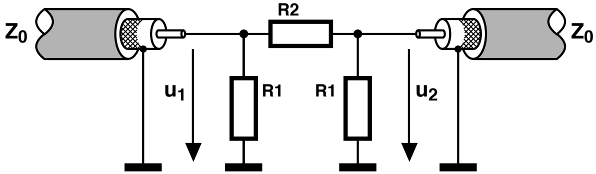
Note that the actual frequency depends on the hysteresis of the 4093, so that it is strongly dependent on the specific manufacturer and fabrication of the IC used. For this reason, P1 and P2 are provided for coarse and fine frequency adjustment, respectively, to allow the pulse repetition rate to be set exactly to the necessary value. If the desired frequencies cannot be obtained in spite of the wide adjustment range of the circuit, the capacitor values should be modified.

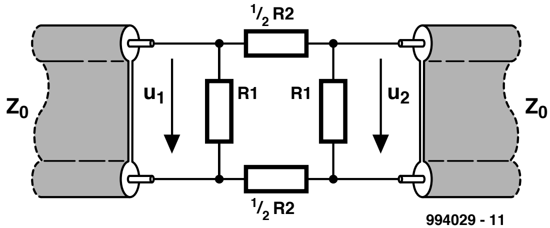
The square wave generator clocks a synchronous decimal counter. Each time the count is incremented, the associated decoded output goes high, while the remaining outputs stay low. DIP switch S2 allows several outputs to be connected to a single lead. The diodes prevent short-circuits between outputs selected by S2, whenever the outputs have differing signal levels. For a high/low ratio of 0.1, only the Q1 switch of S2 should be closed; for a ratio of 0.2 Q1 and Q2 should be closed, and so on. If all outputs of the 4017 (except for Q0) are selected, the resulting duty cycle is 0.9. The switch connected to earth can be closed to disable the PWM generator if all other switches are open.

The signal from the counter IC is connected to two inverters. Two LEDs are connected to IC2b. The lower the duty cycle, the brighter D11 shines and the dimmer D10. IC2b buffers (and inverts) the output signal of the circuit, and IC2d re-inverts the signal levels, so that two complimentary signals are available at the output. The current consumption of the circuit is around 4 mA.

(994011-1)

matching attenuator 005





$$R1 = Z_O \cdot \frac{A+1}{A-1} \qquad R2 = Z_O \cdot \frac{A^2-1}{2A} \qquad A = \frac{U_1}{U_2} = 10^{\left(\frac{-a}{20\,dB}\right)}$$

G. Kleine

When r.f. signals are (to be) attenuated, it is essential that the requisite network retains correct matching to the relevant (coaxial) cable(s). If this is not so, reflected signal waves will ensue along the cable(s), which may attenuate or magnify the forward signal waves. In other words, there will be points along the cable(s) where the resulting signal is much smaller than the original and others where the resulting signal is much larger.

With the attenuators show in the diagram, the cables are correctly terminated, that is, there is proper matching. If the link is via balanced cables, the network must also be balanced. In that case, there is a series resistor in both signal lines that is half the value of the series resistor used with an unbalanced connection.

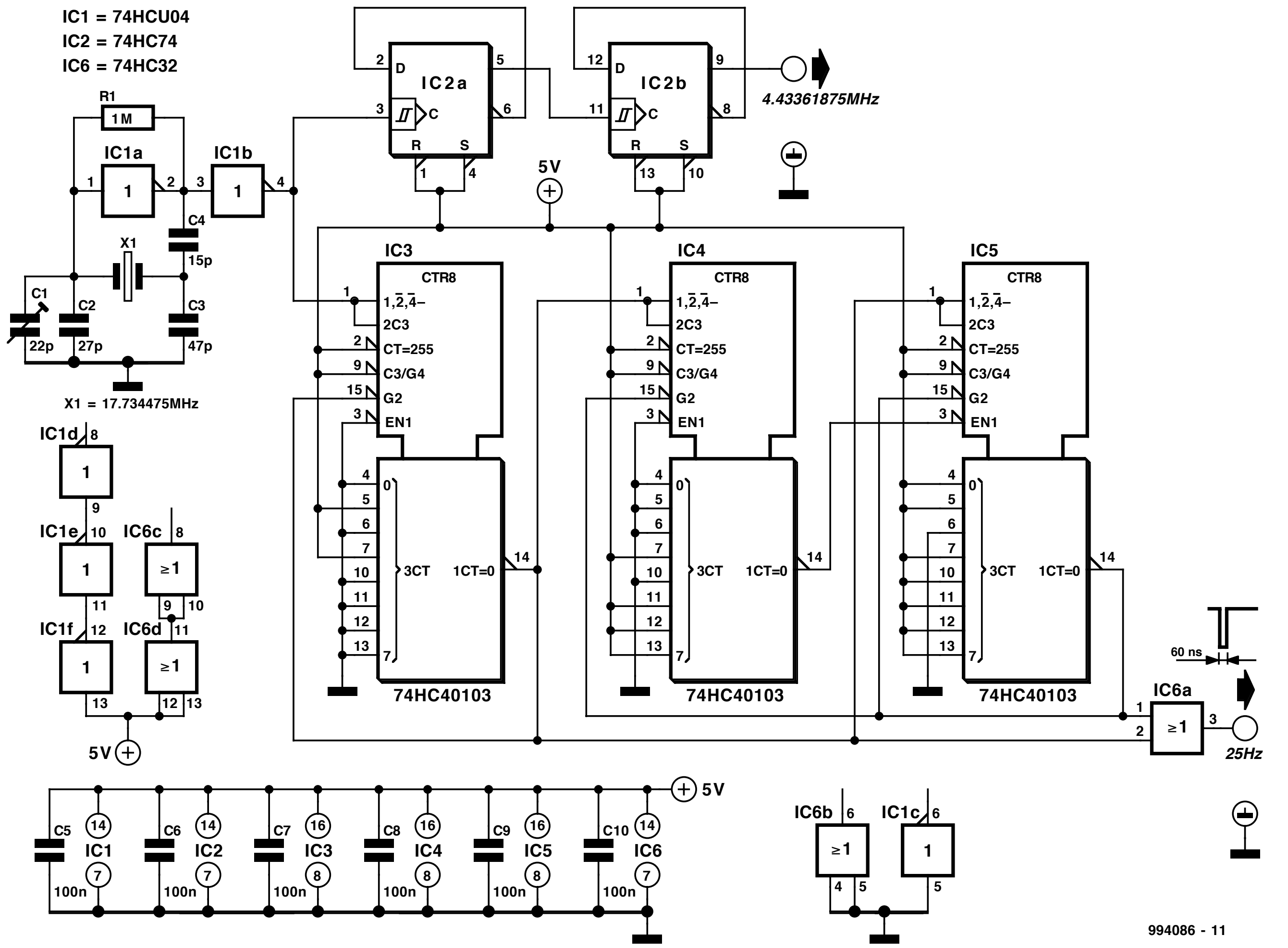
The formulas shown give resistor values for both 50 Ω and 75 Ω cables and wanted attenuation as listed in the table.

[994029]

Attenuation	50 Ω		75 Ω	
	R1	R2	R1	R2
1 dB	909 Ω	5Ω62	1kΩ30	4Ω32
2 dB	475 Ω	10 Ω	619 Ω	18Ω2
3 dB	274 Ω	18Ω2	432 Ω	27Ω4
6 dB	150 Ω	35Ω7	221 Ω	56Ω2
10 dB	100 Ω	68Ω1	150 Ω	100 Ω
15 dB	68Ω1	150 Ω	110 Ω	200 Ω
20 dB	61Ω9	243 Ω	90Ω9	392 Ω

PAL timing (1)

006



Design: T. Giesberts

This circuit is intended more as a design idea than as a finished project, in the light of the number of standard ICs that are employed.

In the PAL television system, the CCIR B and G standards specify that the colour carrier is directly coupled to the line rate, with a 25 Hz offset. The frequency ratio and offset are chosen to suppress interference patterns, according to the formula

$$f_{colour} = 283.75\ f_{line} + 25\ \text{Hz}$$

At a line rate of 15,625 Hz, this means that the PAL colour carrier frequency is 4.43361875 MHz. Single-sideband modulation is frequently used to obtain the correct relationship with the line rate. For example, the frequency of a crystal oscillator can be offset by 25 Hz, divided by 1135 and then multiplied by 8 to obtain twice the actual line rate. This is a rather complicated procedure, which we think could be made a lot simpler.

There is a fixed ratio between the 25 Hz frame rate and four times the colour carrier frequency. You can calculate this yourself —- four times the colour carrier frequency is exactly equal to 709,379 times the frame rate! An obvious approach is to use a crystal oscillator running at four times the colour carrier frequency and divide its output by 709,379 to obtain the frame rate. The line rate can then be derived from the frame rate with the help of a PLL circuit (see 'PAL timing (2)').

The crystal oscillator is a standard Pierce configuration with a trimmer capacitor, built around a 74HCU04 (IC1). The values of C2 and C3 must be properly chosen to obtain the specified load capacitance for the crystal. An incorrect value of C_{load} can make it impossible to adjust the oscillator to the exact frequency. Two D-type flip-flops wired as divide-by-two stages are used to obtain the colour carrier frequency.

Four ICs are used for the division needed to obtain the frame rate signal. IC3, IC4 and IC5 are presettable synchronous down-counters (type 74HC40103) that are very well suited for timing and frequency-division applications. The necessary division factor is split into two factors, namely 11 and 64,489. The 74HC40103 works as an (1+ N) divider, so value of 10 is applied to the preset inputs of IC3 for the first factor. The second factor is obtained by wiring IC4 and IC5 as a synchronous 16-bit divider, with the output of IC5 fed back to both synchronous preset inputs. The preset value is again 1 less than the division factor.

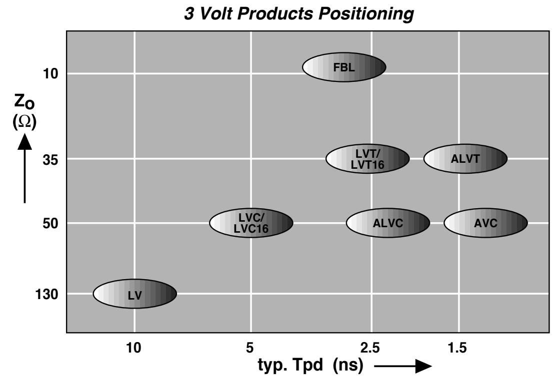
A disadvantage of the 74HC40103 is that glitches can occur, due to differences in internal delay times. These glitches are eliminated by clocking an OR gate (IC6a) at the divider output with the divider input signal. The 25 Hz output signal has an active low pulse approximately 60 ns long, which is essentially equal to one period of the crystal oscillator.

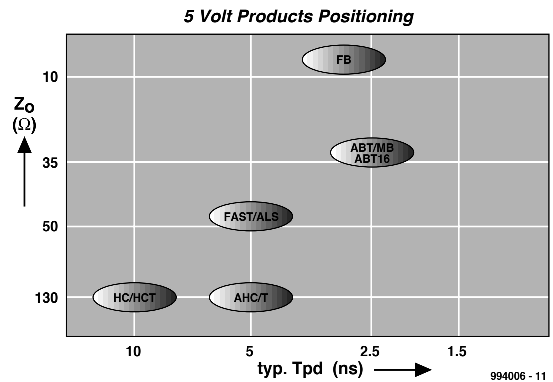
The current consumption of the circuit is a bit more than 12 mA, primarily due to IC1.

(994086-1)

AVC Logic family

007





K.S.M. Walraven

Driven by customer demand, Philips Semiconductor's AVC Logic family is the fastest logic on the market today and offers ultra low noise and low voltage for applications such as DRAM modules, personal computers, workstations, network servers, telecommunication switching equipment and base stations. (AVC is an acronym of Advanced Very-low-voltage CMOS).

Devices in the AVC logic family are intended for use in systems that operate from a supply voltage of 1.2–3.6 V. The manufacturer claims that this is the first family that offers a delay of not more than 2 ns at such a low supply voltage.

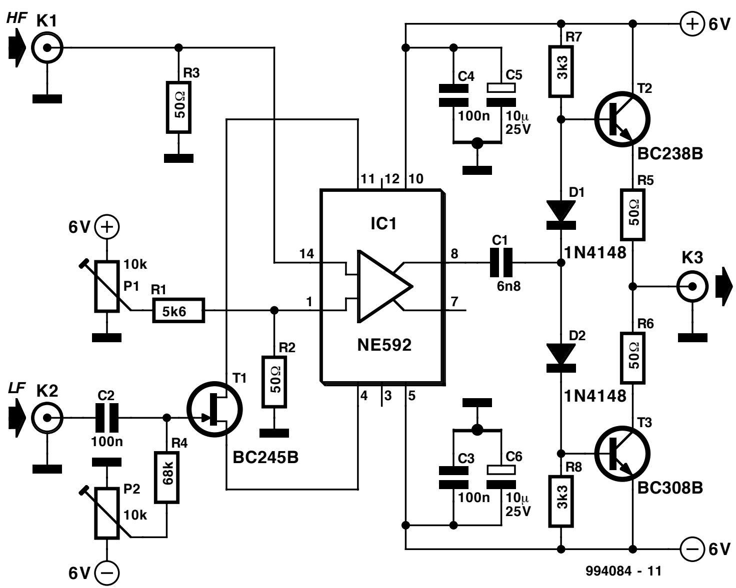
As an example, with a supply voltage of 3.3 V, the 74AVC16244 (a three-state buffer) has a typical delay of 1 ns. At 2.5 V this increases to 1.1 ns, and at 1.8 V, to 1.5 ns. This is about 40 per cent faster than attainable with current logic families.

The devices in the new family are provided with protection that makes hot insertion possible. This is an important aspect when, for instance, expansion cards are to be added to communication systems that should not be switched in any circumstances.

[994006]

AM modulator and 50Ω RF output stage

008



Design: Dr L. Köppen

The 10 MHz **Function Generator** design published in *Elektor Electronics* in June 1995 has one serious deficiency: it cannot provide amplitude modulation. The standard configuration of the MAX038 IC has no provision for amplitude modulation, in contrast to frequency modulation which is easily achieved. The circuit presented here makes amplitude modulation possible, and it also has the significant advantage that it replaces the somewhat exotic and quite expensive OP603AP output opamp with a standard type. Of course, this amplitude modulator can also be used with other models of function generator or for other purposes.

As you know, the gain of an

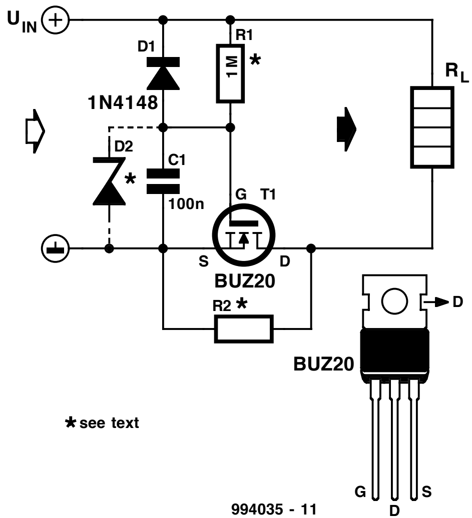
NE592 video opamp can be set to 400, 100 or 10 by means of an external jumper. Intermediate settings can be achieved by using a suitable resistance in place of the jumper. This adjustment takes place in the emitter leads of the differential amplifier, directly at the input to the opamp, where the signal amplitude is low. A BF245B FET is used here as a controllable resistance. With suitably low signal levels, it provides at least 50% of clean amplitude modulation for modulating signals (LF) up to 10 kHz and modulated signals (HF) up to 20 MHz. The FET can also be driven with a DC voltage to control the amplitude of the output signal over a 10:1 range with low distortion. Any slight asymmetry of the modulated signal can be corrected by applying a small correction voltage via P1. P2 is used to bias the FET at around –2.5 V. The output stage is built using discrete transistors and guarantees a 50 Ω output impedance with low DC offset.

The complete circuit can deliver a constant amplitude output signal of up to 2.5 V_{pp} (unmodulated) for frequencies ranging to over 20 MHz. If the signal is not modulated, the maximum amplitude can be increased somewhat. Output level controls (a potentiometer and/or range switches), if used, should be placed between the NE592 output and the input of the output stage. In such cases, an emitter-follower stage with a high input impedance might be a good idea, since the opamp should operated with a load of at least 1 kΩ. Conceivably, the gate of the FET could be driven via an additional opamp, together with the demodulated signal from the output of the NE592 applied as negative feedback, to achieve higher modulation levels.

(994084-1)

switch-on-current limiting 009

G. Kleine



In certain direct-current operated circuits, such as DC-to-DC converters, the switch-on current may be so high that the output voltage of the power supply cannot reach its nominal level. This difficulty may be prevented with a limiting circuit as shown in the diagram.

When the input voltage, U_{in}, is switched on, transistor T_1 is off since capacitor C_1 is not charged. The level of current I at the moment of switch-on is

$$I_{(t=0)} = U_{in}/R_2.$$

Capacitor C_1 is charged slowly via resistor R_1 until the gate–source threshold voltage, $U_{GS(th)}$, is exceeded, whereupon the transistor begins to conduct. The time interval between switch-on and the transistor coming on is determined by time constant R_1-C_1 and the ratio U_{in}:$U_{GS(th)}$. The gate-source voltage, U_{GS}, of the BUZ20 is in the range ± 20 V. If V_{in} is larger than these values, or a different transistor is used, U_{GS} must be limited to the range mentioned by zener diode D_2, for which a ZPD18 was used in the prototype.

Diode D_1 enables C_1 to be discharged via the load when U_{in} is switched off. The circuit is then ready for the next period of operation.

[994035]

tiny analogue switch alleviates I^2C address conflicts

010

A Maxim application

To avoid address conflicts, every peripheral on an I^2C™ bus must have a unique address. Sometimes, however, peripherals may be assigned the same address. The circuit shown resolves address conflicts by enabling the I^2C bus to select between two peripherals with the same address.

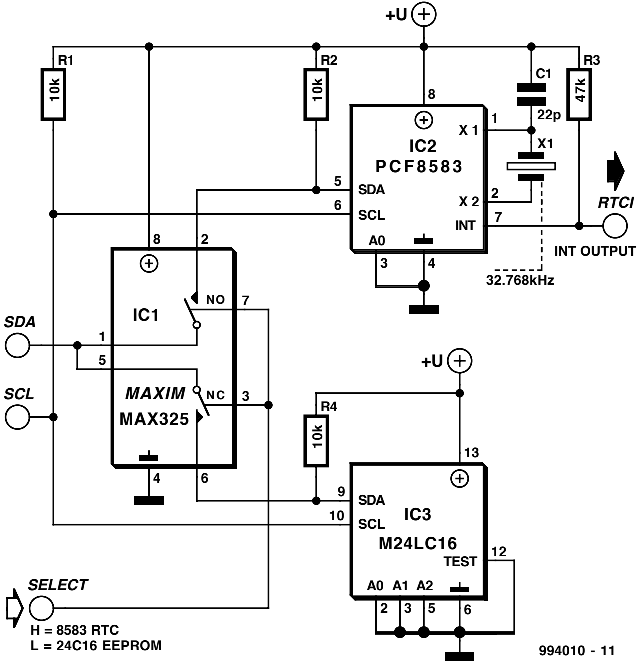
The popular I^2C bus is an open-collector, 2-wire interface that includes a clock line and a bidirectional data line. It allows a controller (the master) to select a particular device (the slave) by first issuing a serial address on the data line, then issuing appropriate commands or data. Master and slave can send data in both directions by pulling the data line low, and slaves can generate wait states by pulling the clock line low. Bus switching is complicated, however, by the open-collector architecture—it cannot be accomplished with the CMOS outputs of AND gates or 74HC157 data selectors.

The peripherals shown in the diagram are a Philips I²C real-time clock (PCF-8583) and a large I²C EEPROM (Microchip M-24LC16). Both have an internal, hexadecimal slave address of A0. (The EEPROM takes up the entire address range, making it impossible to avoid.) The analogue switch connects either one device or the other. Selection involves the data line (SDA) only, because an I²C start condition requires that the SDA signal goes low before the clock goes low. To select between the devices, the master device sets a port pin to control the state of the dual SPST analogue switch.

IC_1 is a CMOS chip well suited to this function. Its normally open switch and normally closed switch perform the 2:1 selector operation with no additional inverters or port line. It features low on-resistance (33 Ω) and low supply current (1 μA), and is specified for operation below 3 V. Also, its tiny 8-pin SOT package (μMAX) is only half the size of an SO-8 package.

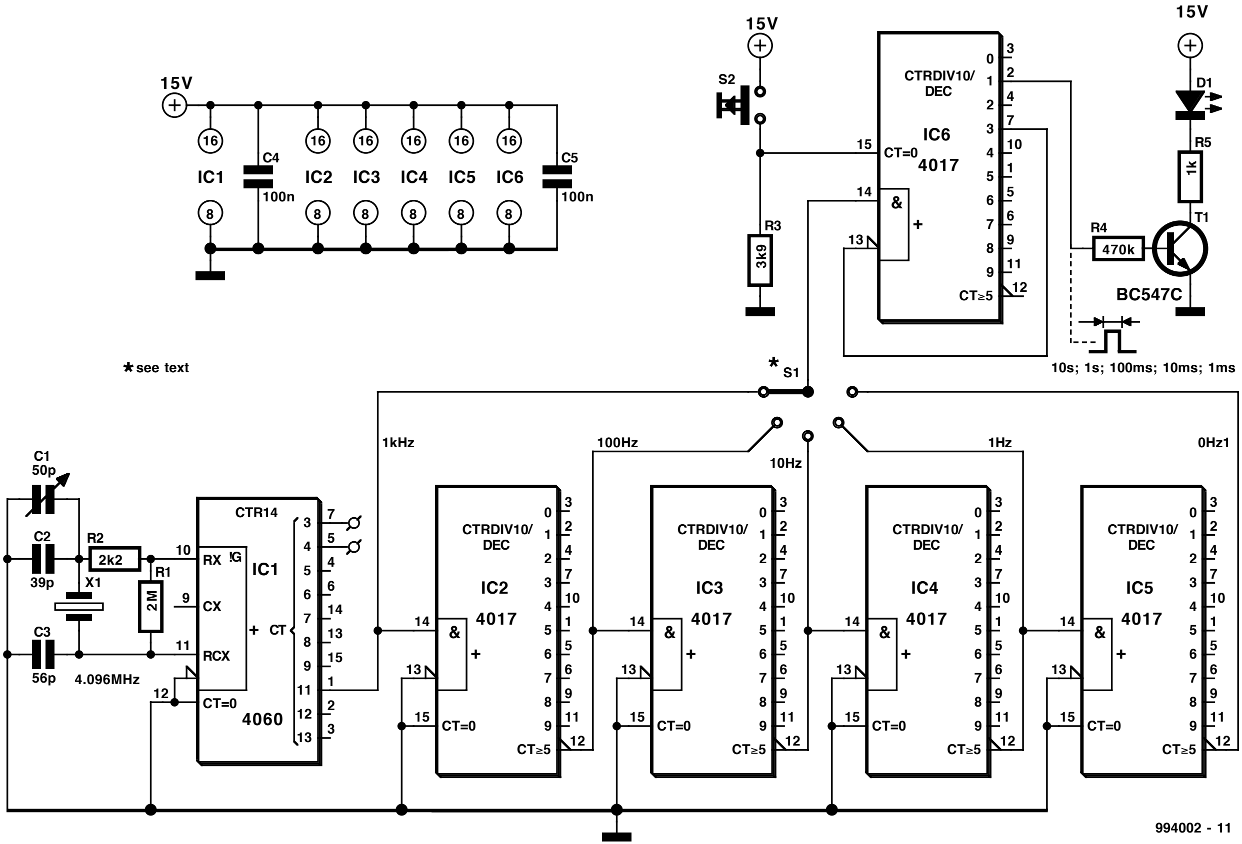
Note: I²C is a trademark of the Philips Corporation.

[994010]



measurement interval generator

011



Design: K.-H. Lorenz

The purpose of this circuit is to generate a pulse with a predefined duration when a button is pressed. It is especially well suited for use as a timing window generator for a frequency counter. It uses only inexpensive standard components and can be quickly put together.

In the schematic diagram, IC1 (a 4060) is a 14-stage binary counter with an integrated oscillator. An inexpensive 4.096 MHz crystal is used as the timing reference, which means that a 1 kHz signal appears at the output (pin 1) after division by 2^{14}. Following IC1 is a series of decimal counters (IC2 through IC5, type 4017) that are cascaded via their Carry Out outputs (pin 12). These counters produce reference frequencies of 100 Hz, 10 Hz, 1 Hz and 0.1 Hz.

The non-shorting rotary switch S1 selects one of the reference frequencies and applies it to the clock input of an additional 4017. In contrast to the other ICs of this type, its control inputs Reset and /Enable (pins 15 and 13) are used dynamically. When pushbutton S2 is pressed, the count is reset to zero. When S2 is released, the first rising edge at pin 14 clocks the counter. The input signal, divided by 2, appears at the Q1 output (pin 2). However, since Q3 (pin 7) is connected to the /Enable input, the counter is disabled after the first period of the output signal, so that only one pulse is generated. Depending on the input signal, this pulse has a length of 10 s, 1 s, 0.1 s, 0.01 s or 0.001 s.

A simple transistor buffer drives an LED that is illuminated for the duration of the pulse. An additional, similar buffer stage at the output would also be a good idea. The circuit should be powered from a stabilized 15 V supply. It draws around 10 mA.

(994002-1)

high-current, high-speed buffer

012

T. Giesberts

The circuit shown in the diagram is intended for applications in which relatively large pulse-shaped signals are to be applied to a standard impedance of, say, 50 Ω. The parallel circuit of two high-speed buffers prevents overheating during periods of high loads and high drive.

The operational amplifiers used, Analog Devices' Type BUF104, have a bandwidth of 110 MHz and a very high slew rate: 3000 V μs^{-1}. The peak output current is 65 mA, which is not sufficient to provide 5 V into 50 Ω, but the parallel combination is able to. Connecting 100 Ω resistors, R_3 and R_4, in series with the outputs of the op amps gives an overall output impedance of 50 Ω.

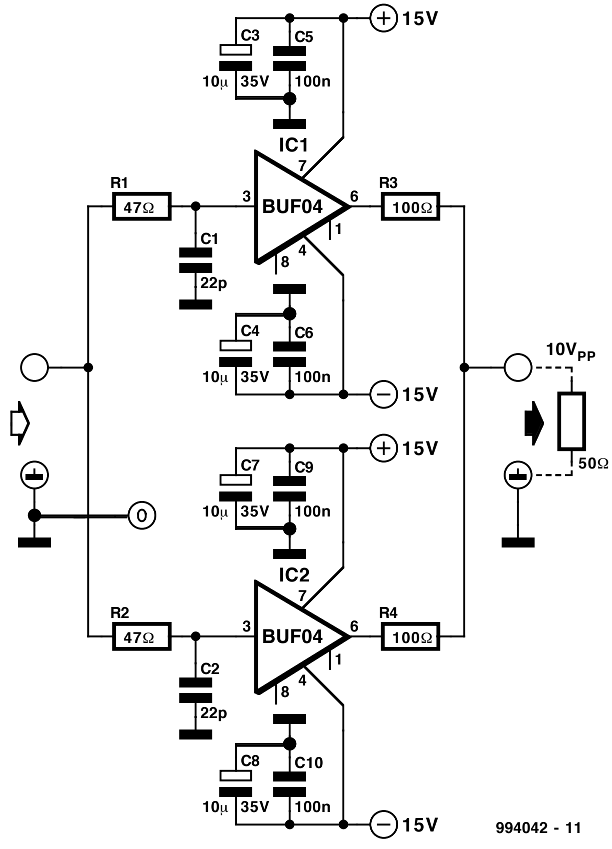
Owing to the large bandwidth, effective decoupling is imperative, which is why its is advisable to use tantalum capacitors for C_3, C_4, C_7, and C_8 and ceramic ones for C_5, C_6, C_9, and C_{10}.

With output currents exceeding 50 mA, the pulse response may be enhanced by damping the self-inductance of the tantalum capacitors with the aid of series resistors of 1–4.7 Ω.

If the specified bandwidth of 110 MHz is to be attained, a central earth plane and SMT components must be used, since the parasitic self-inductance of standard components is too high. One of the prototypes constructed with standard components had a bandwidth of only 25 MHz. Also, with such a construction, the screening is less effective, so that at high frequencies positive feedback, and thus oscillations, may occur. This is the reason that there is an *RC* filter at the input of the op amps: R_1-C_1, and R_2-C_2 respectively, which limits the bandwidth to 80–90 MHz.

The circuit draws a quiescent current of ± 15 mA. When the output signal is rectangular at a level of 10 V_{p-p}, into 50 Ω, the current drain rises to 60–65 mA.

[994042]



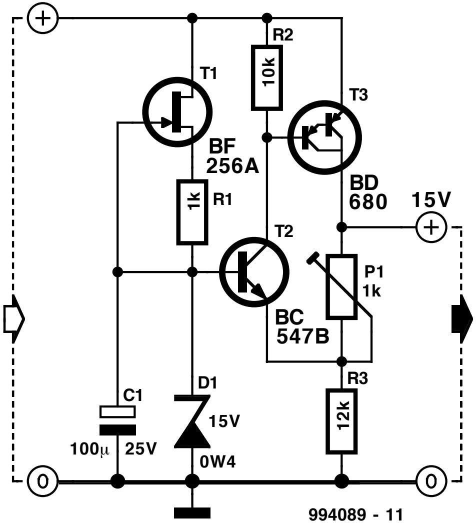
discrete voltage regulator

013

Design: T. Giesberts

The title of this article naturally raises the question of why we think that the generous selection of fully integrated voltage regulators needs to be extended with a version constructed using discrete components. In other words, what does this circuit offer that the well-known 'three-leggers' don't have?

To start with, we can point out that this circuit is refreshingly simple for a discrete version. Three semiconductors, three resistors,



a capacitor and a diode are all it needs. Of course, that's still more components than an integrated regulator, so what exactly are the advantages of this circuit? They are to be found in three areas: voltage range, bandwidth and current rating. The last of these is the primary strength of this circuit, since the maximum current depends only on the specifications of the output transistor. With the BD680, as used here, a current of 4 A can be delivered at a collect-emitter voltage of 10 V with adequate cooling (R_{th} = 3.12 K/W). The peak current is even 6 A. Try matching that with an integrated voltage regulator!

The maximum input voltage is 30 V with the illustrated version of the circuit (U_{DSmax} of T1), but this can easily be increased by using special high-voltage transistors. The same applies to the bandwidth, which can be extended as desired, without any modifications to the circuit, by using high-speed transistors. Generally speaking, wide bandwidth is also not one of the strong points of integrated voltage regulators.

As noted, the circuit is basically very simple. A zener diode (D1) fed with a constant current of around 1 mA by a JFET current source (T1) provides the reference potential. C1 is connected in parallel with D1 to provide well-behaved startup behaviour (*soft start*). This capacitor also provides additional buffering and decouples noise and other disturbances. The startup time is around three seconds.

The only additional item that is needed for the voltage regulator is an output buffer for the reference potential. This takes the form of a sort of super-Darlington using T2 and T3. This works very well, but has the disadvantage that the output voltage is a bit lower (one diode drop) than the Zener voltage. P1 can be added to correct this, but this does reduce the regulation of the circuit. If the voltage difference is not important, it is thus better to replace P1 with a wire jumper. The main specifications of the voltage regulator are listed in Table 1.

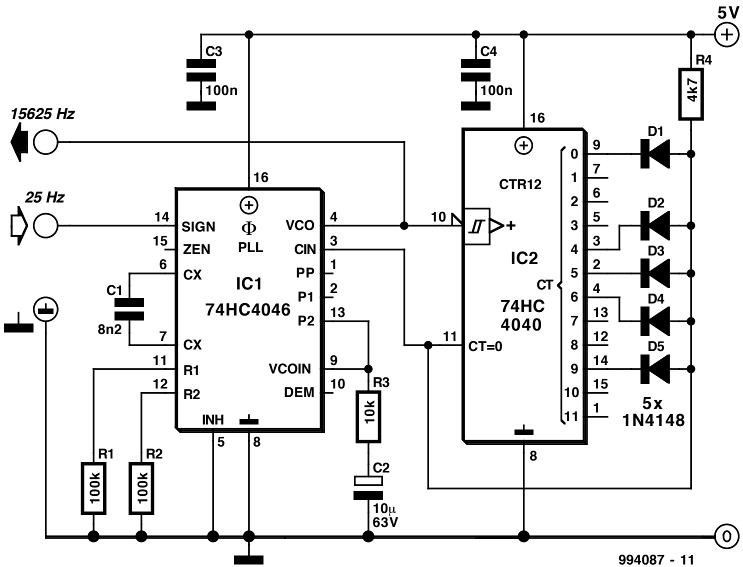
(994089-1)

Table 1. Specifications

	with P1	without P1
Output voltage	15 V	14.5 V
Ripple suppression	58 dB	64 dB (I_{out} = 100 mA)
	46 dB	54 dB (I_{out} = 1 A)
$U_{dropout}$	1.6 V	1 V (I_{out} = 100 mA)
I_{noload}	2.1 mA	ditto
Maximum input voltage	30 V	ditto

PAL timing (2)

014



Design: T. Giesberts

This design is complementary to the design described in the article 'PAL timing (1)', which also appears in this issue. It is intended to derive a line rate signal from a television frame rate signal, using a PLL. Naturally, this technique can also be used in situations where the line synchronization pulses are corrupted.

In the PAL television system, there are 625 lines per frame. In the PLL circuit, a nominal frequency of 15,625 Hz is thus divided by 625 and then compared to the 25 Hz input signal. A 74HC4040 (IC2) is used for the divider. The correct division factor is obtained with the help of an AND circuit formed by several diodes, which produces the counter reset signal (625 decimal = 1001110001 binary).

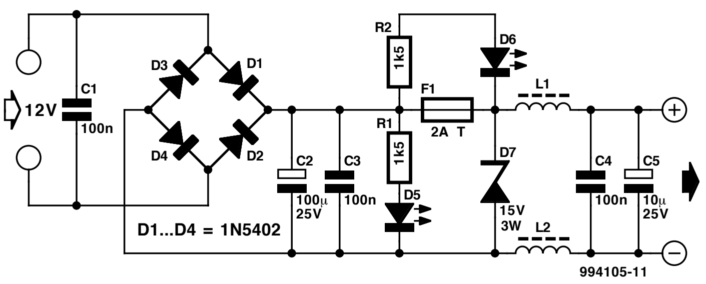
The well-known HC version of the 4046 IC has been chosen for the PLL. HC logic must be used here to keep up with the fast pulse from the output of the 'PAL timing (1)' circuit. Since phase comparator 2 is used, the inputs are edge triggered, and no further requirements need be placed on the input signals.

As can be seen, the internal oscillator of the PLL IC is also used (pin 9). The necessary low-pass filter R3/C2 is not dimensioned entirely according to the prescribed formulas, but this version proved to yield the least jitter in practical tests. This brings us directly to the weak point of this circuit. With a normal RC oscillator, as used here, it is not possible to reduce the jitter of the 15,625 Hz signal to less than around 200 ns. For most applications, this is not good enough, so that there is no getting around the use of an external crystal oscillator for the VCO, in combination with a suitable divider.

(994087-1)

polarity-free PSU filter for ham radio

015



Design: N.S. Harisankar VU3NSH

Many radio amateurs will not fail to recall the chaotic situations that may occur during fielddays or contests, when several radios have to be connected in a hurry and under circumstances less comfortable than those in the shack at home. For instance, many operators may be busy at the same time connecting up the power leads to equipment which is not theirs. In such situations, supply polarity errors may readily occur, with disastrous results.

Many currently available handhelds from Sony, Yaesu, Standard, Kenwood, Alinco and other makes may be powered from an external vehicle battery. However, the supply polarity on the external power connector may not always be known or easily found out when a hectic situation arises (traditionally, few hams have the Owners Manual available…).

This circuit was developed to allow handheld rigs to be connected to an external 12V vehicle battery without paying attention to polarity. This function is due to a bridge rectifier, D1-D4, at the input of the circuit. Irrespective of the battery polarity, the radio will always receive the correct supply voltage.

Additional functions of the circuit include an effective noise filter (L1-L2-C4-C5), high-voltage DC protection (zener diode D7), and blown fuse/power indicators (LEDs D6 and D5 respectively). Coils L1 and L2 consist of 8 turns of 24SWG (0.6 mm) enamelled copper wire on a large ferrite toroidal core from Amidon's T series (check coil saturation specification!). Alternatively, use 'EMI suppression beads' type 4330 020 3326 from Philips Components. The LEDs should be high-efficiency types.

The circuit as shown can be used with any modern handheld that draws less than 2 A at supply voltages between 4.5 V and 14 V. In fact, most of these rigs will draw 1.3-1.5 A at 13.8 V for 5 watts of RF output power.

(994105-1)

call for papers

Technical authors and designers are now invited to contribute to the Autumn and Winter 1999 issues of *Elektor Electronics*, in which we plan to cover the following subjects:

- *Digitizing audio signals*
- *New battery and charging technologies*
- *New PC technology*
- *Digital medium and short-wave radio*
- *The 20th century in retrospect*

Advice on style, article size and technical requirements regarding text and illustrations (file formats, etc.) may be obtained from the Editor.

We also call for stories covering interesting topical subjects in the field of electronics and computers, as well as for reviews and construction projects with an extensive explanatory text. Some experience in writing is appreciated, but not essential (who knows, you could be a natural talent).

If you have recently finished an interesting construction project, write a text with it and send us the article. Preferably, the text and illustrations should be supplied on floppy disk. The same applies to reviews and topical stories.

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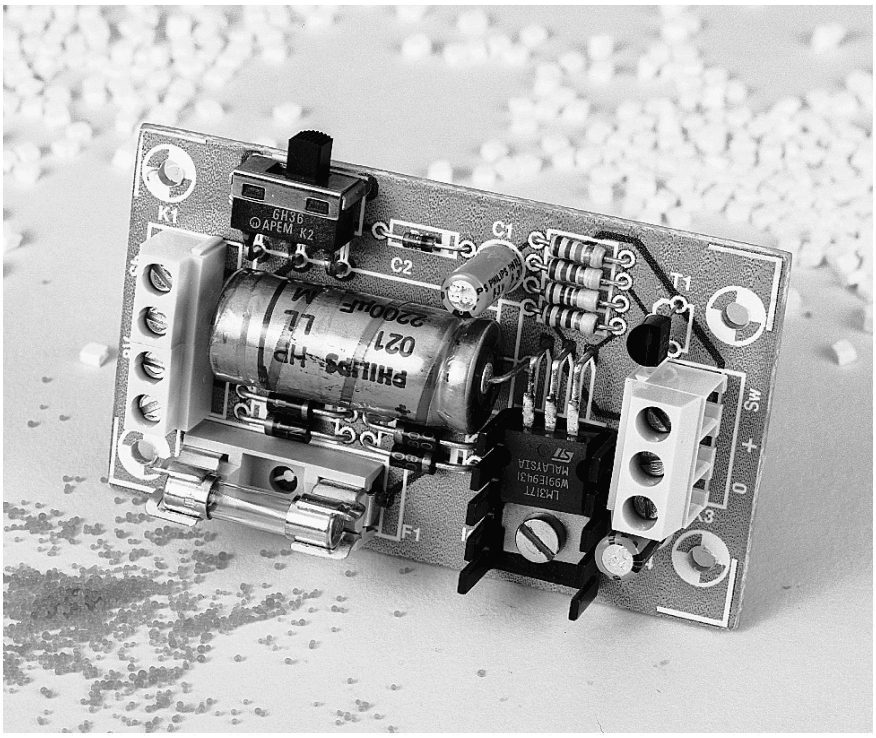
If you would like to offer your free-lance writing services for assigned subjects, inform us (in writing) about your specialism or favourite interest, and any proposals you may already have. Even if your specialism is not mentioned above, we would still like to hear from you in view of other subjects to be covered next year.

Every article is judged by the editorial staff on the basis of its publication value. You will receive our verdict as soon as possible. If your article is of interest, you will also receive our conditions for publication.

This call is also addressed to companies having press releases and other interesting background information available on the subjects mentioned above.

bell transformer supply for wave-file player

016

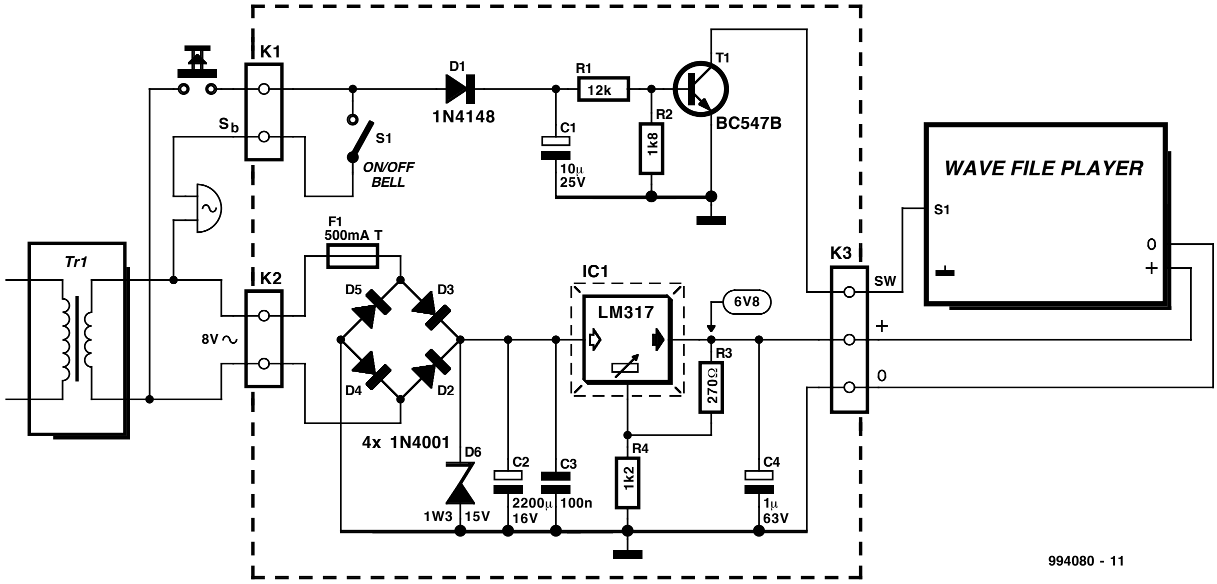


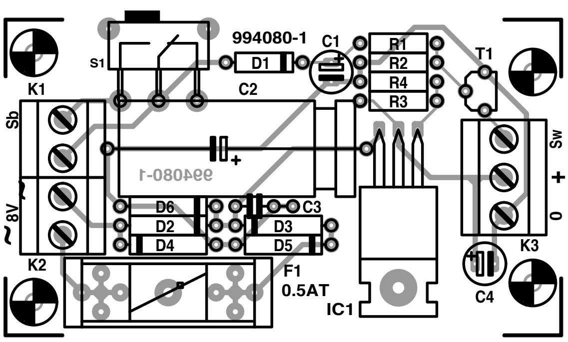
H. Bonekamp

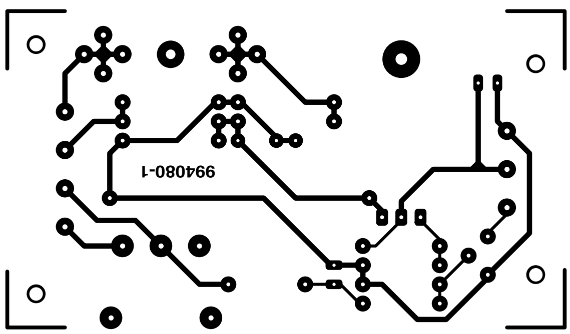
If the wave-file player described in the February 1999 issue of this magazine is used as a programmable doorbell, it is, of course, handy if its supply is derived from the doorbell transformer. In the design of the circuit in the diagram, it was borne in mind that as little as possible should be changed in the existing wiring of the doorbell and that it would be convenient to be able to switch the doorbell back on when the wave-file player is removed to program it with a new sound.

The alternating voltage at the secondary of the doorbell transformer is rectified by diode bridge D_2–D_5, and smoothed by capacitor C_2. Zener diode D_6, a fast type, serves to suppress transients. The resulting direct voltage is stabilized by regulator IC_1 which is set for 6.8 V. When the drop across the protection diode in the wave-file player is deducted from this, a direct voltage of about 6 V remains, which is used to supply the amplifier IC

The need of modifying the existing wiring is precluded by the circuit around tran-







sistor T_1, which converts the alternating voltage arriving from the doorbell into a switching signal that is applied to, and processed by, the wave-file player. Switch S_1 enables the doorbell to be used as normal when the wave-file player is removed for any reason. Remember to open the switch again when the wave-file player is replaced, otherwise the player does not work and it is set to the wrong speed of 9600 baud via the S_1 input.

If desired, the unit can be coupled to a computer via a screened cable to make it possible for the program of the wave-file player to be altered without it being necessary to remove the unit.

The circuit is best built on the printed-circuit board shown, which is available through our Readers' Services (see towards the end of this issue). Note that the voltage regulator should be mounted on a small appropriate heat sink of 24 K W^{-1}.

[994080]

Parts list

Resistors:
R_1 = 12 kΩ
R_2 = 1.8 kΩ
R_3 = 270 Ω
R_4 = 1.2 kΩ

Capacitors:
C_1 = 10 µF, 25 V, radial
C_2 = 2200 µF, 16 V
C_3 = 0.1 µF, ceramic
C_4 = 1 µF, 63 V, radial

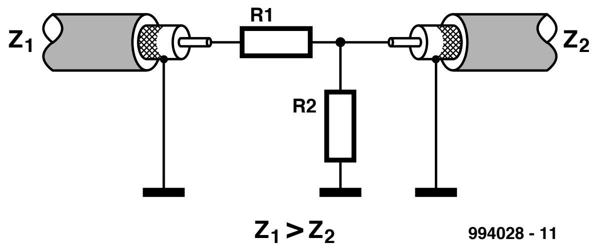
Semiconductors:
D_1 = 1N4148
D_2–D_5 = 1N4001
D_6 = BZT03, 15 V, 1.3 W
T_1 = BC547B

Integrated circuits:
IC_1 = LM317T

Miscellaneous:
K_1, K_2 = 2-way terminal strip, pitch 5 mm
K_3 = 3-way terminal strip, pitch 5 mm
S_1 = slide switch
F_1 = fuse holder with 500 mAT fuse
Enclosure, e.g. Bopla E410
Heat sink for IC_1: 24 K W^{-1}

impedance matching network

017



Z1	Z2	R1	R2	Attenuation
75Ω	50Ω	43Ω2	82Ω5	5,7 dB
150Ω	50Ω	121Ω	61Ω9	9,9 dB
300Ω	50Ω	274Ω	51Ω1	13,4 dB
150Ω	75Ω	110Ω	110Ω	7,6 dB
300Ω	75Ω	243Ω	82Ω5	11,4 dB

G. Kleine

When r.f. signals are transferred directly from a cable or other output terminal with an impedance Z_1 to a signal input terminal or cable with an impedance Z_2, reflections ensue that cause standing waves. Reflected signals then collide with incoming signals. The consequent superimposition of the two signals causes the resulting signal to be weak at certain points in the cable or network and very strong at others.

The matching network shown in the diagram matches two unequal impedances, provided that Z_1 is greater than Z_2. The table shows a number of frequently encountered values of Z_1 and Z_2 and the requisite resistors, as well as the resulting attenuation. The resistor values are the nearest standard values in the E-96 series to the computed ones.

The matching of impedances in this manner is wideband and is often used in the test and measurement operations when 75 Ω ad 50 Ω appliances are used.

The resistor values are calculated from

$$R_1 = Z_1 – Z_2 R_2/(Z_2 + R_2)$$

$$R_2 = Z_2 \surd Z_1/(Z_1 – Z_2)$$

where Z_1 and $Z_2$are as described earlier and their, and the resistor, values are in ohms.

[994028]

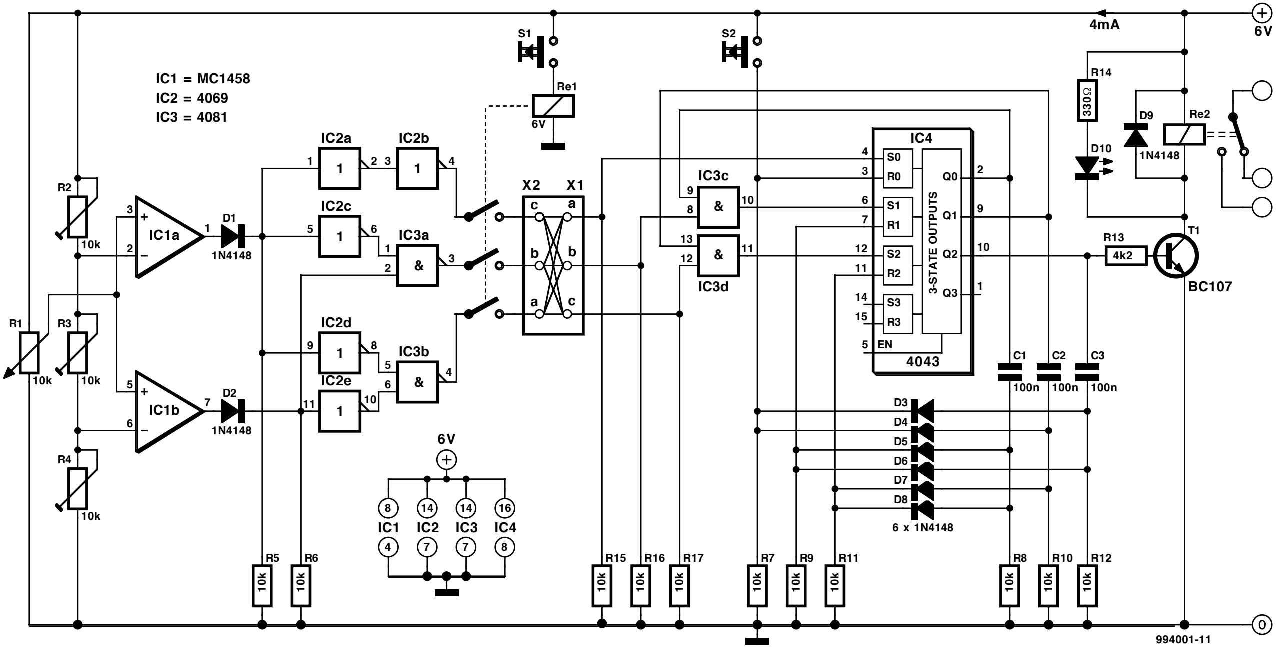
nostalgic combination lock

018

Design: P. von Lay Tech. Bureau

There are many different types of code locks, ranging from numeric keypads through chip cards and magnetic-card readers. The one presented here resembles an old-fashioned combination lock.

IC1a and IC1b are wired as comparators, with reference potentials that can be adjusted using trimpots R2, R3 and R4. Diodes D1 and D2 allow only positive voltages to pass to the subsequent logic gates, contained in IC2a-e and IC3a/b. These gates are connected such that only one of the three contacts of relay K1 will have a high level, according to the setting of R1 (which controls



the output levels of IC1a and IC1b).

If switch S1 is pressed, relay K1 is actuated. If a high level is present at X1a, RS flip-flop IC4a will be set, and the remaining flip-flops will be reset at the same time. If R1 is then repositioned so that a high level is applied to X1b when S1 is pressed, RS flip-flop IC4b will be set in turn. Finally, if R1 is again repositioned and S1 pressed to apply a high level to X1c, RS flip-flop IC4c will be set. This switches on T1, so that the LED D10 lights up and relay K2 is actuated. Relay K2 can be used to energize a door-opener solenoid, as an example. The lock can be reset by briefly pressing S2.

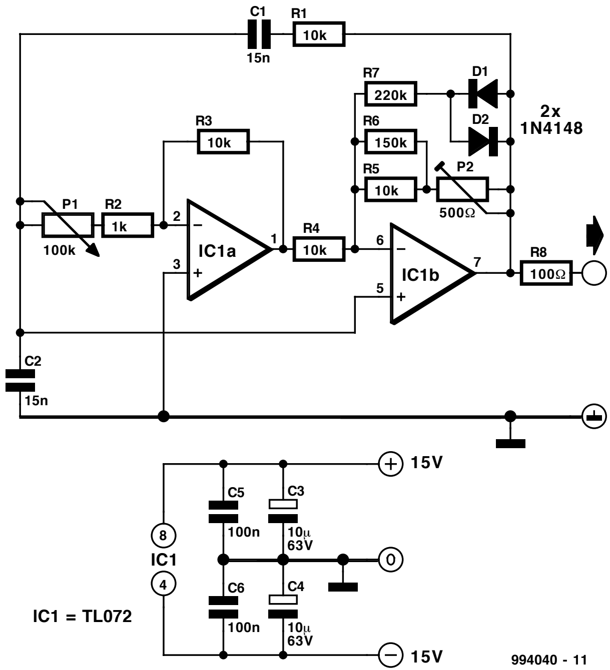
Points X1a-c are connected to points X2a-c by wire jumpers. The desired lock combination can thus be set using trimpots R2-R4 together with these jumpers. Since the reference voltages are analogue, there is theoretically an infinite number of possible combinations.

The circuit draws around 4 mA, plus the currents drawn by the LED and the relays. If a high-efficiency LED is used, the value of R14 must be suitably increased (to 3.9 kΩ).

(994001-1)

variable oscillator

019



T. Giesberts

Although the oscillator in the diagram at first sight resembles a standard Wien bridge type, it is in fact a variant of it since it is tuned by varying only one component. This has the advantage of not needing a carefully selected stereo potentiometer; instead, a single potentiometer may be used. In the diagram, this is P_1, and with values as specified, the output frequency of the oscillator may be varied between 340 Hz and 3.4 kHz.

The basic Wien bridge consists of R_1-C_1 and $(R_2+ P_1)$-C_2. Since in this variant the well-known ×3 attenuation does not occur, the conditions for stable oscillation are met by including the current through $R_2+ P_1$ in the positive feedback loop. This means that the circuit cannot be based on a single operational amplifier, which is the reason that IC_{1b} has been added to it. Diodes D_1 and D_2 ensure reasonable stability of the signal.

The design requires that the resistance of R_4 is more or less equal to the impedance of network R_5-R_6-R_7P_2-D_1-D_2. Potentiometer P_2 is set to a position which ensures that the level of the output signal is just below that of the supply voltage: the distortion is then a minimum. For best results, it may be worthwhile to experiment with the values of R_5, R_6, and P_2.

Frequency control P_1 may have a linear or logarithmic characteristic, although the latter will normally give more linear control.

The frequency, f, is, at least theoretically, determined by

$$f = 1/2\pi R_1 C_1 \sqrt{\alpha},$$

where $\alpha = (R_2 + P_1)/R_1$.

Note the conditions that $R_1 = R_3$ and $C_1 = C_2$.

The circuit has a drawback in that the frequency is dependent to some degree on the peak value of the signal, which cannot be nullified with the present design. It can, however, by replacing the parallel network D_1-D_2 by a proper stabilization circuit.

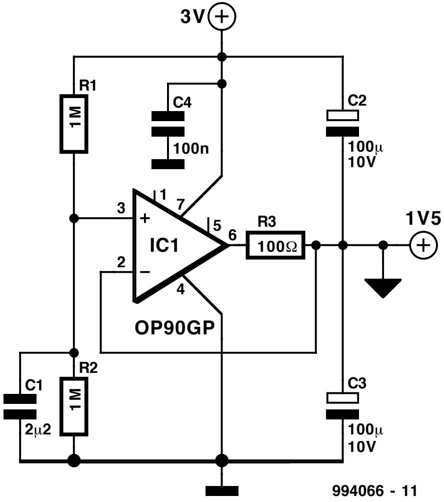
The circuit draws a current of about 4 mA without load. When a supply voltage of ± 15 V is used, the peak output signal is 9.4 V r.m.s. With the use of a Type TL072 as specified, the circuit can work from supply voltages as low as ± 5 V.

[994040]

3 V supply splitter

020

T. Giesberts



Many modern circuits tend to work from a single supply voltage of 3 V. But often they need a virtual earth at half the supply voltage for efficient operation.

The splitter shown in the diagram bisects the supply voltage with a high-resistance potential divider, R_1-R_2, and buffers the resulting 1.5 V line with an op amp. Since the op amp used is not a fast type, the output is decoupled by capacitive divider C_2-C_3. This ensures that the impedance of the virtual earth point remains low over a wide frequency band. Because the potential at the junction C_2-C_3-R_3 is fed back to the inverting input of IC_1, the circuit becomes a standard voltage follower.

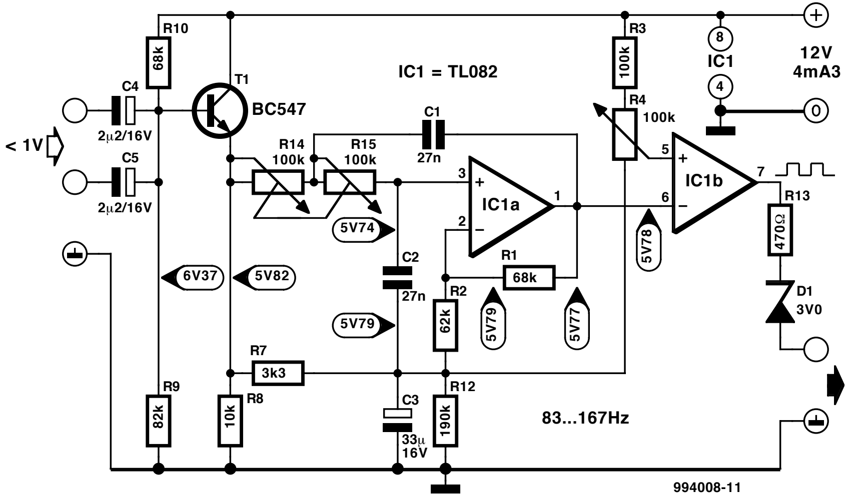
Resistor R_3 ensures that the regulation remains stable. The circuit can regulate ± 2 mA without any difficulties. Because of the low current drawn by IC_1, and the high resistance of R_1 and R_2, the overall current drain is low. In the absence of a load, it was 13 μA in the prototype, of which 1.5 μA flows through R_1-R_2.

Finally, since IC_1 can operate from a voltage as low as 1.6 V, the splitter will remain fully operational when the battery nears the end of its charge or life.

[994066]

stroboscope filter

021



Design: J. Ferber

To drive a stroboscope from an audio signal, the signal must first be reduced to its low-frequency component. This can be done with the circuit presented here. Coupling capacitors C4 and C5, for the left and right channels, prevent any DC voltages in the audio signals from reaching the transistor buffer stage (T1). The buffered audio signal is applied to an active second-order low pass filter, whose upper frequency limit can be adjusted over the range of approximately 80 to 170 Hz using the stereo potentiometer

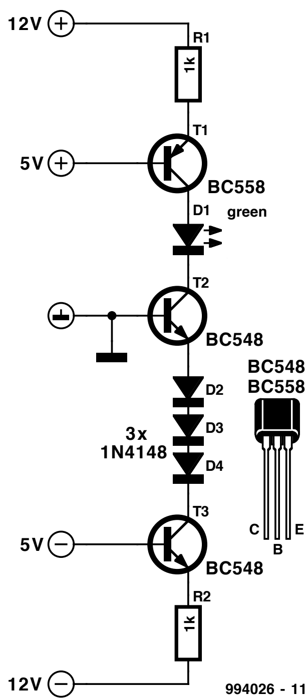
R14/R15. Good tracking between the two halves of this potentiometer is a basic requirement for proper operation of the filter. Here we are not so much interested in minimum distortion of the low-frequency component of the input signal, since all we need is a signal that is suitable for triggering the stroboscope circuit. This is achieved by applying the signal to a comparator with an adjustable reference potential. The trigger level of the circuit can be varied using R4. When the signal amplitude is high enough, a pulse signal appears at the output of IC2a.

An optocoupler is essential to provide galvanic isolation between the filter and the stroboscope. As a rule, this is present at the input of the stroboscope, so all we have to do is to reduce the output voltage by 3 V (using D1) and provide a current-limiting resistor (R13) at the filter output.

Perfectly inexpensive opamps (such as the TL082) can be used for the filter. With a simple + 12-V supply and the indicated component values, the current consumption of the filter circuit is around 4.3 mA.

(994008-1)

supply voltage monitor 022



G. Kleine

A circuit for monitoring supply voltages of ± 5 V and ± 12 V is readily constructed as shown in the diagram. It is appreciably simpler than the usual monitors that use comparators, and AND gates. The circuit is not intended to indicate the level of the inputs.

In normal operation, transistors T_1 and T_3 must be seen as current sources. The drop across resistors R_1 and R_2 is 6.3 V (12–5–0.7). This means that the current is 6.3 mA and this flows through diode D_1 when all four voltages are present. However, if for instance, the –5 V line fails, transistor T_3 remains on but the base-emitter junction of T_2 is no longer biased, so that this transistor is cut off. When this happens, there is no current through D_1 which then goes out.

[994026]

temperature-compensated crystal oscillator

023

A Dallas Semiconductor application

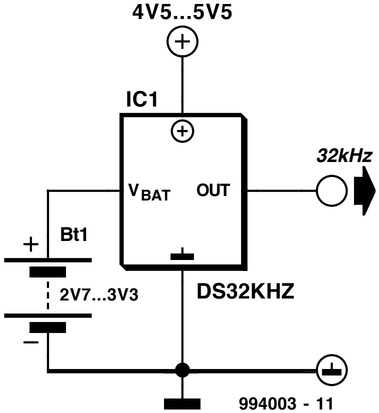
The clock in computers and many other electronic systems is normally provided by a simple crystal oscillator. Unfortunately, the electromechanical properties of such a clock are normally such that it may vary as much as 100 minutes per year from real time. This is, of course, a highly unsatisfactory, and, to many people, inexplicable situation. After all, if a cheap watch can keep (reasonable) time, why can an expensive computer not?

Yet, the reason for this is fairly simple. Watches, even the cheap ones, are designed to work at body temperature, which is fairly constant Clocks in computers and other electronic appliances, however, are designed to work at room temperature, say, 20–25 °C. When the ambient temperature is higher or lower, as happens in rooms and offices which are not constantly heated or cooled as the case may be, the clock will drift.

Dallas Semiconductor has now introduced a temperature-compensated oscillator (TXCO), which is eminently suitable for use in computers and other appliances where correct time-keeping is important. The very small integrated oscillator enables a clock to be constructed that does not vary by more than ± 1 minute per year (± 2 ppm) over a temperature range of 0–40 °C.

The IC type-coded DS32kHz is an accurate and affordable

1



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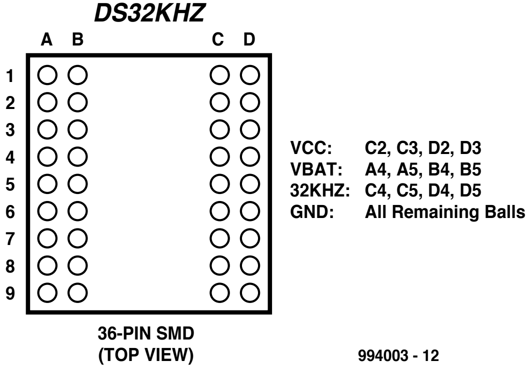


replacement for standard 32,768 kHz crystals and oscillators. Its output can drive virtually any RTC chip.

The SMD case of the DS32kHz contains a quartz crystal and a temperature-compensating circuit. In this circuit, use is made of a thermal sensing technology specially developed by Dallas. External components are not needed: the IC is calibrated at the factory.

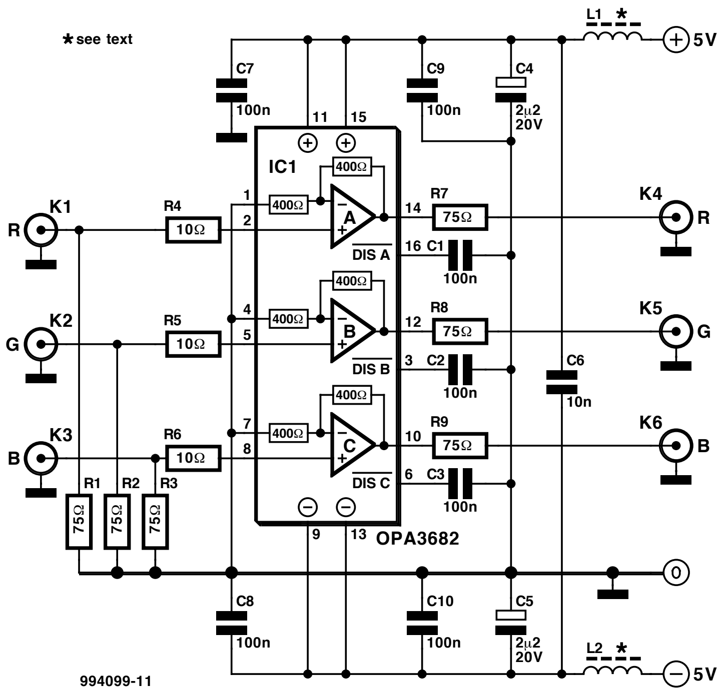
The circuit in **Figure 1** shows that connecting the TXCO is straightforward. The backup battery connected to V_{BAT} ensures that when the mains voltage fails, the clock remains on. If a backup battery is not used, V_{CC} should be connected to GND and a supply voltage of 2.7–5.5 V to V_{BAT}.

The device is available only in SMD format. Its pins are arranged as a 36-pin ball grid array. The pinout is shown in **Figure 2**.

[994003]

024

fixed-gain line driver OPA3682



A Burr-Brown application

The OPA3682 provides an easy-to-use, broadband fixed gain, triple buffer amplifier. Depending on the external connections, the internal resistor network may be used to provide either a fixed gain of + 2 video buffer or a gain of ± 1 voltage buffer. Operating on a low 6 mA/channel supply current, the device offers a slew rate and output power normally associated with a much higher supply current.

The output stage architecture provides high output current with minimal headroom and crossover distortion to give excellent single-supply operation. Operating from a single + 5 V supply, the OPA3682 can deliver a 1–4 V output swing with over 100 mA drive current and a bandwidth of 200 MHz. This combination makes the OPA3682 ideal for use as an RGB line driver or a single-supply, triple ADC input driver.

Each amplifier has a dedicated disable pin (3, 6, 16). When the disable function is not used, a decoupling capacitor, C_1–C_3, links the relevant pin to earth. Correct decoupling, as well as faithful adherence to the circuit layout, is important. A good guide is the DEM-OPA368xE evaluation fixture sheet available from the Burr-Brown Corporation or its dealers or at http://www.burr-brown.com/ This sheet also outlines the reasons why all components should be in surface mount technology (SMT).

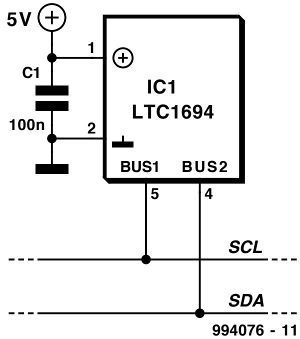
Resistors R_1–R_3 determine the input impedance, and resistors R_7–R_9, the output impedance.

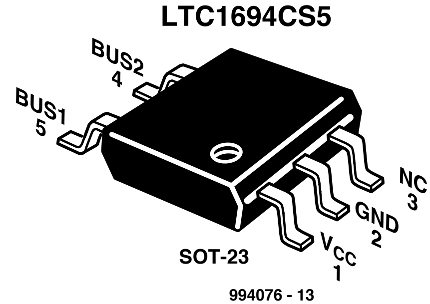
The quiescent current with all amplifiers enabled is about 18 mA and with the amplifiers disabled, about 900 μA.

[994099]

pull-up accelerator

025





K.S.M. Walraven

Systems like the SMBus or I^2C™ use a standard resistor to pull up the signal levels to the positive supply rail (normally 5 V). The bus goes low because an appliance connected to it pulls the signal to zero via its open-collector output. The well-known problem is this output can draw a much higher current than the pull-up resistor can compensate. This results in a steep trailing edge, but a much more gradually rising leading edge, whose transition in addition is not linear but exponential. This adversely affects the duty factor of the signals and also reduces the speed of the bus.

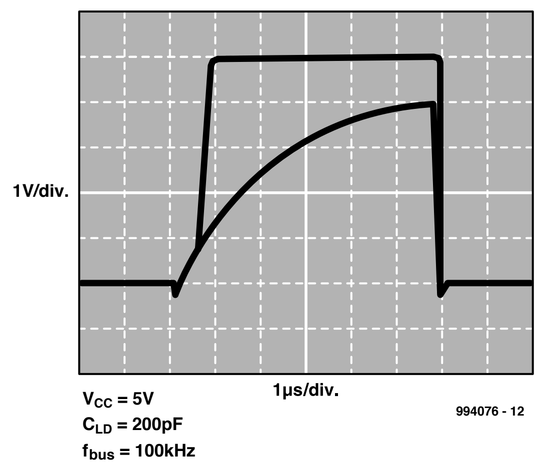
Linear Technology have available an IC (Type LTC1694) to replace the traditional pull-up resistor which can produce a current that is dependent on the changes in level taking place on the bus. When that level rises, the IC gives 2.2 mA, but when it falls, the current is only 275 μA.

Since the IC contains two circuits for replacing both pull-up resistors, it is possible to detect when the bus is in the quiescent mode (both pull-ups high). In this case, the current is reduced even more: to 100 μA.

The IC is intended for an I^2C bus frequency of 100 kHz. The 400 kHz and recently introduced 3.4 MHz versions are not supported. The IC is housed in a SOT-23 case.

The characteristic shows the difference of the leading edge obtained with a standard resistor and that resulting when the IC is used.

[994076]



pulse doubler

026

T. Giesberts

The design of frequency and pulse doubling circuits is normally complex and critical. The circuit in Figure 1a is a pleasant exception to this. It is based on a standard monostable multivibrator (MMV) and produces an output pulse for both the leading and the trailing edge of the input pulse. The duration of the output pulses is determined by the time constant R_3-C_3.

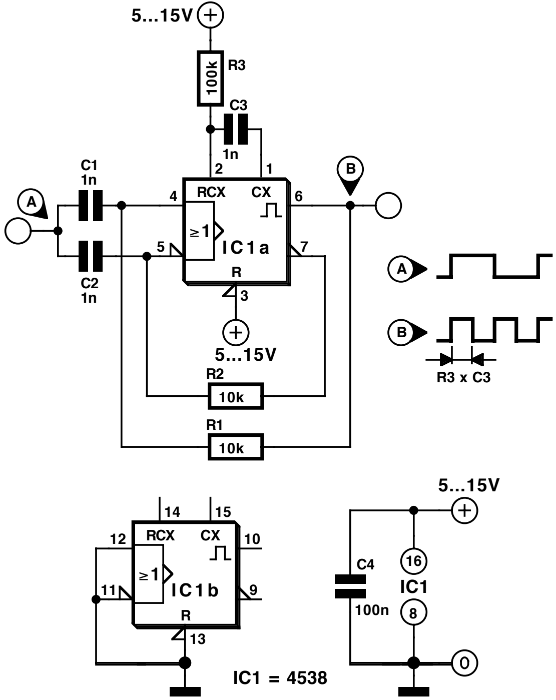
The TTL input signal is linked to both the + T (positive pulse) and the –T (negative pulse) inputs IC_{1a} via capacitors C_1 and C_2 respectively. The two inputs cannot be active simultaneously. This means that at the leading edge of the input pulse, the negative input must be high, and at the trailing edge, the positive input must be low.

Since IC_{1a} is a retriggerable MMV, each output pulse is stretched by the time constant R_3-C_3. The linking of both outputs with the relevant input via resistor R_1 and R_2 respectively ensures that a quiescent trigger input is at a non-active level. But, because the other trigger input is then at an active level for the duration of the pulse, the design ensures that the MMV is not retriggerable. If the width of the input pulse is shorter than the width of the output pulse (determined by R_3-C_3), only one output pulse will be produced, since the MMV can be retriggered only when the output pulse has terminated. It should therefore be ensured that the time constants R_1-C_1 and R_2-C_2 are shorter than R_3-C_3 at all times.

If a retriggerable version of the circuit is desired, the design shown in Figure 1b may be used. Again, the input signal is applied to the two trigger inputs via capacitors. In this case, however, resistors R_1 and R_2 are linked directly to the supply voltage to make the inputs inactive. This results in the outputs being active as soon as the duration of the input signal is shorter than that of the output pulse. No output pulses are produced then, of course.

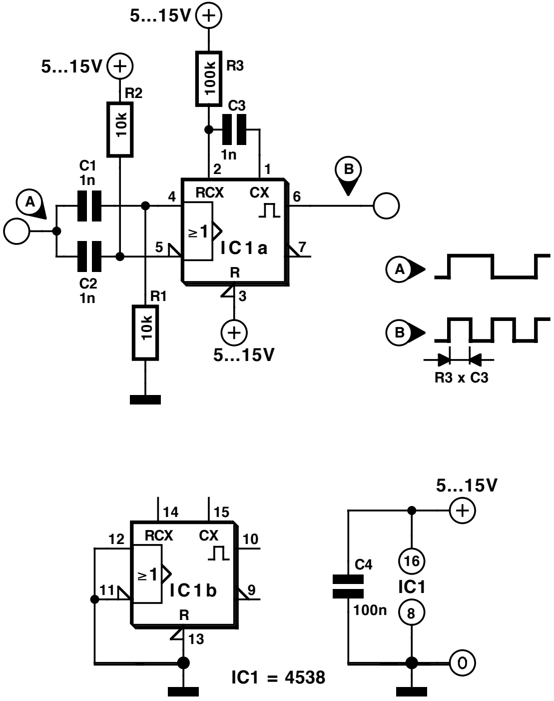
[994061]

a



994061 - 11

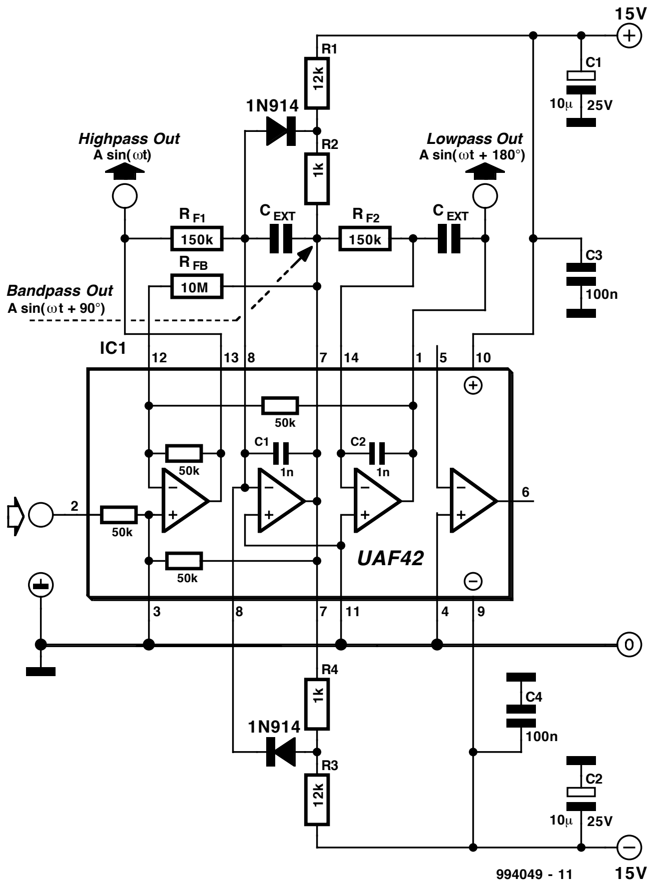
b



994061 - 12

three-phase sine wave generator

027



A Burr-Brown application

The diagram shows how a three-phase sine wave oscillator can be built with a single Type UAF42 state-variable filter and some resistors and diodes. Three output nodes are available: high-pass out, band-pass out, and low-pass out. The signal at the band-pass and low-pass out nodes is 90° and 180° out of phase, respectively, with that at the high-pass node. An on-chip auxiliary op amp is available for use as a buffer or amplifier stage.

The frequency of oscillation is set with resistors R_{F1} and R_{F2} according to

$$f_{OSC} = 1/2\pi RC,$$

where

$$R = R_{F1} = R_{F2}$$

and

$$C = C_1 = C_2 = 1000\ \text{pF}$$

The maximum frequency of oscillation obtainable with the UAF42 state-variable filter is 100 kHz. Distortion becomes a factor, though, for frequencies above 10 kHz. For frequencies of oscillation below 100 Hz, the use of external capacitors is recommended. These should be placed in parallel with the internal capacitors C_1 and C_2. This will reduce the requisite values of R_{F1} and R_{F2}. The external capacitors should preferably be NP0 ceramic or mica types.

To obtain the requisite output levels, resistors R_1–R_4 should meet the following requirement:

$$R_1/R_2 = R_3/R_4 = (V_O + V_S)/(V_O - 0.15) - 1$$

The values indicated in the diagram apply to a frequency of 1 kHz.

At this frequency,. the external capacitors may be omitted, since the internal ones are sufficient.

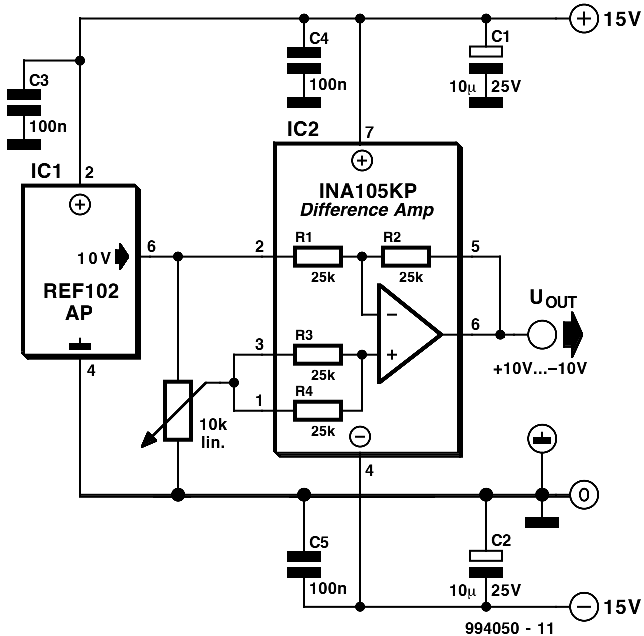
The actual output level may differ slightly from the calculated one owing to non-ideal operation of diodes and op amps. It may therefore be necessary to adapt the ratios R_1/R_2 and R_3/R_4 to some extent.

Positive feedback necessary for the onset of oscillation is provided by coupling the output of the band-pass section to the input of the summing amplifier via resistor R_{FB}. Suitable values for this resistor are 10 MΩ for $f > 1$ kHz, 5 MΩ for $f = 10$–1000 Hz, and 750 kΩ for $f < 10$ Hz. Smaller values result in an increase in the output level and, consequently, distortion.

[994049]

adjustable precision voltage source

028



A Burr-Brown application

Many applications require a precision voltage source which can be adjusted through zero to both positive and negative output voltage. An example is a bipolar power supply. Perhaps the most obvious implementation of a bipolar voltage source would be to use a bipolar voltage reference. However, a simpler solution is to use a single voltage reference and a precision unity-gain inverting amplifier. If a precision difference amplifier is used for the unity-gain inverting amplifier, the circuit requires just two chips and a potentiometer.

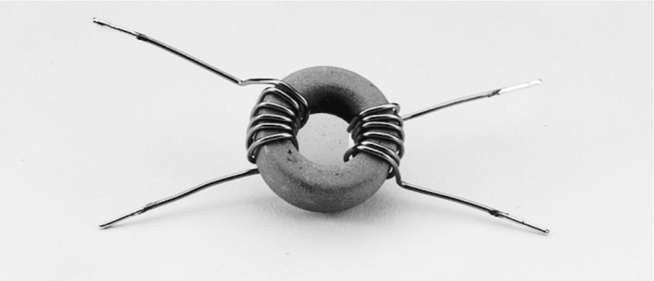
In the present circuit a Type INA105 differential amplifier is used as the unity-gain amplifier. A potentiometer is connected between the input and ground. The slider of the potentiometer is connected to the non-inverting input of the unity-gain amplifier. (The non-inverting input of a unity-gain amplifier is normally connected to ground.) With the slider at the bottom of the potentiometer, the circuit is a normal precision unity-gain inverting amplifier with a gain of –1.0 V/V ± 0.01% max. With the slider at the top of the potentiometer, the circuit is a normal precision voltage follower with a gain of + 1.0 V/V ± 0.001% max. With the slider at the centre of its travel, there is equal positive and negative gain for a net gain of 0 V/V. The accuracy between –1.0 V/V and + 1.0 V/V is normally limited by the accuracy of the potentiometer. Precision 10-turn potentiometers are available with 0.01% linearity.

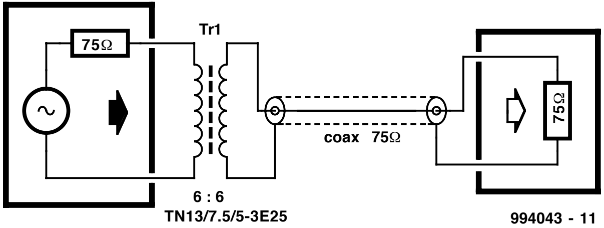
The –1.0 V/V to + 1.0 V/V linear gain control amplifier has many applications. With the addition of a precision + 10.0 V reference, it becomes a –10 V to + 10 V adjustable precision voltage source.

[994050]

isolating transformer for S/PDIF

029





T. Giesberts

WARNING: do not use this transformer for mains isolating, because its insulation is not capable of handling this. It is intended to prevent earth loops arising or undesired signals being applied to the input of an appliance. For instance, a tape recorder is to be linked to a sound card in a computer which has an S/PDIF (Sony/Philips Digital Interface Format); the computer is not connected to protective earth (which in the UK is next to impossible and certainly not advisable). Owing to the mains filter, half the mains voltage will be present on the enclosure and thus on the input earth. The linking of this potential to the tape recorder is prevented by the isolating transformer in the diagram.

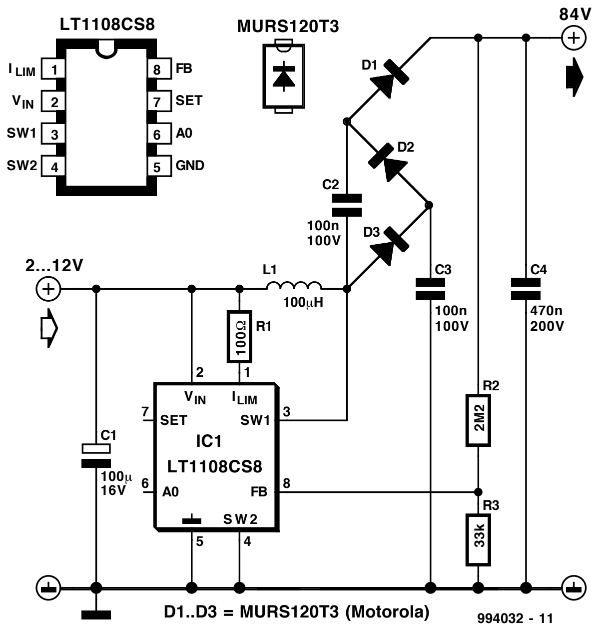
To ensure a good bandwidth, the coupling factor of the transformer must be good (low stray self-inductance), so that a core with a high μ_τ is needed. The prototype uses a Philips Type TN13/7.5/5-3E25, which has a μ_τ of 4500. The primary and secondary windings, each consisting of six turns of 0.5 mm dia. enamelled copper wire, are laid on opposite sides of the toroid. The windings should be covered with insulating tape. If heavy-duty, insulated wire is used for the windings, they can be laid over one another, which improves the coupling factor. But even with the first method, the bandwidth ranged from 50 kHz to 17 MHz, which is more than adequate for an S/PDIF link.

Place the transformer directly at the output of the signal source. The reason for this is that the input and output impedances of the transformer are not exactly 75 Ω. With the transformer directly at the source and provided the coaxial cable at the computer end is terminated correctly into 75 Ω, all will be well.

[994043]

switching regulator

030



G. Kleine

Potentials of up to more than 100 V may be generated by a switching regulator IC complemented by a cascode circuit of diodes and reservoir capacitors. The regulator pumps the voltage up in two stages to the requisite output level determined by potential divider R_2-R_3 according to the equation

$$U_{out} = 1.245(R_2 + R_3)/R_3.$$

With resistor values specified in the diagram, the output voltage is 84 V. Resistor R_3 may be replaced by a fixed resistor and a 10 kΩ preset.

Regulator IC_1 applies the direct voltage at the input to inductor L_1. Internally, pin 3 (SW1) is periodically short-circuited to pin 4 (SW2= earth). When SW1 is opened, a counter-e.m.f. pulse is generated across L_1, which charges capacitor C_3 via diode D_3. The voltage pulse is also applied to C_2. The voltage across C_3 is applied to C_4 via D_2 together with that across C_2 via D_1. The diodes used must be fast types with a high reverse voltage rating. In the prototype, Motorola Type MURS120T3 diodes were used.

The current through switches SW1 and SW2 is determined by resistor R_1. With a resistance of 100 Ω as specified, it is about 700 mA. The peak current must not exceed 1.5 A.

CAUTION The generated voltages may be lethal, so care must be taken in handling the circuit. Also, after the input voltage has been switched off, capacitor C_4 may retain a lethal charge for some time.

Detailed information on Linear Technology's regulator IC Type LT1108 from: http://www.linear-tech.com

[994032]

EEPROM protection in AVR controllers

031

H. Bonekamp

AVR controllers have the unfortunate property of their data EEPROM being affected when the supply voltage drops below a certain level, which can, of course, be prevented by making the reset low in good time to disable the processor. Unfortunately, this requires a circuit for monitoring the supply voltage and for taking the requisite action automatically when needed.

This requirement is met by the circuit in the diagram, which draws a low enough current to enable it being powered by a battery. The circuit may be split into a detector, T_1, and an amplifier, T_2–T_3.

The trip voltage of the detector is determined by the values of R_1 and R_2. Normally, the transistor conducts, but as soon as the supply voltage drops below the trip level, it is cut off. The output of

T_1 is applied to a low-power amplifier.

During normal operation, transistor T_3 is off, so that R_5 functions as pull-up resistor to retain the RST input of the AVR processor high. When the detector goes off, T_3 is switched on and the RST input goes low, a process that is enhanced by transistor T_2 being switched on, whereupon R_3 is shorted out. The resulting hysteresis requires the supply voltage to exceed the trip voltage before this situation can change. A manual reset is possible at all times with witch S_1.

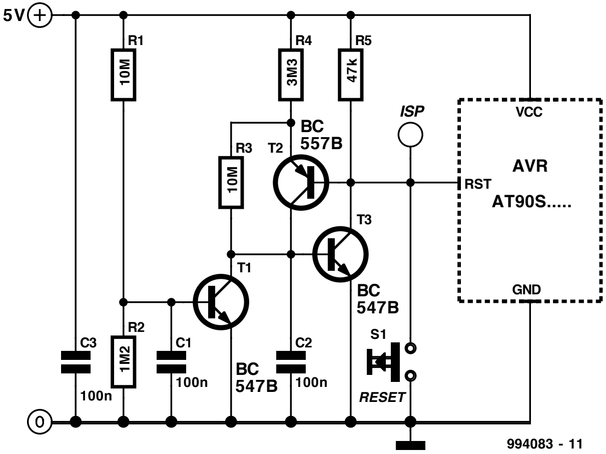
As stated earlier, the trip voltage is determined by the values of R_1 and R_2 (and, to some degree, the base-emitter potential of T_1 – about 540 mV), and the tolerance of these resistors should therefore be 1%. If the trip voltage needs to be altered, it is best to retain the value of R_1 at 10 MΩ and change the value of R_2 according to

$$R_2 = 0.54R_1/(U_b - 0.54),$$

where R_2 is in ohms and U_b is the supply voltage.

The hysteresis is determined by the value of R_4: the smaller this is, the larger the hysteresis. The specified value of 3.3 MΩ is fine for most cases, but some experimentation does no harm.

[994083]



code lock

032

G. Vanderplancke

The combination of a couple of thyristors, key switches and a relay as shown in the diagram forms a suitable, reasonably tamper-proof code lock for use in, say, a car. To open the lock,a number of keys must be pressed in a prescribed sequence to energize a relay, whereupon the battery voltage is applied to the ignition switch.

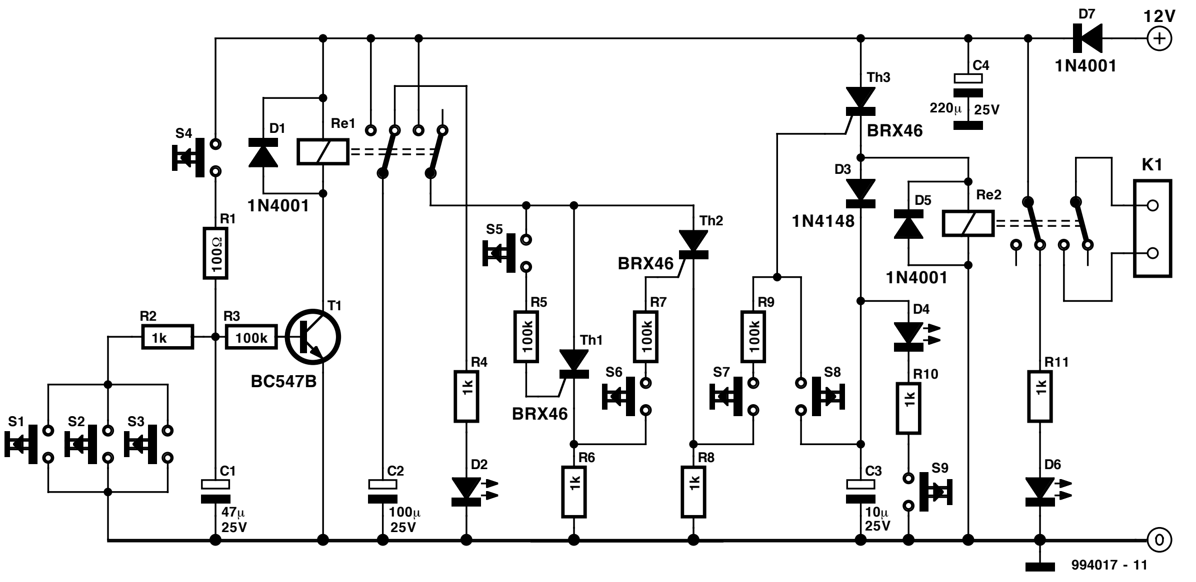
The first key to be pressed is S_4, whereupon capacitor C_1 is charged via resistor R_1. The charge on this capacitor ensures that transistor T_1 is on for about 15 seconds, during which relay Re_1 is energized. However, within these 15 seconds, key S_5 must be pressed to switch on thyristor THR_1. Then S_6 must be pressed to switch on THR_2. Finally, S_7 is to be pressed to switch on THR_3. When that is done, relay Re_2 is energized, and the lock is open.

If within the initial 15 seconds the wrong key is pressed, C_1 is discharged, whereupon T_1 is cut off and Re_1 is deactuated. When this happens, D_2 lights briefly. The lock can then be opened only by starting with pressing S_4 again. This applies also if S_5 is not pressed within the initial 15 seconds.

The lock is provided with a rapid access facility. In the actuated state, capacitor C_3 is charged via THR_3. When the ignition is switched off for only a brief period (for instance, when the driver stops to post a letter [sic]), the capacitor is discharged only slowly, so that THR_3 may be switched on again by pressing S_8. Since this makes the lock less secure, the rapid access facility may be disabled by pressing S_9. Capacitor C_3 is then discharged rapidly and D_4 lights briefly.

The circuit draws a quiescent current of about 12 mA, which rises to some 80 mA when both relays are actuated.

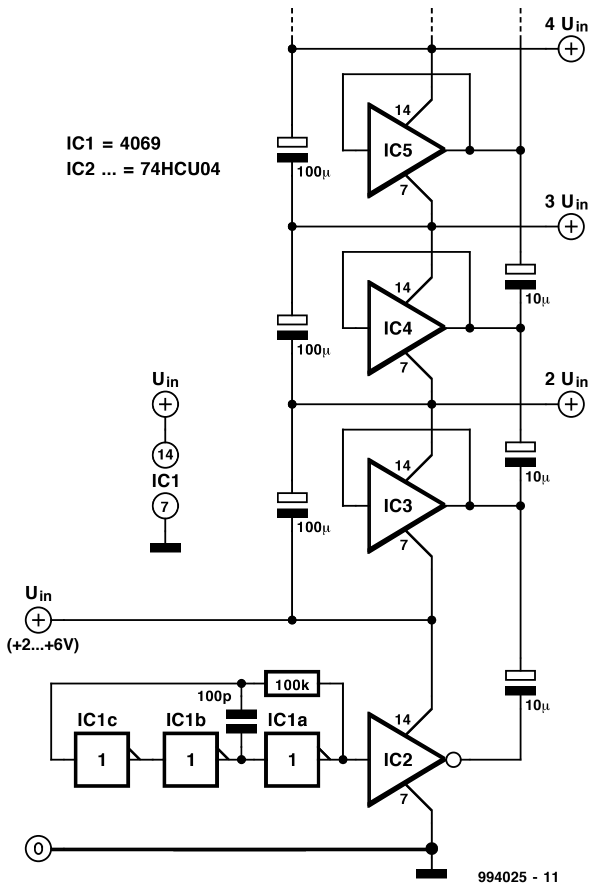
[994017]



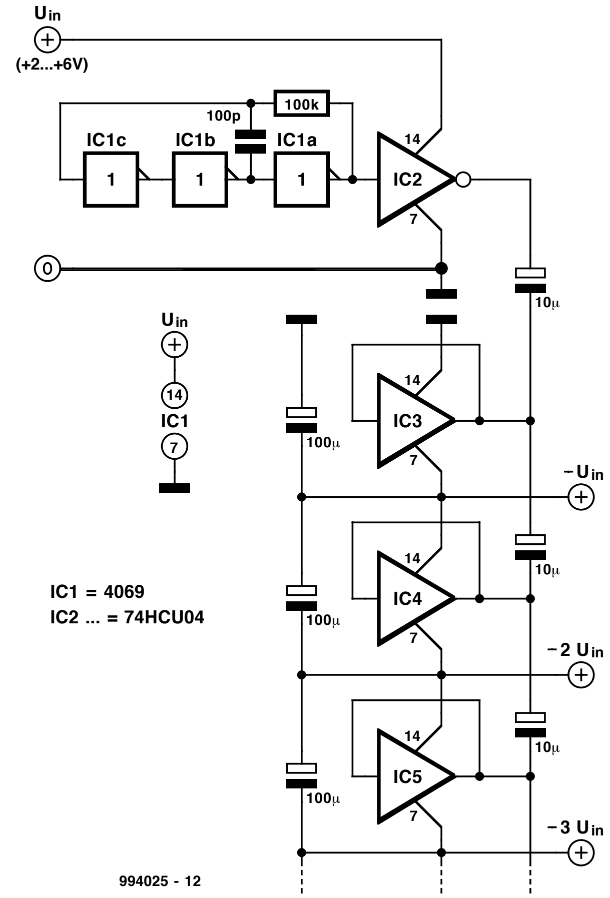
voltage boosting with inverters

033

1



2



G. Kleine

A 'tree' of inverters is highly suitable for boosting a voltage. That in the diagram provides voltages that are whole multiples of the input voltage by clock-driven charging of capacitors. The voltage across the capacitors is added stage by stage to the input voltage. Here, integrated circuits, IC_2–IC_7, each containing six inverters are used. In each IC, except IC_2, one of the inverters is connected in series with the parallel combination of the other five.

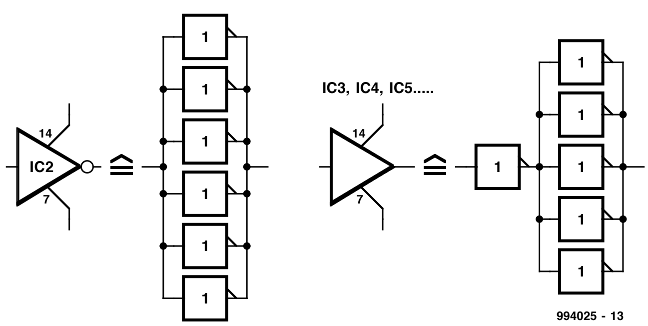
Circuit IC_1 is configured as a 50 Hz oscillator that controls inverting driver IC_2. A 10 μF capacitor interlinks the outputs of IC_2 and IC_3. The bidirectional properties of the MOSFET output of IC_3 ensure that the voltage across supply terminals 7 and 14 is identical to the input voltage. The increased voltage, equal to $2V_{IN}$, is filtered by a 100 μF capacitor.

The outputs of IC_3 and IC_4 are also interlinked by a 10 μF capacitor, and a similar process as just described takes place. This continues up to the last IC on the tree.

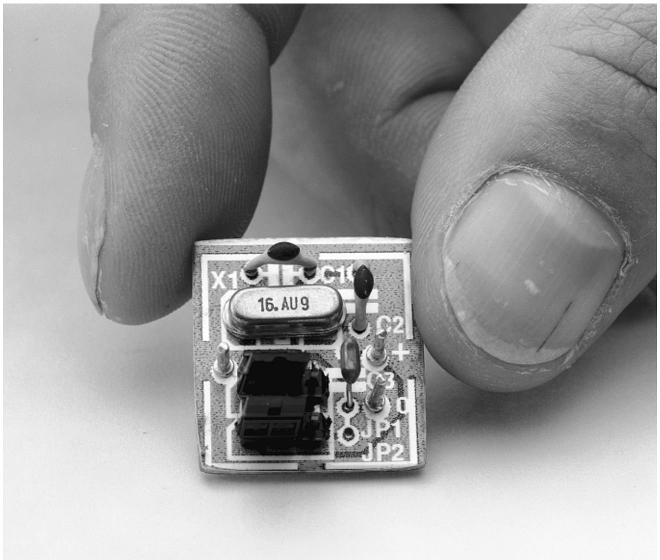
The efficiency of the booster increases when the clock frequency is lower than 50 Hz, but then the available output current drops. If a current of 5 mA is drawn from the terminal at which $3V_{IN}$ appears, the efficiency is about 90%. However, it drops to around 75% when the current is increased to 15 mA.

The circuit can also be arranged as a voltage-inverting booster. The ICs should then be arranged as shown in Figure 2.

[994025]



crystal frequency multiplier 034



Components list

Capacitors:
C1,C2 = 33 p cer.
C3 = 100 n cer.

Semiconductors:
IC1 = ICS501M

Miscellaneous:
X1 = crystal approx. 5–27 MHz
JP1,JP2 = 3-way jumper

H. Bonekamp

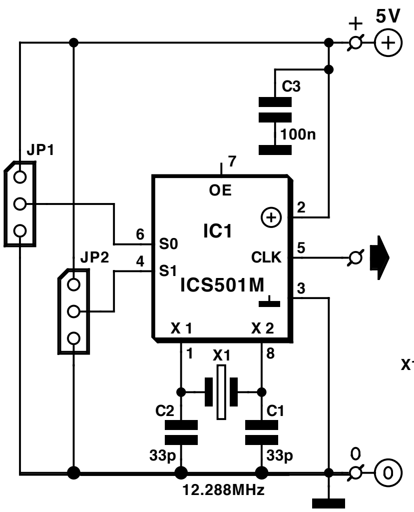
Crystals for operation above 20 MHz are invariably cut to an overtone (harmonic), which may be the third, fifth, or seventh. In other words, the fundamental frequency of such a crystal is a third, fifth or seventh of the operating frequency. If, however, an overtone crystal is used in an oscillator designed for operation on the fundamental, it is doubtful whether the wanted frequency will be generated. In most such cases, there are difficulties that make it necessary for the oscillator circuit to be modified.

One practical solution for such problems is offered by the circuit in the diagram, which enables frequencies up to 160 MHz to be generated with the use of a fundamental-frequency crystal. The output signal is virtually free of any jitter.

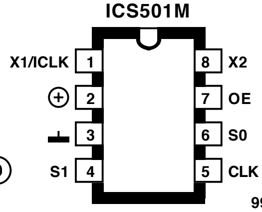
The circuit makes use of an IC that contains not only an oscillator but also a phase-locked loop (PLL) controlled frequency multiplier. The associated ROM stores nine different multipliers, which may be selected by appropriate placing of the jumpers in JP_1 and JP_2 as shown in the table. A 0 in the table indicates that the jumper is linked to earth; a 1, that it is linked to the + 5 V line; and a × that it should be left open.

The circuit may conveniently be built on the printed-circuit board shown, which is not available ready made.

The circuit draws a current of about 20 mA.



JP1	JP2		X1 min
0	0	4 x	
0	x	5.3125 x	20 MHz
0	1	5 x	
x	0	6.25 x	4 MHz
x	x	2 x	
x	1	3.125 x	8 MHz
1	0	6 x	
1	x	3 x	
1	1	8 x	



994067 - 11

[994067]

single-supply precision rectifier

035

An Analog Devices application

The precision full-wave rectifier circuit shown in the diagram accepts a.c. inputs of up to ± 3 V, yet operates from a single + 5 V supply voltage. The quiescent current is only 320 μA. Rectifier gain is unity, with the gain accuracy almost entirely dependent on the match between the two resistors $2R_1$. The frequency range is about d.c. to 2 kHz. The single-supply operation at very low quiescent current drain makes the circuit particularly useful for battery-powered equipment.

When the input voltage, V_{IN} is positive, A_1 drives T_1 and D_2 to make output voltage V_O equal to the input voltage. The output swing at V_O is about three diode drops below the supply voltage, so that the peak output voltage is around + 3 V. The output of amplifier A_2 goes to negative saturation, which is about + 0.8 V; T_2 is then reverse-biased and off.

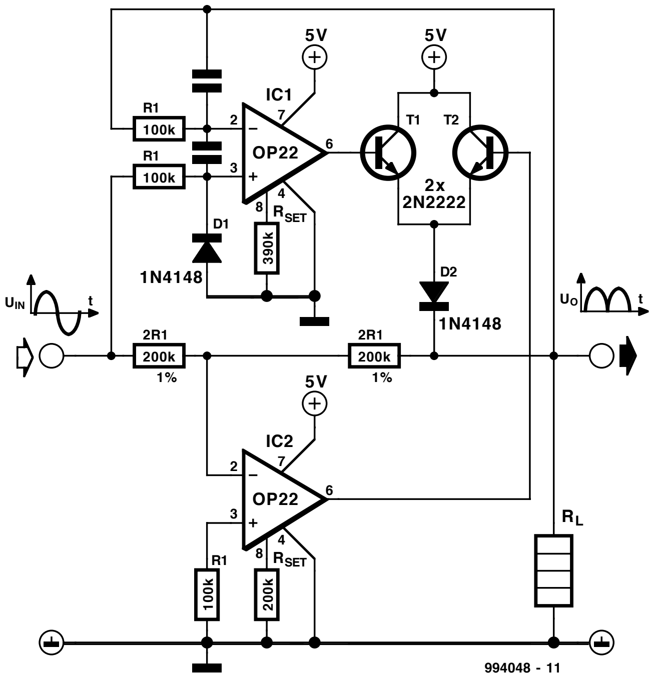
When the input voltage is negative, the output of A_1 goes into negative saturation so that T_1 is switched off. Amplifier A_2 then serves as a unity-gain inverter. Since V_O is equal to V_{IN} in magnitude but opposite in polarity, V_O will be equal to the absolute value of V_{IN}.

The quiescent current is determined by the the set current, I_{SET}. With a 5 V supply, the set current is $3.7/R_{SET}$. Slew rate and bandwidth vary directly with the set current.

Amplifier A_1 essentially operates with unity-gain feedback , while A_2 operates with a feedback gain of 0.5. The closed-loop gain-bandwidth is therefore made equal, and the frequency response symmetrical, by making the set current of A_2 twice that of A_1. Amplifier A_2 has a set current of $3.7/2\times10^5$, that is, 18.5 μA, and amplifier A_1 has a set current of $3.7/39\times10^4$, which is 9.5 μA. These set currents result in quiescent currents of 100 μA for amplifier A_1 and 220 μA for amplifier A_2.

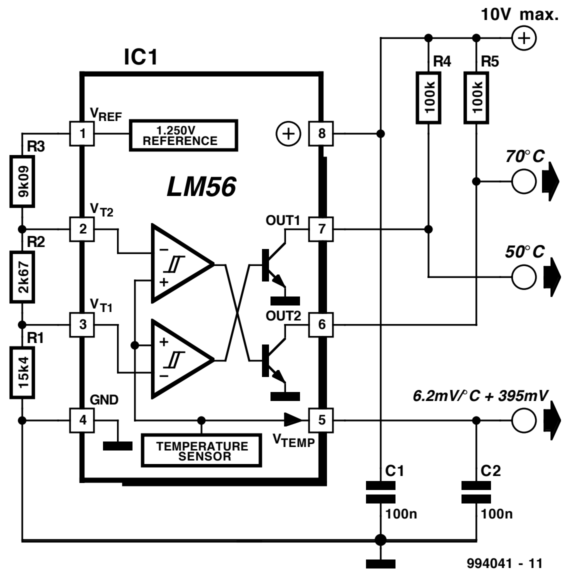
The input stage of the amplifiers is a p-n-p Darlington, so that a negative input voltage can forward-bias the collector-base junction of the input transistor. This potential problem is prevented by adding resistor R_1 and diode D_1 at the A_1 input to limit the negative input voltage.

[994048]



dual-output, low-power thermostat

036



A National Semiconductor application

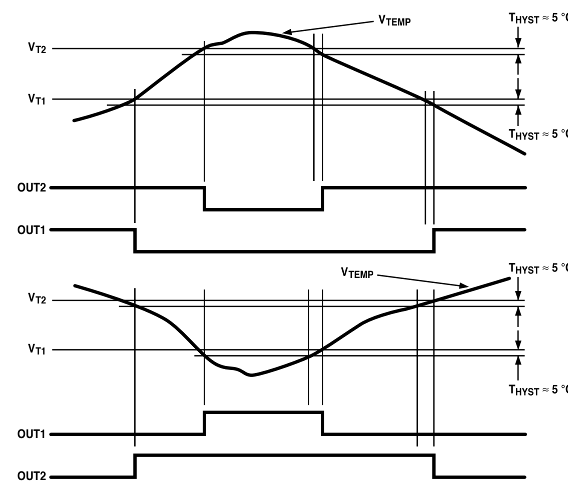
The LM56 from National Semiconductor is an accurate, dual-output, low-power thermostat contained in an 8-pin SMD case. It contains a 1.25 V bandgap voltage reference, two comparators with 5 °C hysteresis and a temperature sensor. The output voltage of the sensor is internally linked to the comparators. The supply voltage may lie in the range 2.7–10 V.

There are several variants: the LM56CIM has an accuracy of ± 4 °C and the LM56BIM ± 3 °C, both over the temperature range –40 °C to + 125 °C. Typical applications are temperature monitoring in a variety of system, protection against low or high temperatures, and control of alarm systems or fans.

Outputs OUT1 and OUT2 are open-collector outputs, which can switch up to 5 mA (400 mV drop at 50 μA). If it is required to switch a higher current, a buffer stage is needed at the output. The outputs are enabled when the values set with R_1, R_2, and R_3 are exceeded—see the timing diagram. Resistors R_4 and R_5 are pull-up components.

The output voltage of the temperature sensor is 6.2 mV °C^{-1} plus a fixed offset voltage of 395 mV. When the component values of potential divider R_1-R_2-R_3 are calculated, assume a load current of 50 μA for V_{REF}. This means that the total value of the three resistors is about 27 kΩ. If great accuracy is wanted, the bias current of the comparators should be taken into account, although the typical value of these is only 150 nA, so that they do not make much difference in practice. With values as specified in the circuit diagram, switching takes place at 50 °C and 70 °C.

Capacitor C_2 serves to decouple any interference. If such inter-



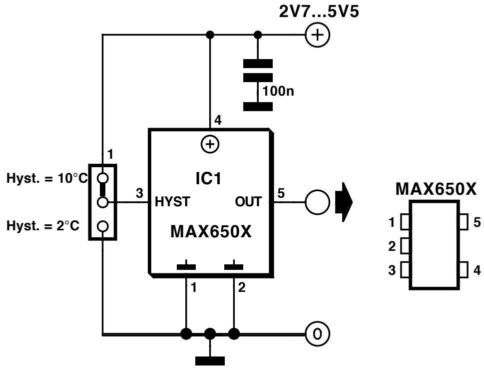
ference persists, the value of the capacitor may be increased to 1 μF without any adverse effect on the speed of reaction.

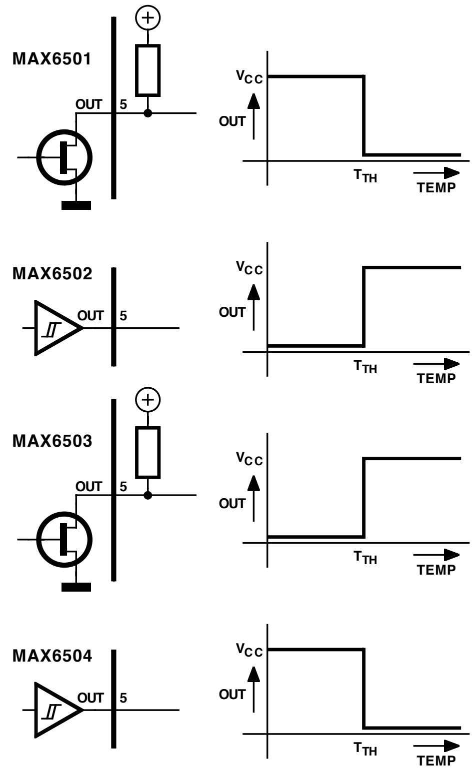
The LM56 draws a current of not more than 230 μA, which means that the total current drain, including the current through the potential divider, will not exceed 400 μA. This makes the IC particularly useful for systems operating from 3 V or 5 V battery packs.

[994041]

thermostat I

037





994037 - 11

G. Kleine

The MAX6501–MAX6504 integrated circuits contain a thermostat with fixed temperature thresholds. Available are thresholds of –15 °C, + 5 °C, + 45 °C, + 55 °C, + 65 °C, + 75 °C, + 85 °C, and + 95 °C. The MAX6501 and MAX6502 are for use over the temperature range + 35 °C to + 115 °C, while the MAX6503 and MAX6504 can be programmed from –45 °C to + 15 °C.

The tiny circuit, terminated in a 5-pin SOT-23-SMD case is ideally suited for building into an existing appliance. The supply voltage may be 2.7–5.5 V. The HYST input allows a hysteresis of 2 °C (HYST= GND) or 10 °C (HYST= V_{CC}) to be selected.

The difference between the four ICs is only in their output configuration. The MAX6501 and MAX6503 have open-drain outputs that need a pull-up resistor, whereas the MAX6502 and MAX6504 have a push-pull output that can gate GND or V_{CC}. At high temperatures, the MAX6501 and MAX6504 gate to ground, whereas the other two link the output to V_{CC}.

Further information about these useful circuits may be had from http://www.maxim-ic.com

[994037]

polarity protection

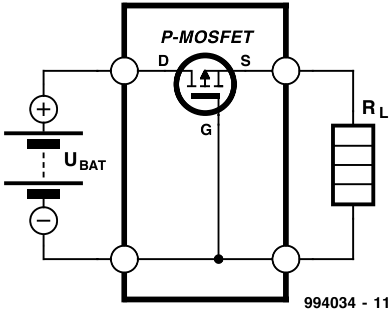
038

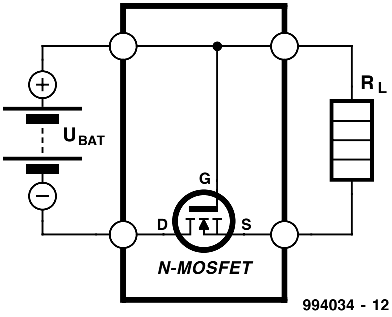
G. Kleine

In many cases, the battery or batteries in electronic equipment may be inserted with incorrect polarity. It is, therefore, advisable to use polarity protection such as shown in the diagrams. It should be noted that although a Schottky diode may be used, this causes a voltage drop of a few hundred millivolts, which in the case of a 3 V or 1.5 V battery supply is too much. The protection in the diagrams does not cause any reduction in the supply voltage.

The use of a MOSFET, p-channel or n-channel, as the case may be, ensures that when the polarity is correct, the battery voltage is applied to the load without any loss. For good efficiency, it is best to use an n-channel MOSFET, although this has the disadvantage of having to be inserted in the negative supply line. In cases where this is impossible or impractical, a p-channel device must be used.

In the choice of MOSFET, it must be borne in mind that the drain–source breakdown voltage, V(BR)DSS, must be larger than



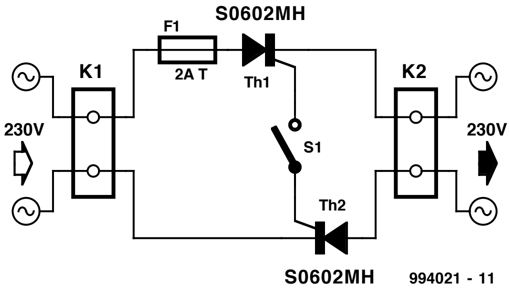


the battery voltage to ensure that the transistor survives an incorrectly connected battery. At the same time, the gate threshold voltage, VGS(th) must be small compared with the battery voltage to ensure that, provided the polarity is correct, the transistor can transfer the battery voltage to the load. Suitable types are certain HEXFETs from International Rectifier. In the case of n-channel types, the IRF7401 in an SO-8 case, the IRF7601 in a Micro-8 case, and the IRLML in a Micro-3 case are suitable. Types suitable for p-channel operation are the IRF7404 in an SO-8 case, the IRF7604 in a Micro-8 case, and the IRML6302 in a Micro-3 case.

Data sheets are available at: http://www.irf.com

[994034]

modified mains switch 039



H. Bonekamp

It sometimes happens that it is necessary for the contacts of a mains switch to be isolated or for the switch to be able to handle a larger load than it was designed for. Normally, a relay is used for these situations, but this has the disadvantage of needing an auxiliary voltage for operating the relay.

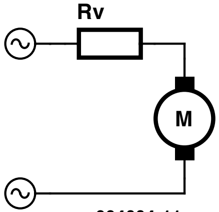
The diagram shows that the wanted aim can also be achieved by two thyristors instead of a relay, which has the advantage of not requiring an auxiliary supply. The arrangement depends on the leakage current of one thyristor firing the other. It is important that the thyristors are sensitive types, otherwise there is a risk that the setup does not work. The thyristors used in the prototype are Type S0602MH from SGS-Thomson. These fire at an I_{GT} as low as 200 μA and can switch currents of up to 3.8 A. For safety's sake, the fuse is rated at 2 A (slow). It hardly needs mentioning that the switch must be a Class II approved type.

[994021]

slowed-down fan

040

K.S.M. Walraven



994004-11

If, like many other people, you have ever been annoyed by the noise of, say, the extractor fan in your bathroom, here's a tip that may quieten things down a bit.

The fans in bathrooms and cooker hoods are normally small ones that rotate at high speed (but note that many cooker hoods have a speed control). The idea is to displace many cubic feet of air at little cost.

Fortunately, the speed of these fans can be lowered fairly simply by placing a resistor in series with the motor. The impedance, Z, of the fan is calculated from

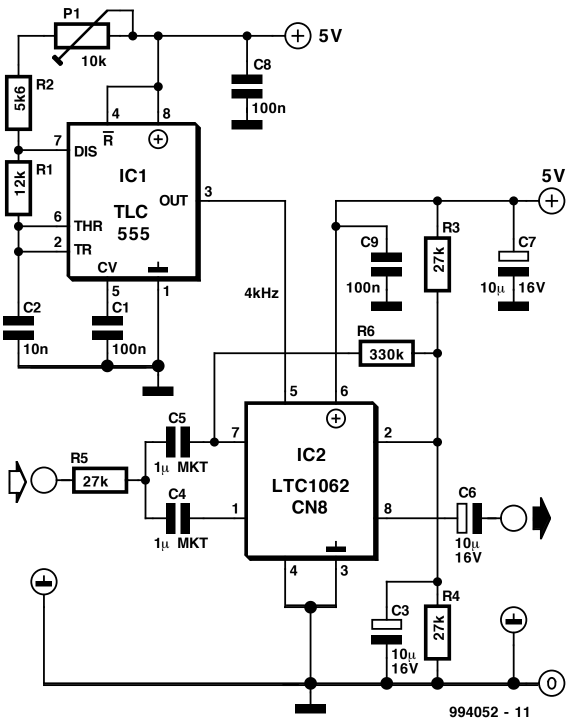
$$Z = U^2/P,$$

where P is the rating of the fan, and U is the working voltage, normally the mains voltage. If, for instance, the rating of the fan is 33 W, and the mains voltage is 230 V, its impedance is 1600 Ω, give or take an ohm.

The series resistor should have a value of about 1/3 of this value, that is, 470 Ω or 560 Ω. Since it will have to dissipate about 10 W, it is advisable to use two 1 kΩ resistors, rated at 10 W, in parallel. In view of the heat produced in them, it is advisable not to solder them to the motor connections, but to make the connections via a three-way terminal block.

[994004]

fifth-order low-pass filter 041



H. Bonekamp

The LTC1062 is an integrated fifth-order low-pass filter that stands out by the absence of any d.c. error. This is achieved by keeping the actual filter outside the d.c. range to eliminate matters like d.c. offset and low-frequency interference. It therefore makes the LTC1062 eminently suitable for filter applications where d.c. errors cannot be tolerated. A pivotal role in this is played by external resistor R_5. The output signal is fed back to the input of the filter via external capacitor C_4. Network R_5-C_4, in association with the internal switched-capacitor network, provides the fifth-order low-pass function.

The cut-off frequency of the filter is determined by an internal clock that can be controlled externally. This control is provided by oscillator IC_1, which is configured as an astable multivibrator (AMV). The filter has an internal divider that can be set for a scaling factor of 1, 2 or 4. In the present circuit, this factor is set to 4, resulting in a cut-off frequency equal to 1/400 of the clock frequency. Since the clock here is 4 kHz, the cut-frequency is 10 Hz. If a different cut-off frequency is wanted, R_5, R_6, C_4 and C_5 must meet the following requirement to retain a smooth pass band.

$$1/2\pi R_5 C_4 = f_C/1.84,$$

provided that $C_4 = C_5$ and $R_6 = 12R_5$.

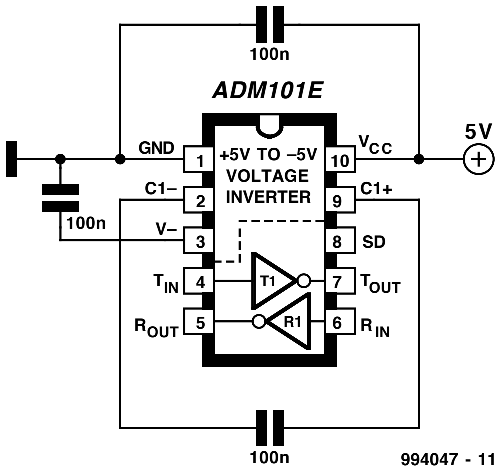
R_1, R_2, P_1 and C_2 must satisfy the following requirement

$$R_1 C_2 = 1.4/3400 f_C,$$

provided that $R_2 = R_1/2$ and $P_1 = R_1$.

[994052]

RS-232 transceiver for portable applications 042



An Analog Devices application

The ADM101E is a single-channel RS-232 driver and receiver in the Analog Devices Craft Port™ series, designed to operate from a single +5 V supply. A highly efficient charge-pump voltage inverter generates an on-chip –5 V supply, which eliminates the need for a negative power supply for the driver, and permits RS-232 compatible output levels to be developed using charge-pump capacitors as small as 0.1 μF.

A shutdown input disables the charge pump and puts the device into a low-power shutdown mode, in which the current drain is typically less than 5 μA.

An epitaxial BiCMOS construction minimizes power consumption to 3 mW and also guards against latch-up. Overvoltage protection is provided allowing the receiver inputs to withstand continuous voltage in excess of ± 30 V. In addition, all pins have ESD protection to levels greater than 2 kV.

The transmitter converts 5 V logic input signals into RS-232-compatible output levels, whose average value is ± 4.2 V. The receiver translates EIA-232 signals into 5 V logic levels.

The inputs are provided with 5 kΩ pull-down resistors. The guaranteed switching thresholds are 0.4 V minimum and 2.4 V maximum. The Schmitt trigger inputs have an hysteresis of 0.5 V, which ensures faultless reception in all conditions.

The ADM101E is available in a 10-pin micro-SO package, which makes it ideal for serial communications in small, portable applications, such as palmtop computers and mobile telephones, where a full RS-232 serial interface is not required, but compact size and low power drain are paramount.

[994047]

synchronous system to measure μΩ

043

An Analog Devices application

The circuit in the diagram uses a synchronous-detection scheme to measure low-level resistances. Other low-resistance-measuring circuits sometimes inject unacceptably large currents into the system on test. The present circuit synchronously demodulates the voltage drop across the system on test and can therefore use very low currents while measuring the resistance.

The generator, whose output is a 1 kHz signal at a peak level of 10 V, injects a 1 mA reference current into unknown resistor R_{TEST}. Instrument amplifier IC_1 and precision op amp IC_{2A} amplify the voltage across $R_{TEST} \times 10^5$. Synchronous detector IC_3 demodulates this voltage, which is then applied to low-pass filter IC_{2B}. The low-pass filtering attenuates all uncorrelated disturbances, such as noise, drifts, or offsets, while passing a direct voltage that is proportional to R_{TEST}.

The relationship between the output voltage and R_{TEST} is

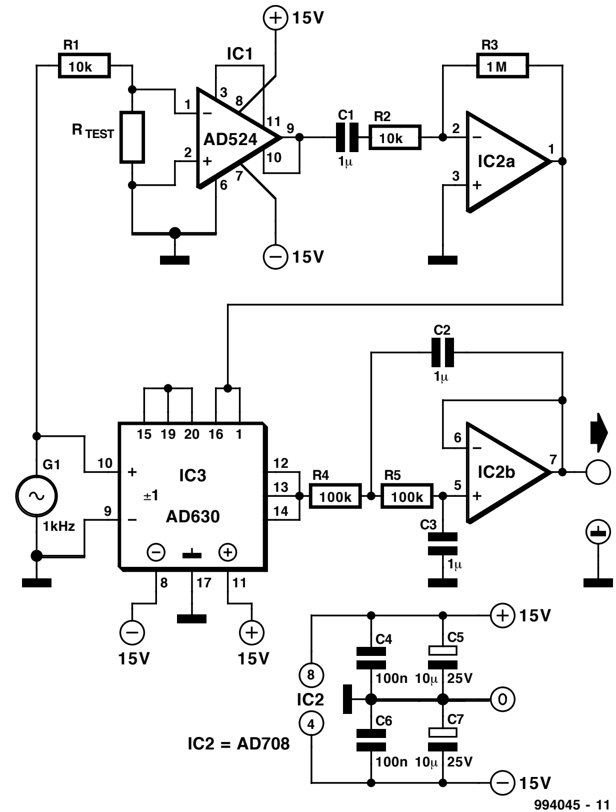
$$V_{OUT} = 10 \times 2/\pi \times R_{TEST} \times 10^5/10^3,$$

so that

$$R_{TEST} = 0.0157 \times V_{OUT},$$

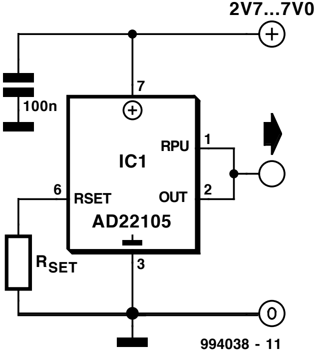
which is 15.7 mΩ V^{-1} at the output of the circuit.

[994045]



thermostat II

044



G. Kleine

The Type AD22105 from Analog Devices is an integrated circuit that contains a temperature sensor, a threshold comparator with hysteresis and an output stage. A single external resistor, R_{SET} allows setting the tripping threshold accurately anywhere between –40 °C and + 150 °C. The value of R_{SET} is calculated with

$$R_{SET} = 39 \times 10^6/(t_{SET} + 281.6) - 90.3 \times 10^3,$$

where t_{SET} is the numerical value of the trip temperature and R_{SET} is in ohms. This gives values of R_{SET} of, for instance, 47.5 kΩ for a trip temperature of 0 °C, 36 kΩ for 25 °C, and 12 kΩ for 100 °C.

The internal comparator trips when the ambient temperature measured by the sensor exceeds the set limit. The maximum error is ± 2 °C at 25 °C and ± 3 °C over the entire temperature range. The hysteresis, which prevents rapid operation of the comparator, is set at 4 °C during production.

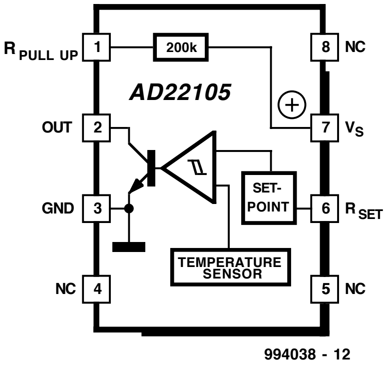
The AD22105 needs a supply voltage of 2.7–7.0 V. Since the dissipation at 3.3 V is only 230 μW, the error caused by this is negligible. The low dissipation makes the device ideally suited for battery operation.

The output stage is an open-collector n-p-n transistor with the emitter at ground potential. A pull-up resistor of 200 kΩ may be connected between pin 1 and pin 7. The transistor comes on when the ambient temperature exceeds the set limit. The output may be connected directly to low-current LEDs and CMOS inputs.

The AD22105 is housed in a SO8 case.

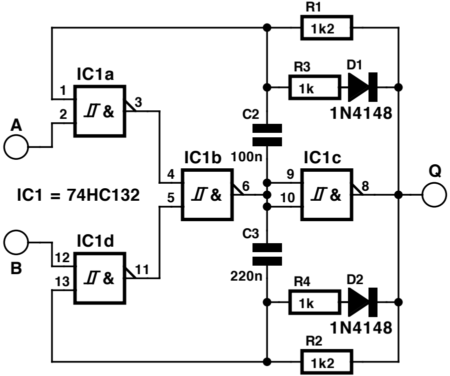
Further information may be had from http://www.analog.com

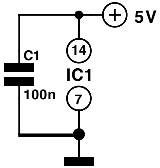
[994038]



3-frequency oscillator 045

G. Kleine





A	B	Q
0	0	OFF
0	1	1300Hz
1	0	2700Hz
1	1	2000Hz

994023 - 11

The output frequency of the oscillator shown in the diagram may be derived via two control inputs, A and B, and may, therefore have three different values. If the logic level at both inputs is low, the oscillator is disabled.

The oscillator proper is formed by gate IC_{1c}. Depending on whether a high logic level is applied to IC_{1a} or IC_{1b}, either network R_1-C_2 or network R_2-C_3 determines the output frequency. If both inputs are high, the output frequency is somewhere between the other two. With values as indicated, the output frequencies are 1300 Hz, 200 Hz, and 2700 Hz.

Branches R_3-D_1 and R_4-D_2 ensure that the pulse duty ratio of the output signal is 1:1. If the oscillator is to be used in applications where this ratio is irrelevant, the two branches may be omitted.

The oscillator is particularly suitable for use in frequency shift keying modulators.

[994023]

switch-mode lithium-ion battery charger

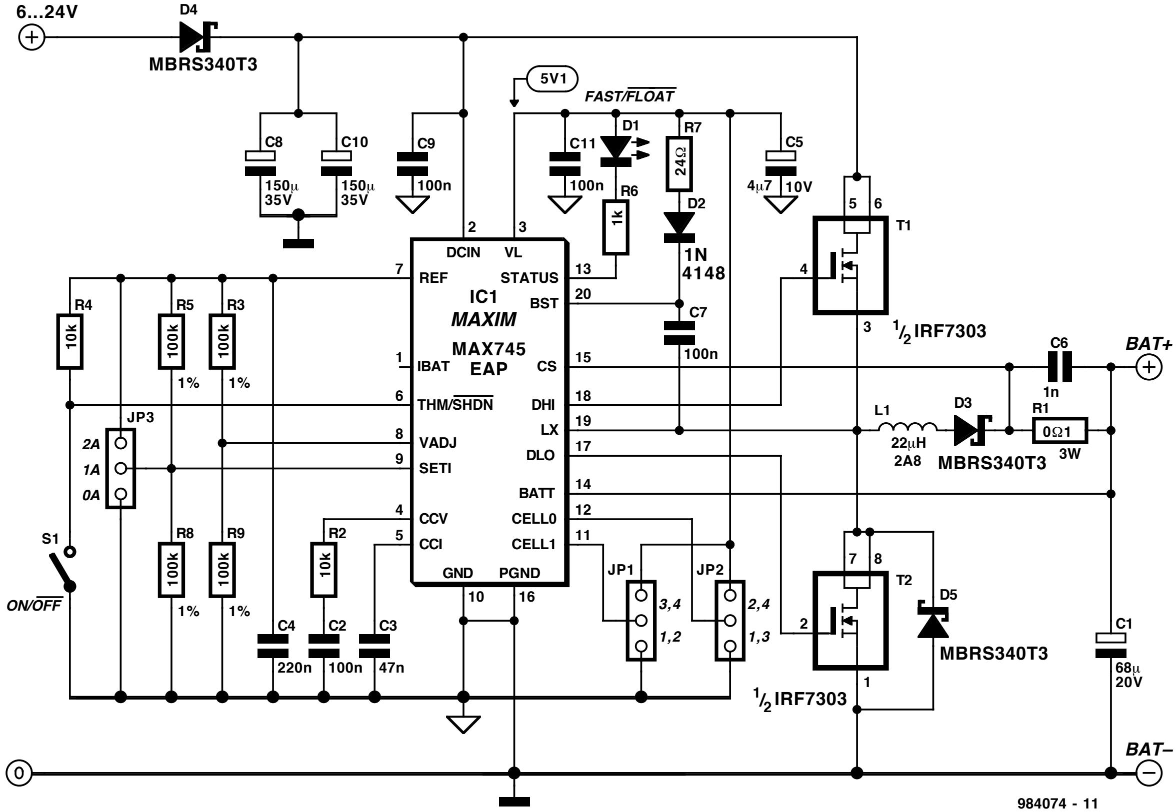
046

A Maxim application

More and more lithium-ion batteries are being used in all kinds of appliances. These require a battery charger and for this Maxim's MAX745 is ideal. It provides all the functions necessary for charging such batteries or packs of them. It provides a regulated charging current of up to 4 A without getting hot, and a regulated voltage with a total error at the battery terminals of only ± 0.75%. It uses low-cost, 1% resistors to set the output voltage, and a low-cost n-channel MOSFET as the power switch.

The MAX745 regulates the voltage set point and charging current using two loops that work together to transition smoothly between voltage and current regulation. The per-cell battery voltage regulation limit is set between 4.0 V and 4.4 V using standard 1% resistors, and then the number of cells is set from 1 to 4 by pin-strapping. The total output voltage error is less than ± 0.75%.

The charger is available as an evaluation kit, which is an assembled and tested printed-circuit board that implements a step-down,



switching power supply designed for charging lithium-ion (Li-ion) batteries. The output voltage can be set for one to four cells. The cell voltage can be set between 4.0 V and 4.4 V.

The Li-ion battery pack is connected between BATT and GND (BATT is positive, GND is negative). The battery may be connected with the charger off without causing damage, or it can be connected after power is applied.

The charging voltage is determined by the potential at junction R_3-R_9. Replacing these resistors by a multiturn potentiometer enables the voltage to be set very accurately.

The charging current is selected with jumper JP_3. Here also, a multiturn potentiometer to replace R_5 and R_8 enables a more accurate setting.

The number of cells, and thus the charging voltage, is set with jumpers JP_1 and JP_2: both to ground for one cell, only JP_2 to VL for two cells, only JP_1 to VL for three cells, both to VL for four cells.

Switch S_1 may be replaced by a resistor with negative temperature coefficient (NTC). When the voltage at pin THM drops below 2.1 V, the circuit is switched off automatically; when the voltage reaches 2.3 V again, the circuit is switched on anew.

Transistor T_1 is an n-channel FET whose auxiliary gate voltage is derived from capacitor C_7.

Diode D_1 is a freewheeling diode in case T_1 is cut off. When this happens, the diode is shunted by T_2 (which is on) to improve the efficiency. This is because the drop across the diode is 0.3–0.4 V, whereas that across a conducting transistor is only 0.1 V.

The three Schottky diodes are fast 3 A, 40 V types from Motorola. The FETs may be part of a dual FET from International Rectifier. If discrete ones are used, in view of the switching frequency of 300 kHz, types with a high input capacity must not be used: there is a current of only about 20 mA available for driving the gates. The IRF7303 has parameters: 30 V, 5 A, 0.05 Ω, and 520 pF.

[994074]

infra-red sensor/monitor 047

A Maxim Application

The sensor/monitor shown in the diagram ‘wakes up’ the host system on detection of infra-red (IR) signals. It draws so little supply current that it can remain on continuously in a notebook computer or PDA device. Its ultra-low current drain (4 μA maximum, 2.5 μA typical) is primarily that of the comparator/reference device, IC_1.

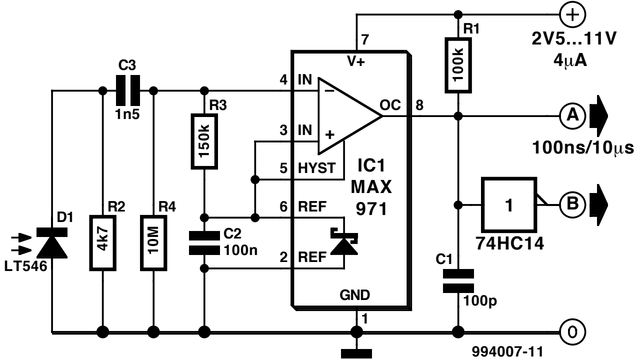
The circuit is intended for the non-carrier systems common in infra-red Data Association (IrDA) applications. It also operates with carrier protocols such as those of TV remote controllers and Newton/Sharp ASK (an amplitude shift keying protocol developed by Sharp and used in the Apple Newton). The range for 115,000-baud IrDA is limited to about 6 in (15 cm), but for 2400-baud IrDA, it improves to more than 12 in (30 cm).

Immunity to ambient light is very good, although bright flashes usually cause false triggers. To handle such triggers, the system simply looks for IR activity after waking and then returns to sleep mode if none is present.

The sensor shown, D_1, a relatively large-area photodiode packaged in an IR-filter material, produces about 60 μA when exposed to heavy illumination, and 400 mV when open-circuited. Most photodiodes may be used.

Operation is in the photovoltaic mode without applied bias. This mode is slow and not generally used in photodiode circuits, but speed is not essential here. The photovoltaic mode simplifies the circuit and saves a significant amount of power. In a more conventional configuration, for instance, photoconductive, photo currents caused by ambient light and sourced by the bias network would increase the quiescent current about ten times.

[994007]



pulse generator with variable duty factor

048

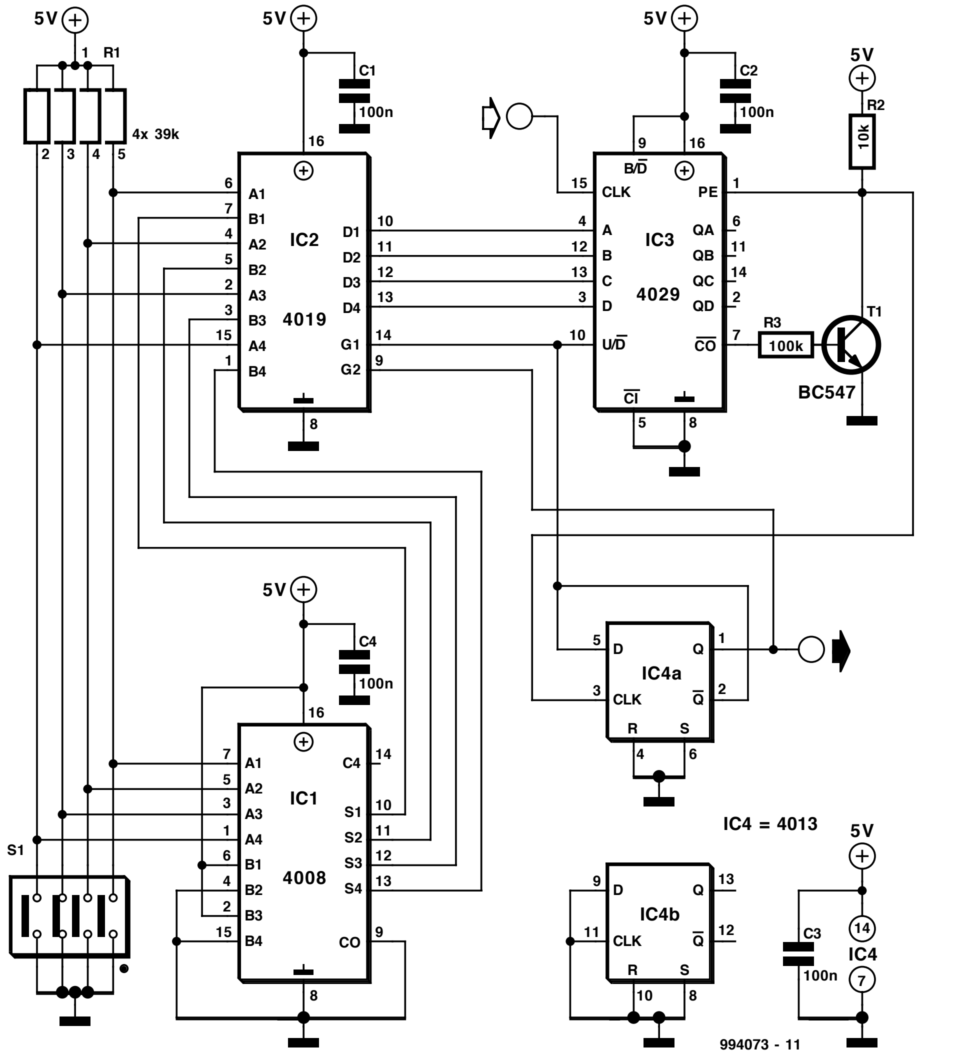
W. Dijkstra

The duty factor of the pulse generator in the diagram is variable in 10% steps from 10% to 90%.

With the aid of thumb wheel switch S_1, a 4-bit word, *S*, is added to one input of IC_1 and to IC_2. Circuit IC_1 is a full adder, while IC_2 functions as a switch. The binary equivalent of 5 is applied to the other input of IC_1. The output of IC_1 is linked to the second input of IC_2.

The output of IC_2 is applied to the programmable input of up/down counter IC_3 via bistable IC_{4a}. The terminal count output of IC_3 clocks IC_{4a} via transistor T_1. The output of IC_{4a} switches the counter from up to down and at the same time links data *S* or data *S*+ 5 to the programmable input of the counter and vice versa.

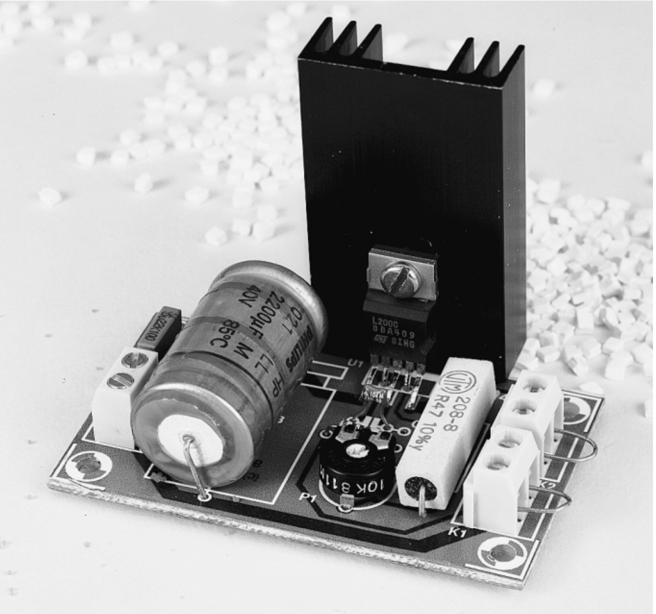
Imagine that the non-inverting output (pin 1) of IC_{4a} is high. Counter IC_3 then counts downward and the programmable input is linked with *S*, which is, say, in position 6. The counter counts downward until it reaches 0, which is after six input pulses. The terminal count output goes low, whereupon the non-inverting output of IC_{4a} also goes low, IC3 starts counting upward and is programmed with data *S*+ 5 (here, 11), so that the terminal count output becomes high again. When the counter reaches position 15, the terminal count output goes low again, pin 1 of IC_{4a} becomes high, and the whole process starts repeating itself. In short: in position 6 of the thumbwheel switch, the non-inverting output of IC_{4a} (pin 1) is high for six and low for four of every ten input pulses.



[994073]

power supply regulator with sense lines

049



K.S.M. Walraven

There are applications in which it is important for the supply voltage to be largely independent of the level of the output current, which is, of course, particularly so in the case of variable loads.

When the load is linked to the power supply by relatively short wires, a good variable power supply maintains the output voltage at a virtually constant level. Unfortunately, in practice, these wires can be fairly long, and since they have resistance, there is a voltage drop across them. This interferes with good regulation; the only way of avoiding this problem is to link the control part of the power supply to the load via separate sense lines.

Unfortunately, this cannot be done readily in every power supply without some tedious work, but as the diagram shows, in the case of the L200 it presents no problems.

In the diagram, A and D are the usual output terminals, while B and C are the sense input terminals. The output voltage, U_O, is

$$U_O = 2.77(1 + R_P/R_1),$$

where U_O is in volts and R_P is the effective resistance of P_1. Resistor R_2 in series with terminal A enables current limiting. The peak level of the output current, I_O, in amperes is

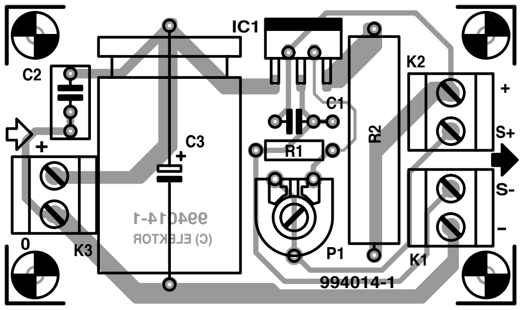
$$I_O = 0.45/R_2$$

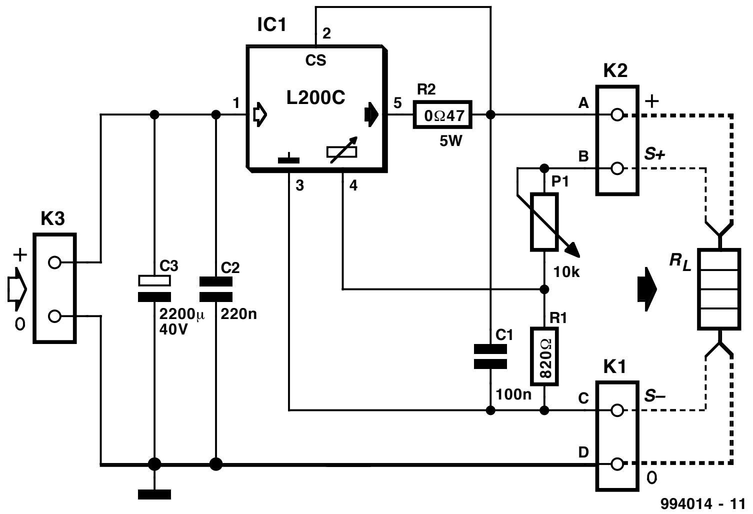
The maximum input voltage to the regulator is 40 V, and the peak output current is 2 A.

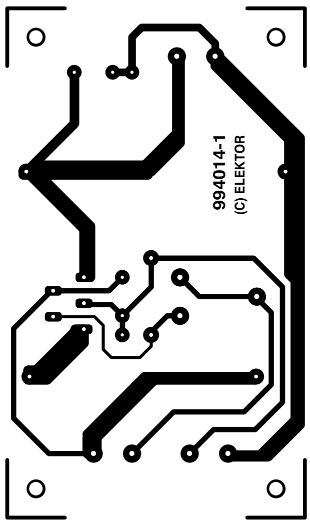
The regulator has on-board thermal protection, but this does not mean, of course, that it should not be mounted on a suitable heat sink when the dissipation is high.

The regulator is best built on the printed-circuit board shown, which is available via our Readers' Services – see toward the end of this issue.

[994014]







Parts list

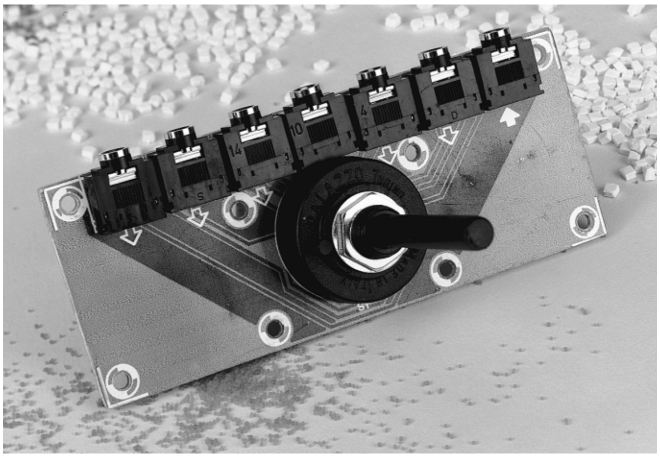
Resistors:
R_1 = 820 Ω
R_2 = 0.47 Ω, 5 W
P_1 = 10 kΩ, preset

Capacitors:
C_1 = 0.1 μF
C_2 = 0.22 μF
C_3 = 2200 μF, 40 V

Integrated circuits:
IC_1 = L200 (ST Microelectronics)

Miscellaneous:
K_1–K_3 = terminal block for board mounting, pitch 5 mm
Heat sink for IC_1
PCB Order no. 994014 (see Readers' Services toward the end of this issue)

line switch for PC sound card 050



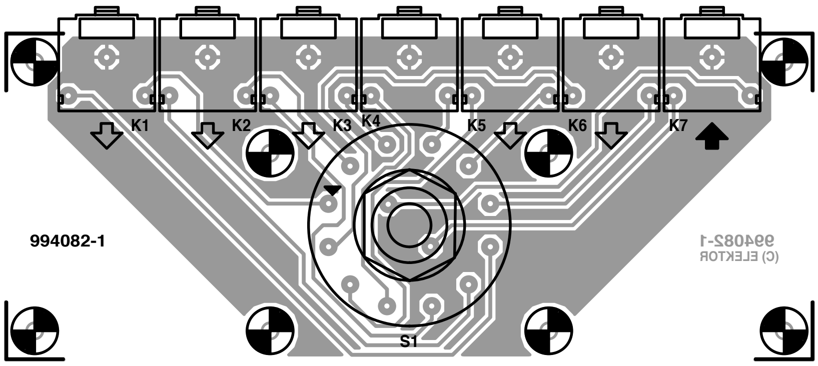
Design: T. Giesberts

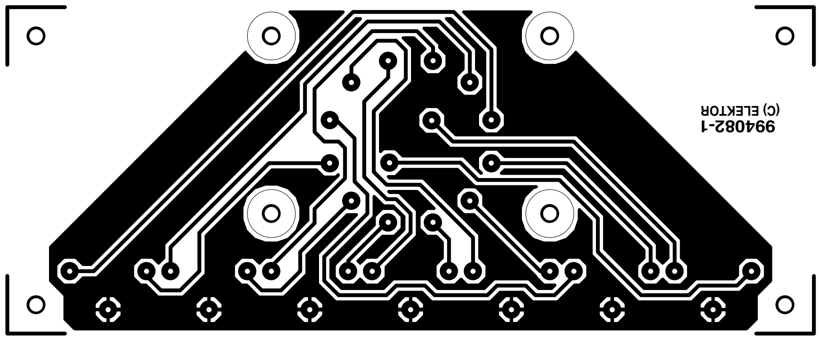
With the equipment that is found in the domestic or office environment, the distinction between the various disciplines is becoming increasingly blurred. The stereo, television set and video recorder have long since been merged into a single audiovisual installation, and there are signs of the same sort of process with the computer. Formerly, this consisted of just a main enclosure, a monitor and a keyboard, but nowadays it is being surrounded by a steadily increasing number of peripheral devices, and it is in a manner of speaking growing in the direction of the audiovisual installation. The same effect can be seen in the application realm. In addition to the classical applications, the computer is being used more and more for digital audio.

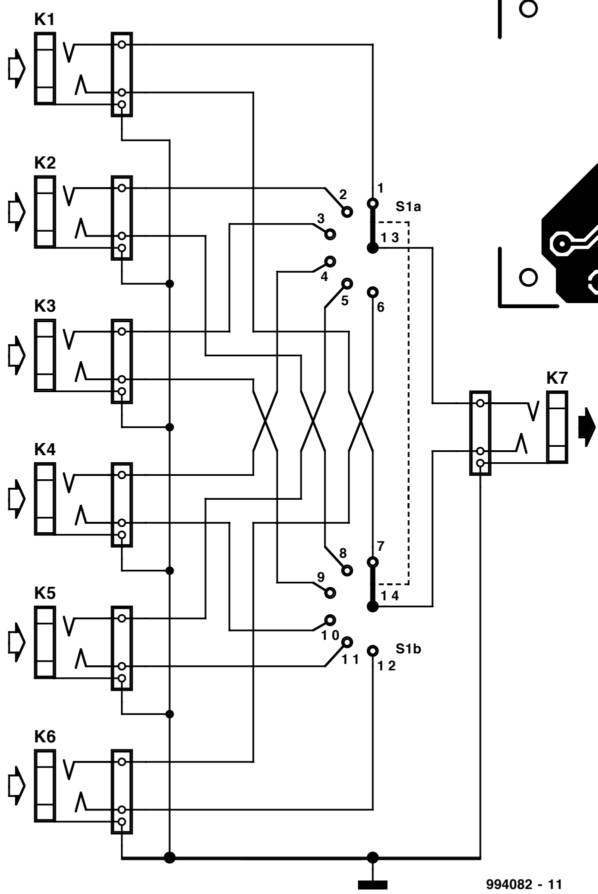
Anyone who for example spends a lot of time with *sampling* and making his or her own CDs, soon finds that the single input connector of the sound card is insufficient to deal with a large number of audio sources. A cassette deck, MiniDisk player, phonograph, microphone — in principle, all of these can be connected, although the phonograph and the microphone naturally require special preamplifiers.

If you want to avoid the inconvenience of disconnecting and reconnecting cables, the only solution is to use a line switch box. Such a box is not at all complicated in the electronic sense, as can be seen from the schematic diagram. A handful of 3.5-mm jacks and a six-position, two-pole rotary switch are all that you need. The practical aspects, as usual, are rather more onerous. For this reason, we have developed a tidy printed circuit board for the line switch box, which eliminates hand wiring — which will no doubt be appreciated by the constructor! It should not be difficult to find a suitable enclosure for the line switch. You should preferably use a metal enclosure and connect it to the circuit earth.

(994082-1)





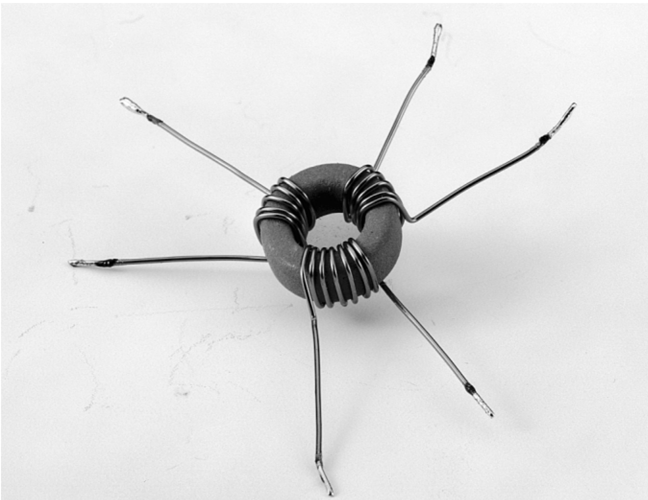


Components List

K1-K7 = 3.5 mm stereo-jack PCB mount (e.g. Conrad no. 73 28 93-55)

S1 = rotary switch, 6 positions/2 poles, PCB mount

passive splitter for S/PDIF 051



T. Giesberts

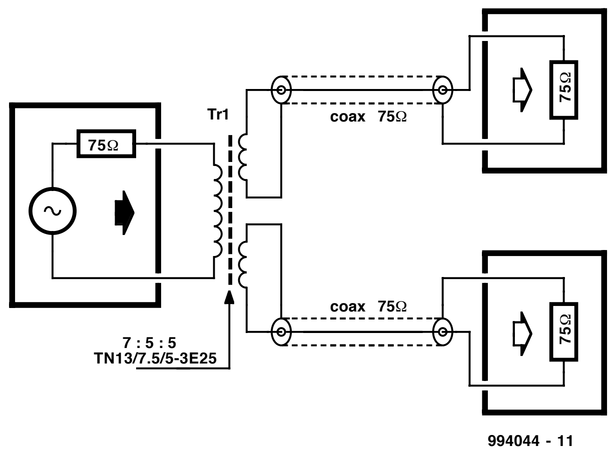
The circuit in the diagram enables the digital audio output of, say, a compact-disc (CD) player to be linked to two different appliances simultaneously. It is, of course, considerably less expensive than the proprietary active splitters on the market.

The circuit is in effect a small transformer that can be wound easily on a Philips Type TN13/7.5/5-3E25 toroidal core. The wire should be 0.5 mm dia. enamelled copper wire. The primary winding is seven turns and there are two secondary windings, each of five turns. The bandwidth of the transformer is 40 kHz to 16 MHz. When both outputs are loaded, there is a voltage of 0.33 V_{p-p} at each output. When one of the outputs is open-circuited, the voltage at the other output rises to 0.43 V_{p-p}, which is caused by the slightly higher primary impedance and the slightly smaller load on the signal source.

A drawback of the splitter is that the output voltage is 34% below the internationally specified level. However, most S/PDIF (Sony/Philips Digital Interface Format) inputs can cope with this perfectly well.

Place the transformer directly at the output of the signal source. The reason for this is that the input and output impedances of the transformer are not exactly 75 Ω. With the transformer directly at the source and provided the coaxial cable at the computer end is terminated correctly into 75 Ω, all will be well.

[994044]

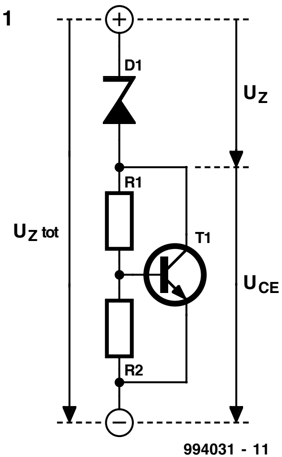


temperature-compensated zener diode

052

G. Kleine

1



Only zener diodes rated at 6 V have a negligible temperature coefficient (TC). At lower ratings, the coefficient becomes negative, and at higher ratings, positive. At a rating of 30 V, the coefficient is 0.01% K^{-1}, and remains constant at higher ratings.

The present transistor circuit enables a positive TC to be compensated by making use of the negative TC (–2.2 mV K^{-1}) of the base-emitter junction

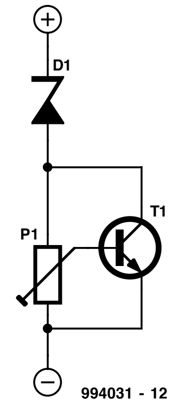
For instance, an 18 V zener diode has a TC of 16 mV K^{-1}, which is ×7.3 as large as the TC of the base-emitter junction in T_1. This gives a guide to the ratio of the resistors in potential divider R_1-R_2: R_1 must be ×6.3 as large as R_2. If, therefore, R_2 is chosen as 1 kΩ, R_1 needs to be 6.3 kΩ. Therefore, to obtain an overall zener voltage of 18 V, a zener diode rated at 15 V is needed in the D_1 position.

If the zener voltage itself is not too critical, but it must be unaffected by temperature changes, variable compensation may be obtained as shown in Figure 2 The potentiometer should preferably be a 10-turn type.

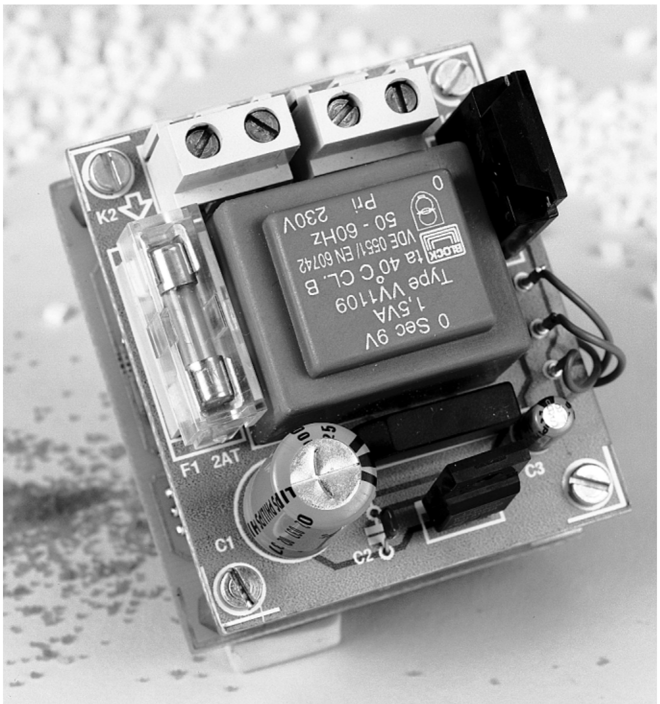
The transistor in both cases may be general purpose n-p-n type such as the BC238.

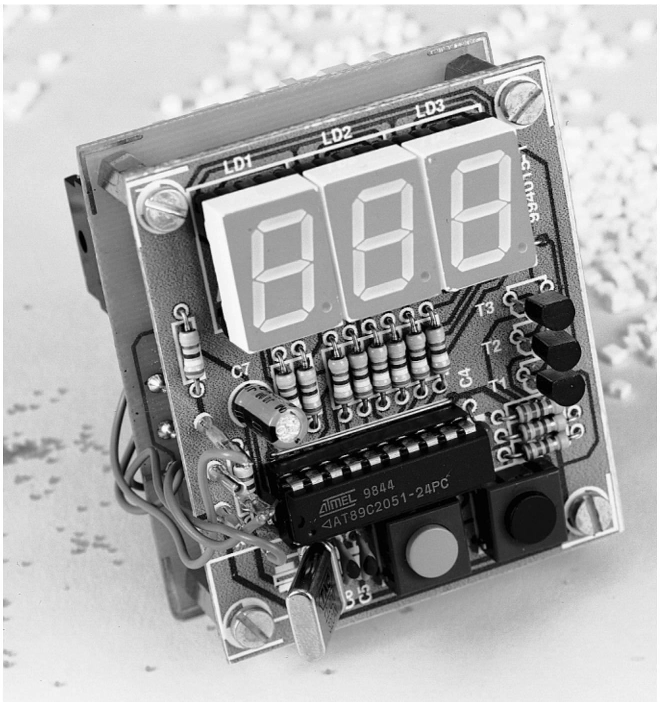
[994031]

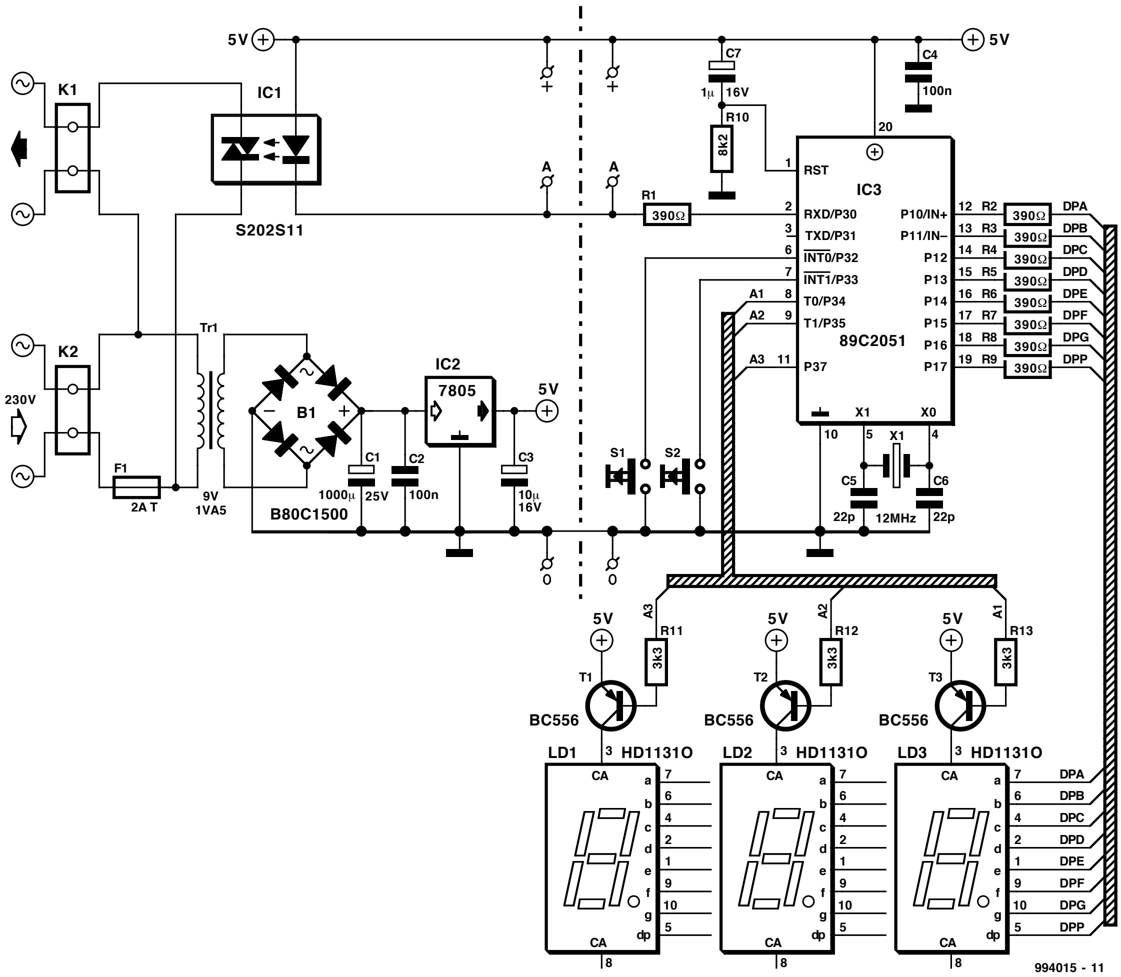
2

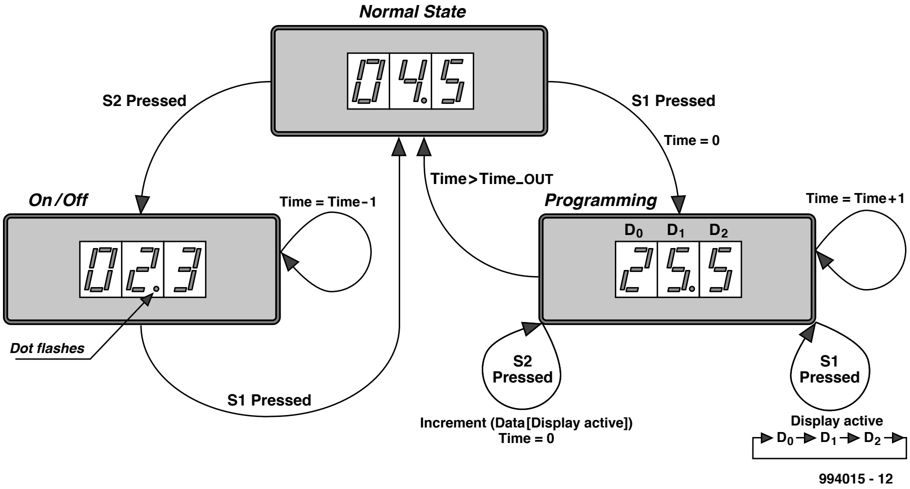


universal countdown timer 053









Design: Prof. A. Roldán Aranda

This universal countdown timer is good example of what can be achieved in terms of bare-bones hardware when using a powerful microcontroller like the AT89C2051 from Atmel. This 20-pin microcontroller has a 2-kBytes Flash ROM which is compatible with the 8051 Intel architecture. Here, the author has loaded the AT89C2051 with a program that simply eliminates a lot of hardware. The microcontroller is available ready-programmed from the Publishers.

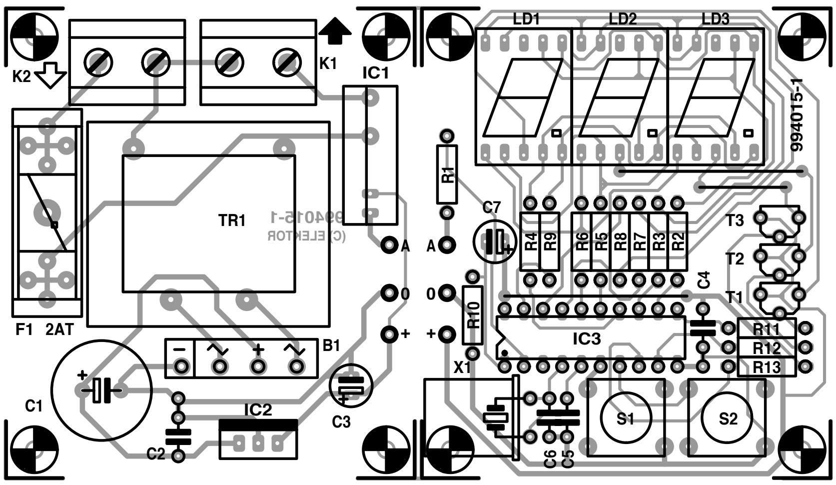
The user interface of the timer consists of two pushbuttons and three multiplexed 7-segment LED displays. As you can see from the circuit diagram, a very small number of inexpensive external parts is required to make it all work. In order to ensure the necessary degree of electrical isolation, a solid-state relay (SSR) type S202S11 is used to control an external (mains-powered) load. This load is switched on when the timer starts, and is switched off again when the programmed time has elapsed. The maximum current that may be switched by the SSR is about 2 A.

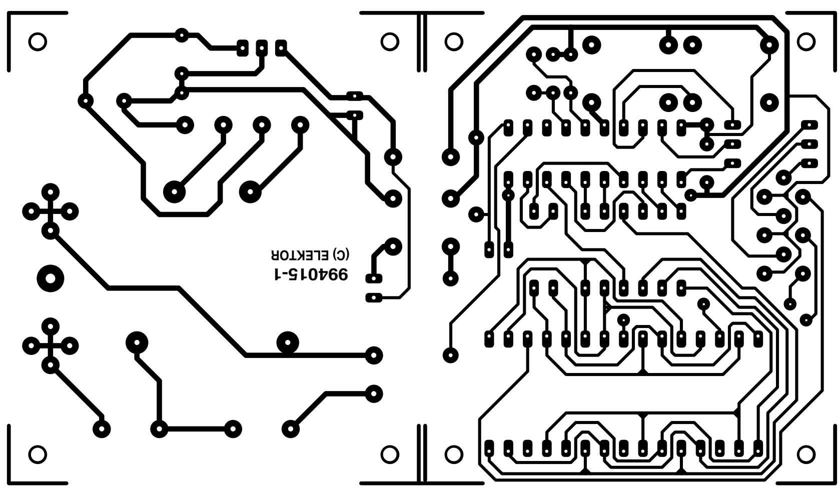
The timer has its own mains power supply consisting of the usual elements: mains transformer (Tr1), bridge rectifier (B1) and voltage regulator (IC2). This section of the circuit may be separated from the rest by cutting the printed circuit board in two (see component overlay). Due attention should be given to electrical safety when connecting the load and all other mains wiring.

Pressing switch S1 selects the desired digit, next its value is incremented by pressing S2. The time format is [mm.s], where the seconds digit indicates tens of seconds. So, the maximum time you can set is 99.5 minutes = 99 minutes and 50 seconds. The resolution of the timer is 10 seconds, and the accuracy is derived from quartz crystal X1.

Once all digits are programmed, you have to wait until the display stops flashing (time-out for entry). Next, pressing S2 causes the load to be switched on, and the countdown operation to start. The programming of the timer is illustrated in the **state diagram**.

(994015-1)





COMPONENTS LIST

Resistors:
R1-R9 = 390Ω
R10 = 8kΩ2
R11,R12,R13 = 3kΩ3

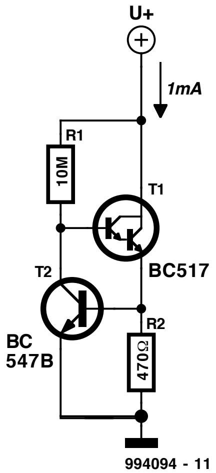
Capacitors:
C1 = 1000µF 25V radial
C2,C4 = 100nF ceramic
C3 = 10µF 16V radial
C5,C6, = 22pF ceramic
C7 = 1µF 16V radial

Semiconductors:
B1 = B80C1500 (rectangular model)
T1,T2,T3 = BC556
IC1 = S202S11 (Sharp; distributor: Eurodis)
IC2 = 7805
IC3 = AT89C2051 (programmed, Publishers order code **996511-**1)

Miscellaneous:
Tr1 = mains transformer, 9V 1.5VA, Block type VV1109
S1,S2 = pushbutton, PCB mount, MEC type 3CTL
X1 = quartz crystal, 12MHz
LD1,LD2,LD3 = HD1131O (Siemens)
K1,K2 = 2-wayPCB terminal block, pitch 7.5mm
F1 = fuse, 2A, slow, with PCB mount holder
PCB, order code **994015-1**

simple constant-current source

054



Design: T. Giesberts

The simplest version of a constant-current source, which we often use for that reason, consists of only a FET with the source and gate connected together. This utilizes the zero-gate-voltage drain current (I_{DSS}) of the FET. Sometimes a source resistor is added to allow the current level to be set more exactly.

A disadvantage of such a very simple current source is that the maximum drain-source voltage of most standard FETs is no more than 30 to 40 V. If we look at bipolar transistors instead, the range of available voltages is significantly larger. This is adequate justification for developing an alternative current source, using bipolar transistors, that is comparably simple.

In the example shown here, we use a BC547 and a small Darlington transistor (BC517). For convenience, we have chosen a current of 1 mA for calculating component values. Transistor T2 controls the current, and resistor R1 determines the base-emitter voltage of T2. R1 also provides the base current for T1, but the value of R1 can be made high since T1 is a high-gain Darlington transistor. The advantage of this is that the resulting error in the current setting is very small. If the value of R1 is 10 MΩ, the base-emitter voltage of T2 is less than 0.5 V, so that a current of around 1 mA flows through the current source when R2 is 470 Ω.

The current regulation that a constant-current source must provide comes from the fact that T2 controls the base current of T1. This means that if the current through R2 should increase, the base current of T1 would be reduced since the collector current of T2 would increase. If we assume that the amplification factor of T2 is at least 10,000, then the value of R1 must be at least 10 MΩ to produce a voltage drop of 1 V. The error current through R1 is thus negligible in comparison to the total current.

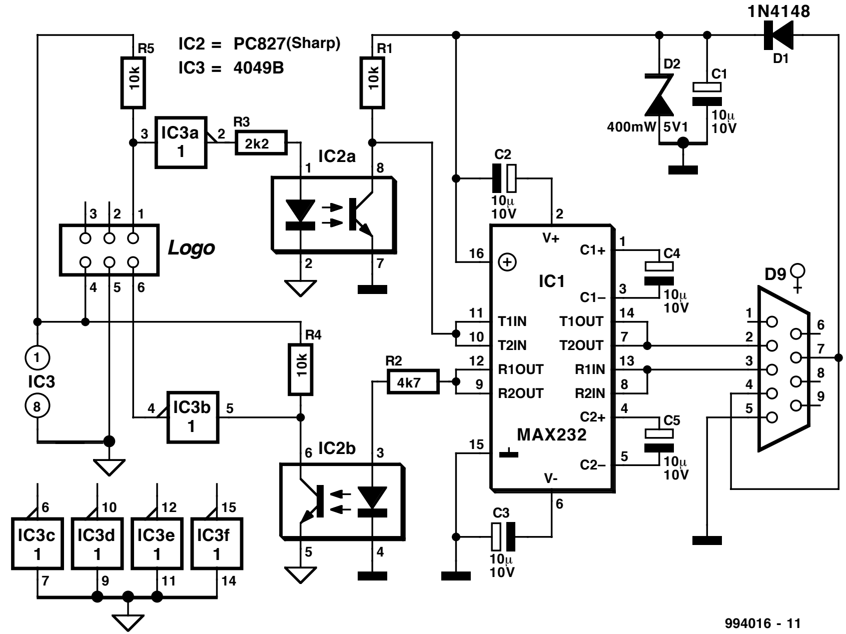
Since the current through R1 varies with the applied voltage, the base-emitter voltage of T2 will also vary. A disadvantage of this is that the internal resistance of the current source is reduced. In addition, the temperature dependence of T2 shows up fully in the output current. For a number of applications, this is however not that important. In fact, this characteristic could be used intentionally, for example to provide temperature compensation or for a particular measurement or control circuit.

In spite of its simplicity, this circuit in fact proved to be able to deliver a nice constant current. With the prototype, the measured current (at room temperature) was 0.91 mA with an input voltage of 5 V; this increased to 0.99 mA at 15 V, and a value of exactly 1.04 mA was measured with a 30 V input.

(994094-1)

LOGO! interface

055



994016 - 11

Design: W. Kriegmaier

A special adapter cable is needed to connect a PLC of the Siemens LOGO! series to the serial interface of a PC. Of course, you can obtain such a cable ready-made (at a price!), but you can also make one yourself inexpensively.

The interface circuit consists of a galvanic isolator and a level converter. The galvanic isolation is provided here by a dual optocoupler (Sharp PC827), although two single PC817 optocouplers could be used instead, or other types as long as their current transfer ratio (CTR) is at least 50% at a forward current I_F of 5mA. Since the two optocouplers are built as inverters, a pair of inverter gates must be used to restore the signals — IC3a (to the PC) and IC3b (from the PC). R3 acts as a current-limiting resistor, and R4 is a pull-up resistor that holds the line securely high when the signal level is not definitely low.

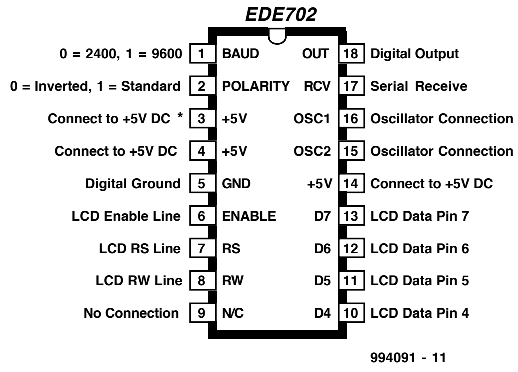
The well-known MAX232 IC is used to convert the signal levels between 0/+ 5 V (on the PLC side) and symmetric ±12 V (RS232) for the serial interface. Since only the RxD and TxD lines are needed, two drivers of the MAX232 can be connected in parallel in each direction.

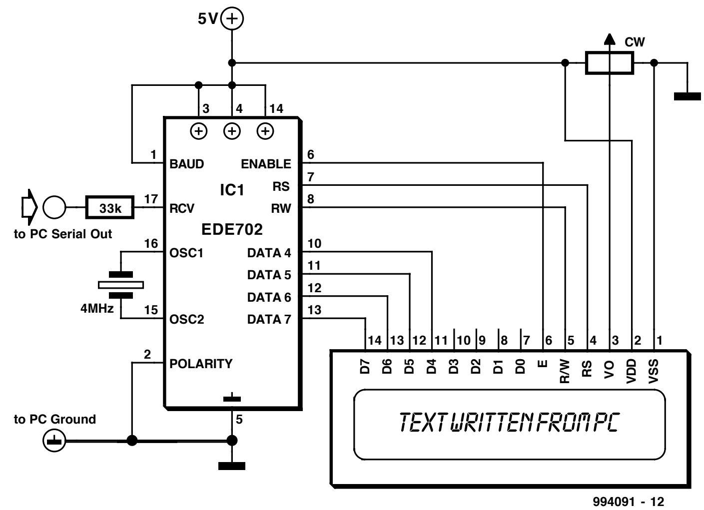
As a rule, the LOGO! interface does not need its own power supply. The level converter, the phototransistor of IC2a and the LED of IC2b are powered from the RS232 interface. Zener diode D2 limits the voltage to + 5 V for this purpose. The LOGO! PLC provides the operating voltage for the inverters, the LED of IC2a and the phototransistor of IC2b.

The interface circuit needs only around 10 mA from the RS232 interface. In certain rare cases this can overload the interface drivers of the PC, in which case an external + 5 V supply will be necessary.

(994016-1)

one-chip LCD interface 056





Source: E-Lab Digital Engineering Inc.

The EDE702 Serial LCD Interface IC has been designed to provide a cost-effective LCD control solution for a wide variety of embedded designs. The chip, a firmware-programmed PIC16C54A, allows nearly any text-based LCD module to be controlled via a simple one-wire data link, freeing an additional 6 to 10 I/O lines on your microcontroller or microprocessor system.

Besides full LCD control, the EDE702 also allows the creation of custom characters. Another useful feature is the serial-controlled digital output pin for lighting an indicator LED, driving a sounder, etc.

With a 2400 or 9600 baud rate and selectable serial data polarity, the EDE702 can easily communicate with any device capable of sending asynchronous serial data (including the BASIC Stamp!). Connection to a PC's serial port (RS232) requires only one 33-kΩ resistor.

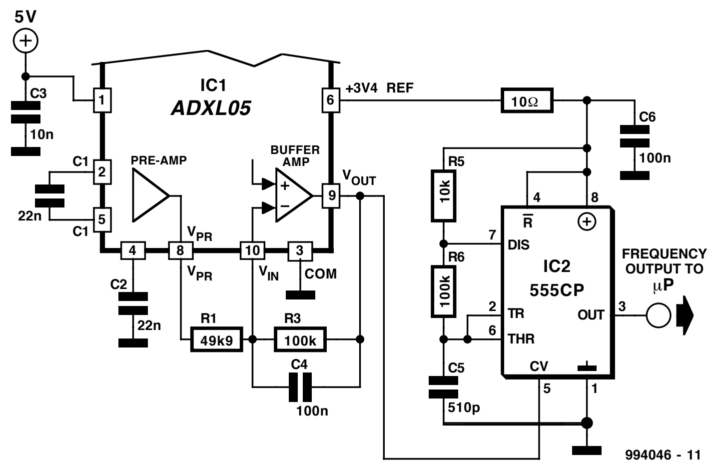
The application diagram shows how the EDE702 may be employed as the 'glue' between a PC and an LCD (based on the HD44780 controller). A 4-MHz resonator is used to clock the EDE702. If an external (TTL) oscillator is used, its output should be connected to only OSC1 (pin 16), while OSC2 (pin 15) is left unconnected. The LCD contrast is set in the usual way with a 10-20 kΩ preset. The schematic may be easily tested with the aid of a small QBASIC program as shown in the listing. More interesting E-Lab products and datasheets in pdf format may be found on their website at *http://www.elabinc.com*. E-Lab's UK distributor is Dannell Electronics, *http://www.dannell.co.uk*.

(994091-1)

```
REM Open communication channel to COM1 at 9600 Baud
OPEN "com1:9600,n,8,1,cd0,cs0,ds0,op0,rs" FOR OUTPUT AS #1

REM Clear Display
GOSUB 999
OUT &H3F8, &HFE
GOSUB 999
OUT &H3F8, &H1

REM Pause for LCD screen clear command to complete on LCD
module
FOR delay=1 to 5000: NEXT delay
REM Write first row of text to LCD screen
GOSUB 999
PRINT #1, "EDE702 Test Screen";

REM Jump to second row on 2 line LCD
GOSUB 999
OUT &H3F8, &HFE
GOSUB 999
OUT &H3F8, &HC0

REM Write second row of text to LCD screen
GOSUB 999
PRINT #1, "Time is: "; TIME$;
END

REM Hold until Transmit Buffer is empty
999 IF (INP(&H3FD) AND &H40) = 0 THEN GOTO 999
RETURN
```

accelerometer tilt sensor

057



An Analog Devices application

The circuit in the diagram shows how a Type ADXL05 accelerometer can be connected to a low-cost CMOS 555 to provide a frequency output. The component values indicated apply for a ± 1 ***g*** tilt application.

The nominal 200 mV g^{-1} output of the accelerometer appears at pin 8 and is amplified ×2 to a level of 400 mV g^{-1} by the on-board buffer amplifier. The 0 ***g*** bias level at pin 9 is about 1.8 V. Capacitor C_4 and resistor R_3 form a 16 Hz low-pass filter to lower noise and improve the measurement resolution.

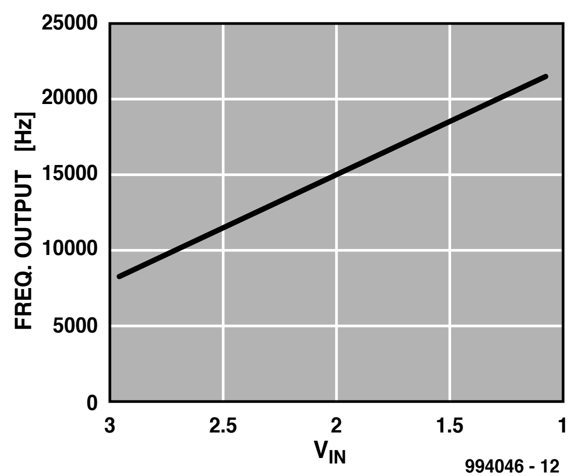
The 555 operates as a voltage-controlled oscillator where R_5, R_6 and C_5 set the nominal operating frequency. The values of R_5 and R_6 give a duty cycle of about 50% when a + 1.8 V (0 ***g***) input signal is applied to pin 5 of the 555. To prevent any change in frequency owing to supply variations, the 555 operates from the accelerometer's + 3.4 V reference rather than directly off the + 5 V supply line.

The output frequency of the circuit is determined by the charging and discharge times set by R_5, R_6, and C_5.

With the circuit and component values shown in the diagram, the output scale factor at pin 9 of the accelerometer will be ± 400 mV g^{-1}, so the voltage output will be ± 1.8 V ± 0.4 V. The output scale factor at pin 3 of the 555 will be about 16,500 Hz ± 2.600 Hz g^{-1}. The characteristic shown is the circuit's output frequency vs the voltage occurring at pin 5 of the 555.

Frequency stability of the circuit is good. With a 15.5 kHz 0 ***g*** frequency, the measured 0 ***g*** frequency drift over the range 0–70 °C temperature range was 5 Hz °C^{-1}, which is 0.03% °C^{-1}. The change in frequency vs supply voltage is less than 10 Hz with a supply voltage of 5–9 V.

[994046]

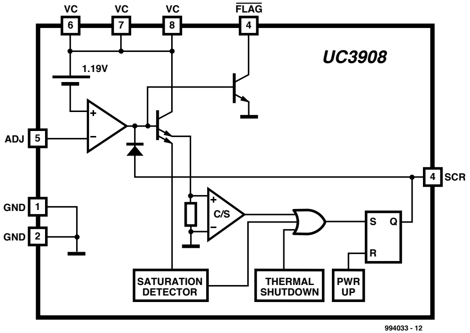


overvoltage protection 058

G. Kleine

Electronic circuits must never be operated with an excessive supply voltage. Such a situation may be prevented with the protection circuit shown in the diagram. If the current through the IC becomes excessive, or the IC overheats, an external silicon-controlled rectifier (thyristor), Th_1, is triggered, whereupon the supply voltage is short-circuited. This causes the current limiting in the power supply to be enabled or the relevant fuse in the supply to blow. Whatever, the circuit being supplied is protected.

In the diagram, the overvoltage protection comes into action when the supply voltage exceeds 5 V, but this may be set anywhere



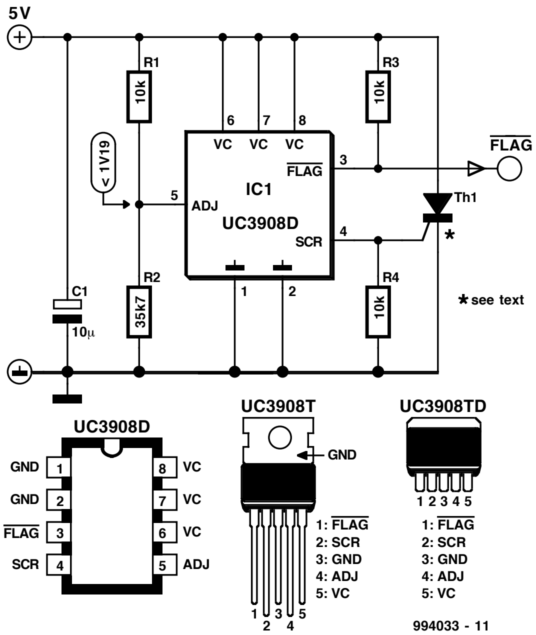
between 3.3 V and 9 V. Potential divider R_1-R_2 reduces the supply voltage to 1.19 V (nominal) at the ADJ(ust) pin of IC_1. As long as the level at this pin is ≤ 1.14 V, IC_1 remains in the standby mode and draws a current of about 70 μA.

When the potential at pin 5 rises above 1.19 V (maximum 1.24 V), IC_1 draws a current of up to 17 A so as to pull down the supply voltage – the $\overline{\text{flag}}$ signal is then actuated. If in this situation the peak current of 17 A is exceeded, or the body temperature of the IC rises above 165 °C, or when the internal shunt transistor goes into saturation, the external thyristor is triggered via pin 4 (SCR). This protects the IC itself and ensures that the overvoltage is negated. The rating of the thyristor must, of course, be in accordance with that of the power supply. In this situation, IC_1 shorts out its internal shunt transistor to minimize the internal dissipation.

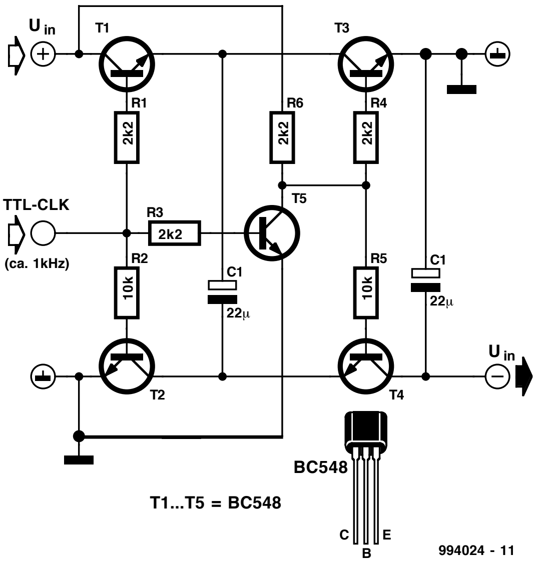
The UCC3908 is available in three different enclosures. For situations in which large supply currents flow for long periods, the TO-220 version is recommended (if necessary with heat sink). When the load current is not large, the SO-8 version may be used. In that situation, it may even be possible to omit the thyristor, but the anticipated maximum temperature must then be calculated very carefully.

Further information from: http://www.unitrode.com

[994033]



discrete voltage inverter



G. Kleine

The circuit in the diagram enables a negative voltage to be derived without the use of integrated circuits. Instead, it uses five n-p-n transistors that are driven by a 1 kHz (approx) TTL clock.

When the clock input is high, transistors T_1 and T_2 link capacitor C_1 to the supply voltage, U_{IN}, which typically is 5 V. During this process, transistor T_5 conducts so that T_3 and T_4 are off.

When the clock input is low, T_5 is cut off, whereupon transistors T_3 and T_4 are switched on via pull-up resistor R_6 and either R_4 or R_5. This results in the charge on C_1 being shared between this capacitor and C_2 Since the + ve terminal of C_2 is at ground potential, its –ve terminal must become negative w.r.t. earth.

The high level at the clock input must be of the same order as the positive input voltage, U_{IN}, otherwise T_1 cannot be switched on.

The clock frequency should be around 1 kHz to ensure a duty cycle ratio of 1:1. Altering the ratio results in a different level of negative output voltage, but this is always smaller than that with a ratio of 1:1.

[994024]

oven-controlled temperature stability

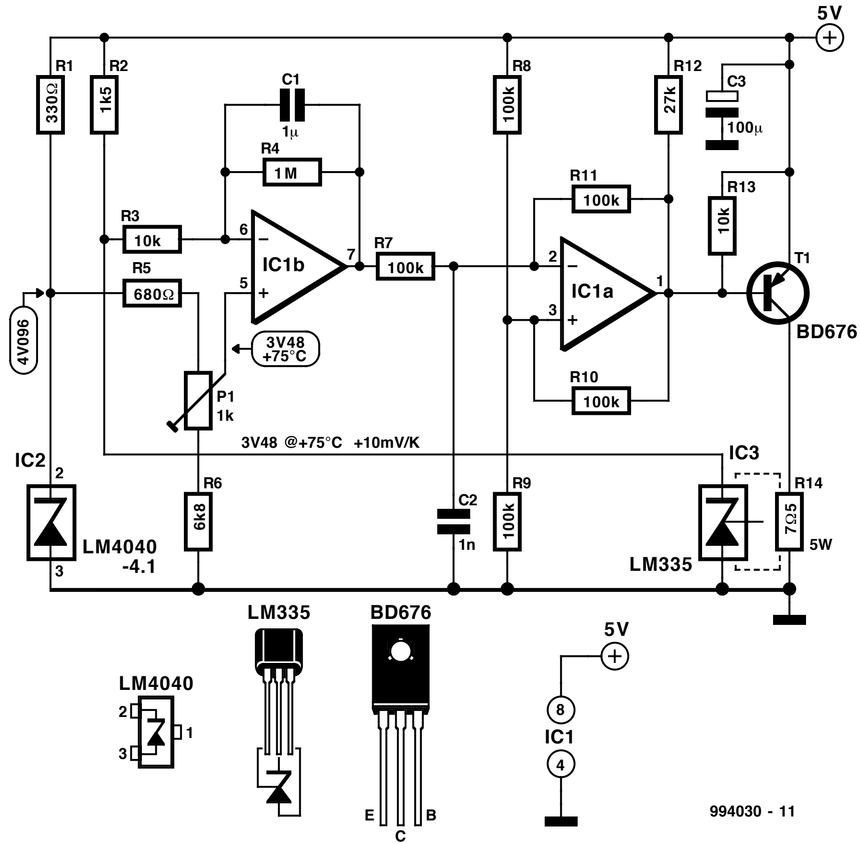
060

G. Kleine

Accurate measurements that are not affected by ambient temperature may be taken when the part or circuit being tested is placed in an oven whose inside temperature is held constant after a short warming-up period. This works very well, indeed, when the temperature inside the oven is held higher than the maximum ambient temperature. This is because the inside of the oven may be heated but cannot be cooled. This type of control is frequently used to stabilize a crystal oscillator or a surface acoustic wave (SAW) filter.

The circuit consists of a heating element, R_{14}, which is thermally coupled to temperature sensor IC_3. The output of the sensor at 75 °C is + 3.48 V, which rises linearly at a rate of 10 mV °C^{-1}.

Integrated circuit IC_1 comprises an operational amplifier (at pins 5, 6 and 7) and a comparator (at pins 1, 2 and 3). The op amp is arranged as a ×100 amplifier and delivers an error voltage that depends on the difference between the actual temperature and that set with P_1. The preset can set the wanted temperature between + 55 °C and + 105 °C. The stable voltage across potential divider R_5-P_1-R_6 is 4.096 V, which is provided by reference voltage source IC_2.

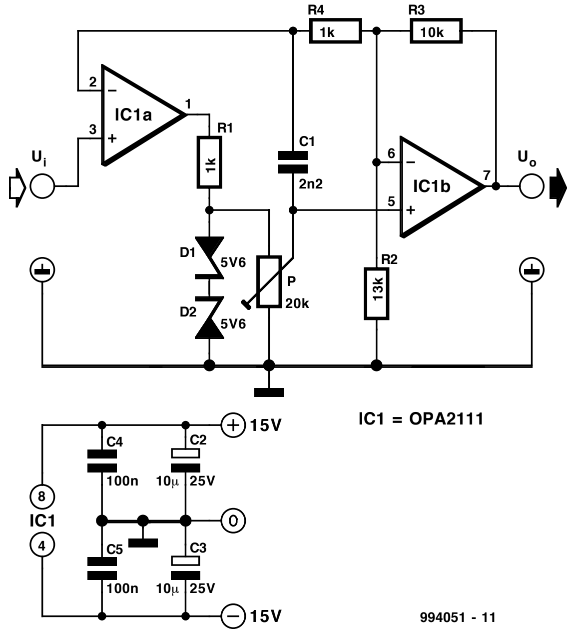


The error voltage across R_7 is applied to the oscillator which is based on the comparator in IC_1. It alters the duty factor of the oscillator output in such a way that when the temperature drops, transistor T_1, and thus heating element R_{14}, remains on a little longer than when the temperature is stable.

[994030]

feedback circuit clamps precisely

061



A Burr-Brown application

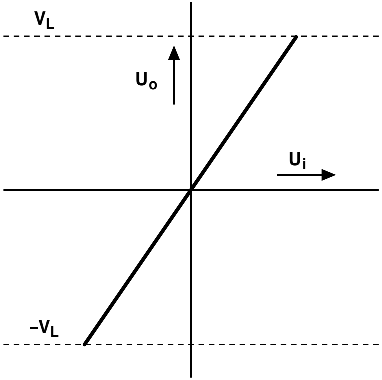
A linear circuit consisting of an input buffer, IC_{1a}, and output-scaling amplifier, IC_{1b}, two zener diodes, D_1 and D_2, and several other components can supply sharp, precise, bipolar clamp levels with continuous variable control, from 0 V to ± 11 V. A feedback loop enclosing the amplifiers and zener diodes generates the high clamping accuracy—see diagram.

Within the limit range of the clamp, $\pm V_L$, the zener diodes are off, and IC_{1b} feeds back its output to the inverting input of IC_{1a} via R_4. At the same time, IC_{1a} drives IC_{1b} via voltage divider R_V. The feedback forces the inverting input of op amp IC_{1a} to equal U_i at the non-inverting input terminal.

The circuit forces the inverting input of IC_{1b} also to follow U_i. There is no signal voltage drop across R_4, because no current can flow from it into the inverting input of IC_{1a}. Consequently, the non-inverting input of IC_{1b}, which defines the potentiometer output at feedback equilibrium, must also track U_i. In fixed-level limiting applications, a resistive divider may replace potentiometer R_V. Amplifier IC_{1a} then delivers an output

$$U_O = (1 + R_3/R_2)/U_i$$

when



$-V_L < U_O < V_L$

and

$$V_L = x[(1 + R_3/R_2)](V_Z + V_F)$$

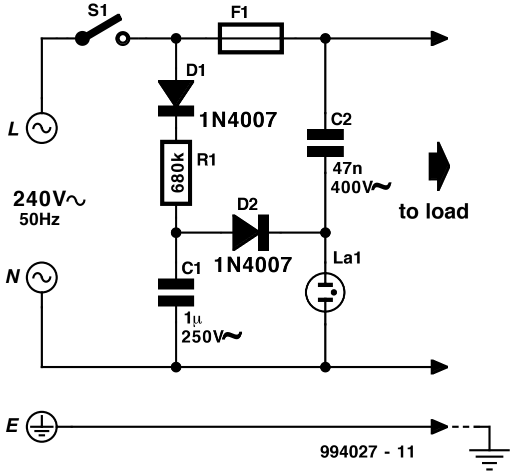
where x is the setting fraction of R_V and V_Z and V_F are the zener and forward voltages respectively. The overall circuit response, then, is simply that of a voltage amplifier when the output signal is within the limit boundaries.

Amplifier IC_{1a} generates small deviations from an ideal response because the gain of IC_{1b}, $(1+ R_3/R_2)$, magnifies any offset voltage and noise from IC_{1a}. Similarly, the loop gain mitigates the clamping error by sharpening its clamping response. The zener drive increases during the transition to the clamping state. The maximum clamping level depends on the zener voltage and the closed-loop gain of IC_{1b}. Zener diodes rated at 5.6 V provide a wide control range and good temperature stability. At higher zener voltages, the even wider control range is offset by increasing drift of the clamping level with temperature.

[994051]

mains/fuse failure indicator

062



G. Kleine

The indicator shows when the mains is present at its output by a continuous glow of a neon bulb, La_1, and when the fuse is blown by flashing of the neon bulb.

When the fuse is intact, capacitor C_2 acts as the series resistance for the neon bulb, so that this glows continuously. When the fuse has blow, the mains voltage across diode D_1 is applied as a pulsating direct voltage to network R_1-C_1. Capacitor C_1 charges slowly and when the voltage across it reaches 80–100 V, the neon bulb comes on. Capacitor C_1 is then discharged slowly via diode D_2 and the bulb. When the voltage across it has dropped sufficiently, the bulb goes out, whereupon C_1 slowly charges again. This process repeats itself, so that, provided the values of R_1 and C_1 are right, the bulb flashes visibly.

The potential across capacitor C_2 is a ramp with a peak value of 30 V (which is, of course, applied to the load).

Note that the neon bulb used for this purpose must not be a type that has a built-in series resistor.

[994027]

13 V/2 A PSU for handheld rigs

063

Design by N.S. Harisankar VU3NSH

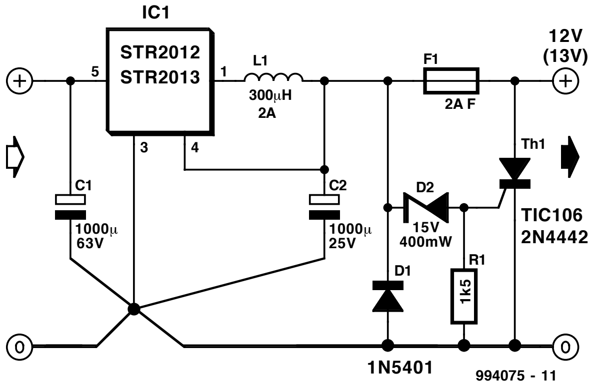
This compact 13-V/2-A power supply for ham radio rigs and other VHF/UHF portable PMRs is based on the STR2012/13 voltage regulator IC from Sanken Electric Co. Many power supplies for handheld amateur radio rigs are based on the LM317, LM350 or even the good old LM723. Unfortunately, these regulators are invariably associated with a fair number of external components, while we should also consider design factors like total power dissipation and input voltage range.

The STR is a hybrid power IC containing a switch-mode power supply. It supplies a fixed output voltage and accepts relatively high input voltages. Another advantage is its relatively high power dissipation rating. The 5-pin STR is available for 5.1 V, 12 V, 13 V, 15 V and 24 V at an output current rating of 2 A. Here, the STR2012 and STR2013 are suggested for output voltages of 12 V or 13 V respectively. The normal operating voltage of most handhelds being between 12.6 V and 13.8 V, the STR1303 will be the preferred device in most cases.

A high-speed crowbar circuit is added to the regulator output. Thyristor Th1 (a TIC106 or 2N4442) is triggered when the output voltage rises above the zener voltage of D2, that is, 15 volts (approximately). When this happens, the thyristor short-circuits the supply output, protecting the radio against overvoltage and blowing fuse F1. Diode D1 acts as a reverse polarity protection, also in combination with fuse F1.

To allow for its dissipated heat, the STR regulator should be mounted on a heatsink. Efficiency will be around 80%, with ripple rejection at a comfortable 45 dB. The raw input voltage to the regulator should be in the range 18 to 35 V.

The coil, L1, may be selected from the range produced by Newport. The type 1430430 is suggested. If difficult to obtain, then an ordinary triac suppressor type may be used instead. Note, however, that the inductance of these coils is usually just 100 μH, so you have to count the number of turns and add another 0.7 times that number to arrive at about 300 μH.



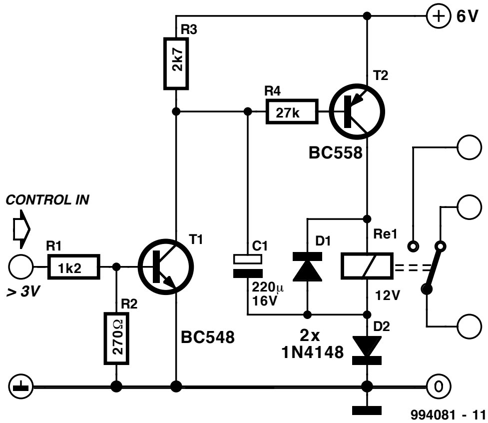
Finally, keep the wire between pin 3 of the STR and ground as short as possible, and connect at least the negative terminals of C1 and C3 to this point to give a ‘star’ type ground connection.

(9944075-1)

simple relay step-up circuits

064

A



Design by R. Graham

Have you ever needed to power a 12-volt relay in a circuit but only had 6 or 9 volts available? This simple circuit will solve that problem. It allows 12-volt relays to be operated from 6 or 9 volts, or 24-volt relays from 12 volts. While most normal relays require the manufacturer-specified coil voltage to reliably pull the contacts together, once the contacts are together you only need about half that rated voltage to hold them in. This circuit works by using that principle to provide a short burst of twice the supply voltage to move the contacts and then applies the available 6 or 9 volts to the relay to lock the contacts in place.

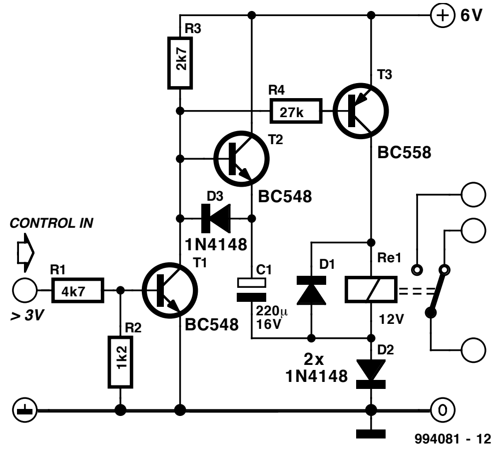
With reference to **Figure A**., when the main supply is applied to the circuit the 220-μF capacitor, C1, charges quickly to + 6 volts through resistor R3. The circuit is now awaiting voltage on the control input. When a control voltage (can be as little as 3 volts) is applied to the control input, transistor T1 switches on. The other transistor, a BC558, is also switched on. This allows connection of the relay coil to the main supply rail while T1 shorts the positive terminal of the 220-μF capacitor to ground. Now the negative terminal of the capacitor is at a potential of –6 volts. This is applied to the other side of the relay coil. The relay coil potential is then briefly 12 volts — enough to actuate the contact(s). However, the coil voltage drops to the supply voltage fairly quickly. The period is determined by the R-C time constant of the relay coil resistance and the 220-μF capacitor.

While this circuit is simple and works well in many situations, it has a few weaknesses in its current form. The relay may remain energized for as long as one second after the control input has fallen. Also, if the control input goes high before the capacitor has fully recharged, it may not have enough energy to control the relay reliably. Also, the voltage drop across the diode limits the voltage to about 10.8 volts. The more complex version of the circuit shown in **Figure B** fixes these problems by using an extra transistor and diode. In this arrangement, the BC558 is now isolated from the recharge current of the capacitor. The new transistor provides fast charging for the capacitor. Charging is completed within the mechanical response time of the relay.

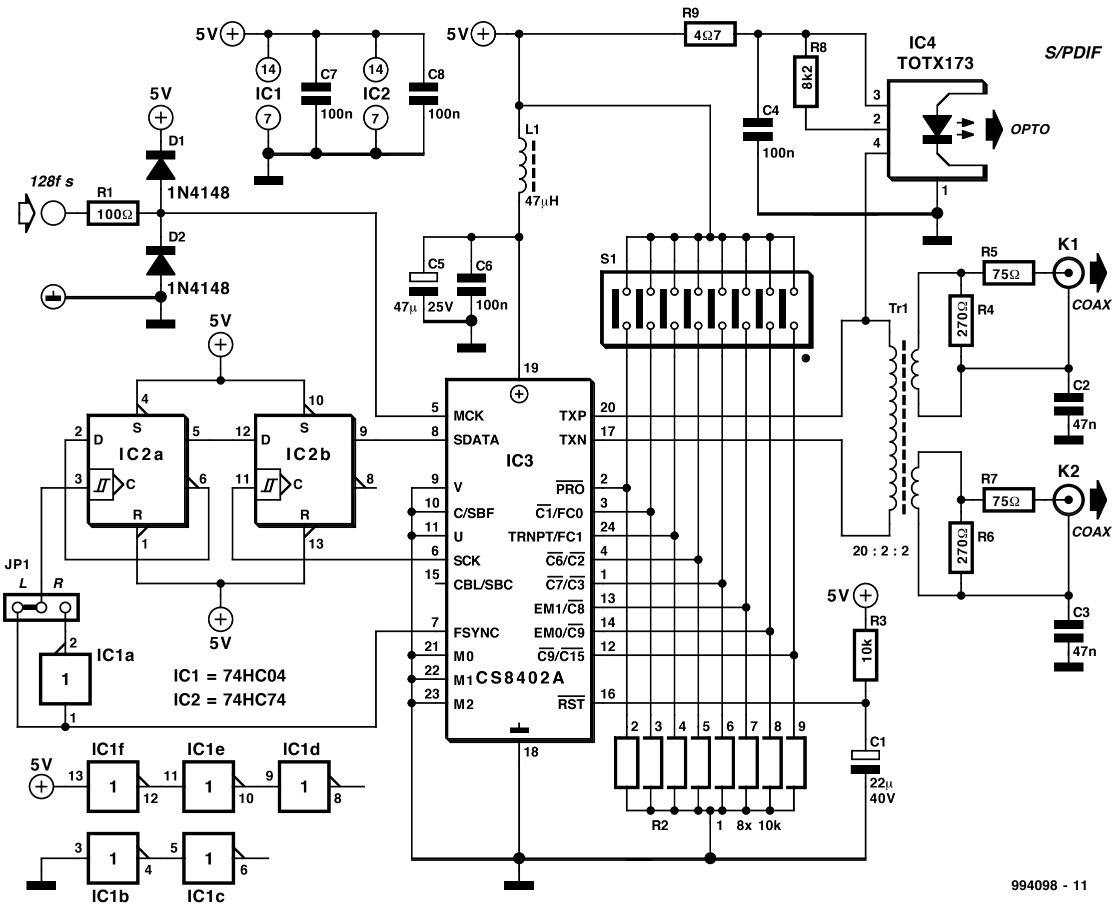
When using these circuits it should be noted that the contact pressure of the relay contacts may be al little lower than with the nominal coil voltage. It is therefore advisable to keep contact currents well below the maximum specified value.

(994081-1)

B



S/PDIF test generator 065



T. Giesberts

The generator is intended primarily for checking S/PDIF (Sony/Philips Digital Interface Format) receivers and any associated digital-to-analogue converters (DAC) and/or output filters. The external clock – standard TTL level – enables 128 sample frequencies to be generated. The clock may also be used for generating standard frequencies with the remaining inverters serving as crystal oscillators (provided a 74HCU04 is used).

The sender is a Type CS8402A digital audio interface transmitter from Crystal. In this short article it is not possible to list all settings that may be obtained with switch S_1: the reader is referred to the data sheet of the IC or to the 'sampling rate converter' published in the October 1996 issue of this magazine. The connections to the switch are exactly as described in that article.

There is an optical (IC_4) as well as a coaxial output (K_1, K_2). Toroidal transformer Tr_1 provides electrical isolation of the coaxial sockets and also serves to prevent earth loops. Capacitors C_2 and C_3 provide the earth connections for the sockets.

The transformer is wound on a TN13/7.5/5-3E25 core with a transformation ratio of 20:2:2 since TXP and TXN (on IC_3) are differential outputs. The primary voltage is 10 V_{pp} to give a signal across the 75 Ω coaxial outputs of 0.5 V_{pp}. After a reset, both outputs are low and are not short-circuited by Tr_1. A coarse audio signal is added to prevent, for instance, muting of the outputs.

Jumper JP_1 enables either the left-hand or right-hand signal to contain a rectangular signal at peak value and half the sampling frequency. This enables, for instance, the channel separation and the combination of digital and analogue signals to be checked. In most DACs, filter action commences at half the sampling frequency. At that instance, there is hardly any attenuation by the analogue filters, so that the level of the sinusoidal signal more or less coincides with that of a 0 dB signal. At this frequency, it is also clearly discernible whether de-emphasis correction is present ($S_{1–4}$ off: de-emphasis on) and, if so, whether this provides the requisite attenuation of 10 dB.

The CS8402A is used in mode 0 (low level at inputs M_0–M_2). This mode is really intended for interfacing with analogue-to-digital converters (ADC), but is used here since it enables the FSYNC of the L/R clock and the bit clock, SCK, to be derived internally from the MCK clock, and to be arranged as outputs. The data for half the sampling frequency are obtained by halving the L/R clock in IC_{2a}. Since the data must be the 2s complement, they are shifted by one clock period in IC_{2b}, so that, depending on the phase of the L/R clock, that is, inverter IC_{1a}, either the left-hand or the right-hand channel contains a peak-level signal. The other channel then toggles one LSB at identical frequency.

It should be noted that some DACs, particularly 1st generation 1-bit types, fail to operate correctly with 0 dB signals, which may cause difficulties with overdriven CDs (see 'Clipping and the CD' in the Readers' Letters column in the April 1999 issue of this magazine). This may be checked with the present generator. If the audio signal is not wanted, the SDATA input should be linked to earth and IC_1 and IC_2 omitted.

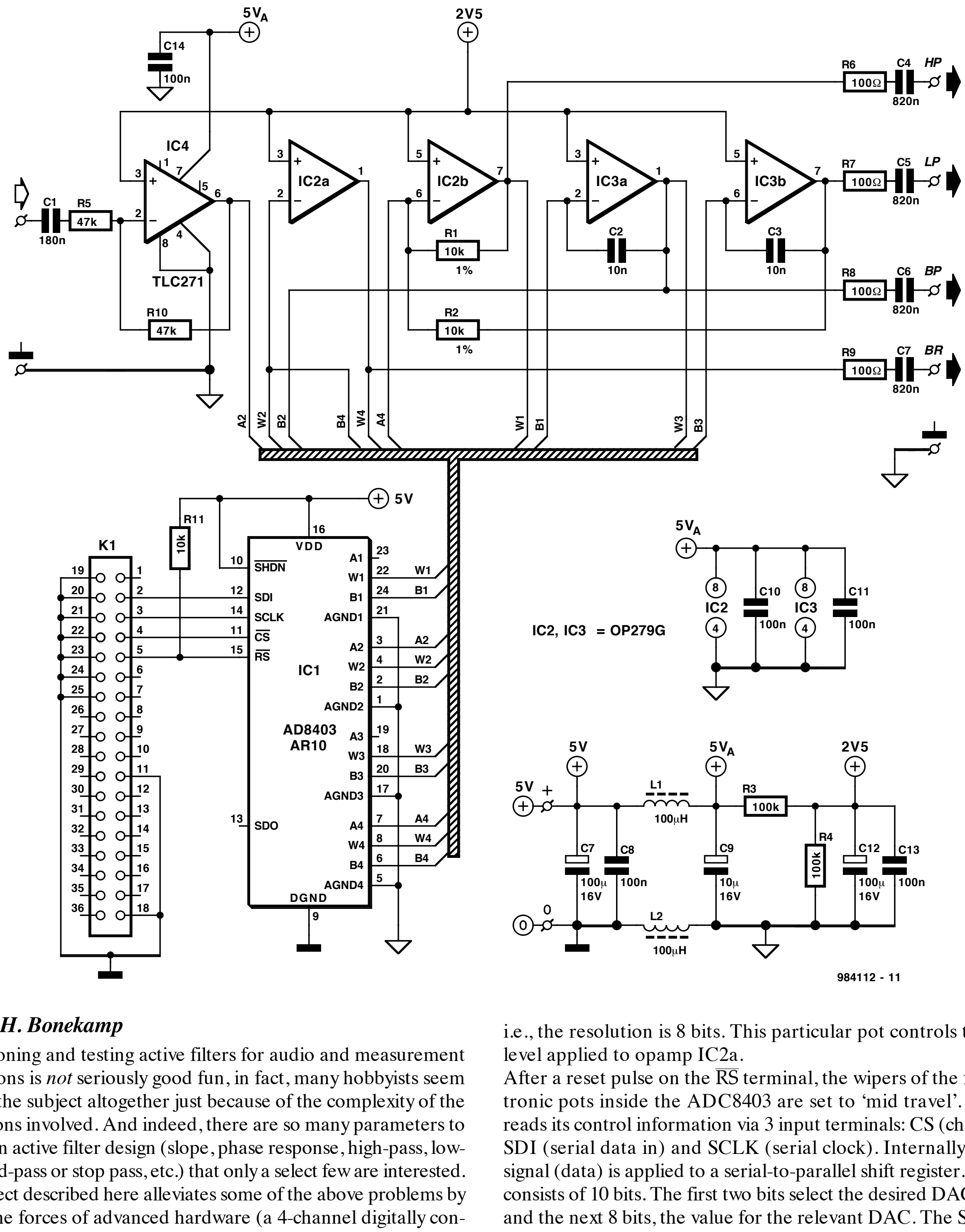
Resistor R_1 and diodes D_1, D_2 protect the MCK input against excessive or unbalanced clock signals.

The generator draws a current of about 30 mA.

[994098]

programmable state-variable active filter

066



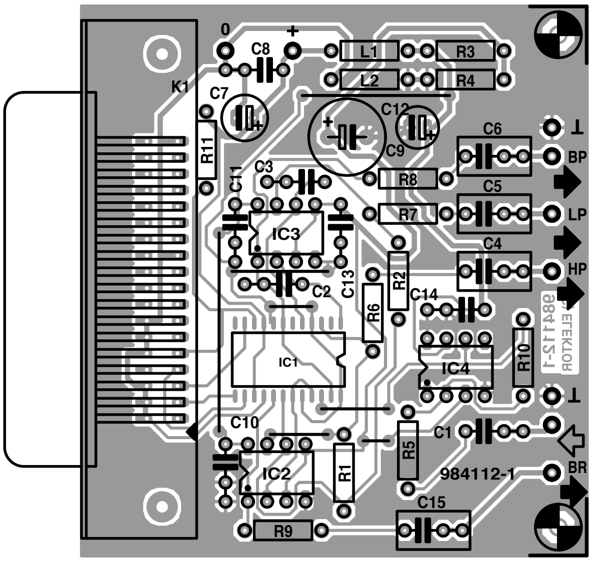
Design: H. Bonekamp

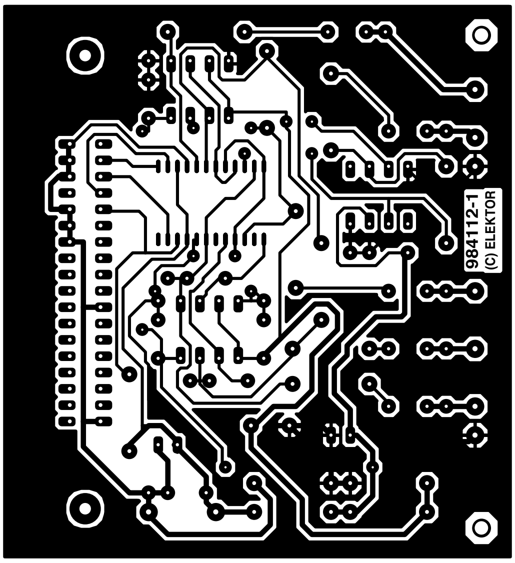
Dimensioning and testing active filters for audio and measurement applications is *not* seriously good fun, in fact, many hobbyists seem to avoid the subject altogether just because of the complexity of the calculations involved. And indeed, there are so many parameters to observe in active filter design (slope, phase response, high-pass, low-pass, band-pass or stop pass, etc.) that only a select few are interested. The project described here alleviates some of the above problems by joining the forces of advanced hardware (a 4-channel digitally controlled variable resistor chip) and some clever computer software (a program written in C). The upshot is that you, the user, define the filter you want, and the hardware/software combination does the rest. The hardware consists of a basic active filter comprising four opamps. The resistive elements in the filter (which determine the filter response) are electronically controlled potentiometers contained in IC1, a 4-channel 'TRIMDAC' type ADC8403. For example, one such potentiometer (with a value of 10 kΩ typ.) is available on pins A2, W2 and B2 of the ADC8403, where W2 is the wiper. By means of suitable control signals received from the PC's printer port, this pot can be programmed to take on 1 of 256 values, i.e., the resolution is 8 bits. This particular pot controls the signal level applied to opamp IC2a.

After a reset pulse on the $\overline{RS}$ terminal, the wipers of the four electronic pots inside the ADC8403 are set to 'mid travel'. The chip reads its control information via 3 input terminals: CS (chip select), SDI (serial data in) and SCLK (serial clock). Internally, the SDI signal (data) is applied to a serial-to-parallel shift register. The data consists of 10 bits. The first two bits select the desired DAC (1 of 4), and the next 8 bits, the value for the relevant DAC. The SDO (serial data out) pin allows two or more ADC8403's to be cascaded.

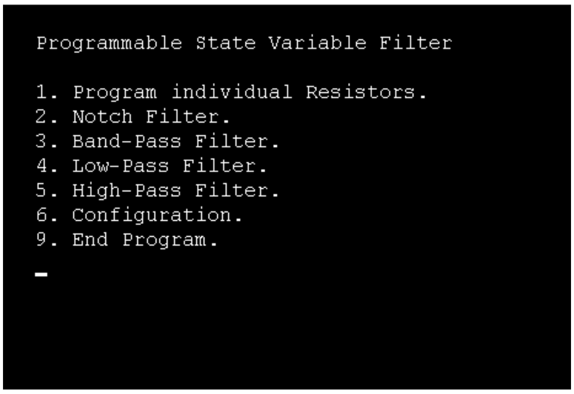
The filter has one input and four outputs: HP (high-pass), LP (low-pass), BP (band-pass) and BR (band-reject). The relation between the filter type and the associated frequency band is summarized in the Table. The highest and lowest frequencies may be lowered by a factor of 10 by replacing C2 and C3 with 100-nF polystyrene close-tolerance capacitors.

The circuit is powered by a regulated 5-volt supply. Note the use of two chokes (L1 and L2) and a fair number of decoupling capacitors to ensure a pristine supply voltage to the DACs and opamps. The program that arranges for the correct filter parameters (i.e.,





potentiometer values) to be set was written in the 'C' higher programming language. Its source code and executable file may be found on a diskette supplied through the Publishers' Readers Services. The screendump gives an impression of the available options.



The filter is built on a compact printed circuit board. Once fully populated, the board may be powered up and then connected direct to the PC's printer port using a standard parallel printer cable. The circuit draws about 10 mA.

Although the electronic potentiometers inside the ADC8403 are matched to 1%, their absolute value may deviate from the nominal 10 kΩ. The actual value has to be measured and entered into the control program. To do so, switch on the circuit and measure the resistance between pins 23 and 24 of IC1. Enter this value into the program — it will be stored in a configuration file. This calibration procedure is only required once. Finally, the control program is best used in 'real-DOS mode — we recommend against running it in a Windows 'DOS box'.

(984112-1)

Filter Type	Frequency Range (Hz)
Band-pass	2.0k – 20k
Band reject	2.0k – 20k
Low-pass:	
Critically damped	1.03k – 20.5k
Bessel	1.26k – 25.0k
Butterworth	1.61k – 31.8k
Chebychev 0.5dB	1.89k – 37.4k
Chebychev 1dB	2.00k – 39.6k
Chebychev 2dB	2.14k – 42.4k
Chebychev 3dB	2.23k – 44.2k
High-pass:	
Critically damped	2.50k – 49.5k
Bessel	2.04k – 40.5k
Butterworth	1.61k – 31.8k
Chebychev 0.5dB	1.37k – 27.1k
Chebychev 1dB	1.29k – 25.6k
Chebychev 2dB	1.21k – 23.9k
Chebychev 3dB	1.16k – 22.9k

COMPONENTS LIST

Resistors:
R1,R2 = 10kΩ 1%
R3,R4 = 100kΩ
R5,R10 = 47kΩ
R6-R9 = 100Ω
R11 = 10kΩ

Capacitors:
C1 = 180nF MKT (Siemens)
C2,C3 = 10nF 1% polystyrene
C4,C5,C6,C15 = 820nF MKT (Siemens)
C7,C12 = 100μF 16V radial
C8,C10,C11,C13,C14 = 100nF ceramic
C9 = 10μF 16V radial

Inductors:
L1,L2 = 100μH choke

Semiconductors:
IC1 = AD8403AR10 (Analog Devices)
IC2,IC3 = OP279G
IC4 = TLC271CP

Miscellaneous:
K1 = 36-way Centronics socket, PCB mount, angled pins
PCB, order code **984112-1**
Disk (source code and executable), order code **996018-1**