

ELEKTOR ELECTRONICS

THE ELECTRONICS & COMPUTER MAGAZINE

JUNE 2002

£3.20

www.elektor-electronics.co.uk

HIGH-SPEED CONTROLLER BOARD

33 MIPS from a DS89C420

**DASP-2002
Digital Audio
Signal Processor**

**USB 1-Wire
Interface**

**Portable
DMX Tester**

Tube Box

LED Torch

**Alternative
Image Sensors**



Alternative Image Sensors

redefining the pixel

By Reg Miles

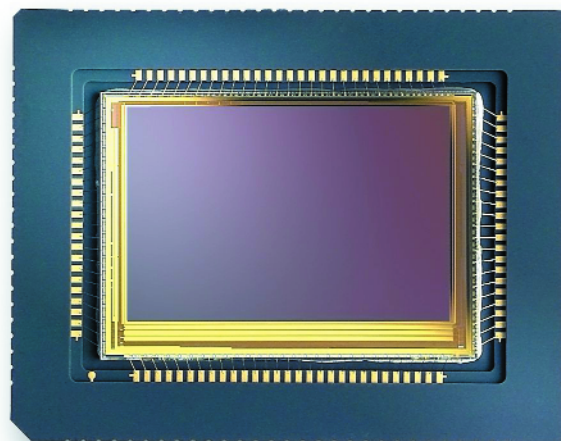
regmiles@tesco.net

Although the vast majority of image sensors in use are of the Charge Coupled Device (CCD) variety (particularly in consumer products), and those that are not are of the Complementary Metal Oxide Semiconductor (CMOS) type; other types are being used in a variety of applications or being developed. A number of these have interesting properties that would suit them to a wider market. And there are also variations on the CCD to adapt it to particular roles.

However, it is worth noting that they all share the same underlying principle of operation. The sensitive area is divided into pixels; where impinging photons can produce electron-hole pairs in the silicon. Either the holes or, more usually, the electrons are then gathered into a potential well while the others are drained into the substrate. The charge in the well is then moved out, amplified, processed and, with the charges from all the other pixels, forms the picture.

Linear sensor

One variation on the common area array sensor is the **linear sensor** — which, as the name implies, is a strip of photosensitive pixels. This type is used in professional digital cameras and scanners. It works by exposing a strip at a time (see **Figure 1**). In each position, the charge is built up (integrated) in the pixels, corresponding to the brightness of the light, the charges are then read out, and the sensor moves to the next position. In practice this is a virtually continuous motion. The advantage of it is that it can cover a relatively



large area with far fewer pixels than an area array; the obvious disadvantage is that it is restricted to static subjects. If it is a monochrome shot

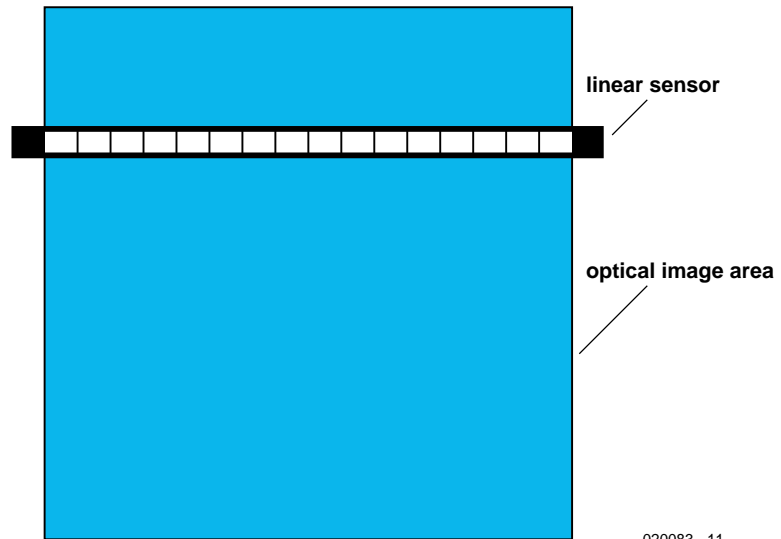
then only one pass of the sensor is required; if it is a colour shot then it requires three passes, through red, green and blue (RGB) filters in turn.

The alternative is to have a **tri-linear sensor** comprised of three strips of pixels filtered for RGB — thus requiring only one pass.

Linear sensors can provide very high resolution images because of the relatively large area covered. But the resolution of area sensors can also be increased by movement. This can be done by moving either the sensor or the optical image by fractional amounts that will shift it one pixel at a time. Thus, a single, filtered sensor can be shifted three times so that each red, green and blue filtered pixel will be sequentially exposed in the same position — effectively tripling the resolution. The resolution can be increased still further if a monochrome sensor is used and the movements are reduced so that the actual photosensitive area within each pixel is exposed to a different part of the image — gradually filling in the gaps in the sensitivity. Many sensors have pixels that are not uniformly sensitive to light: this ratio of sensitive to non-sensitive is known as the **fill factor**, and can vary from 10% to 100%. If a colour image is required then all the movements will have to be repeated three times.

A variation on the linear sensor is a type used for line scan imaging of, normally, industrial processes. This is the exact opposite of the moving sensor and static image — here, the sensor is static and the image is moving (objects passing on a conveyor belt, for example). To achieve maximum sensitivity, **Time Delay and Integration (TDI)** imaging is normally employed. This utilises more sensor area than a linear array; and shift registers are used to integrate and transport charge in the direction of image motion. Obviously, this has to be done at high speed. For colour, the red, green and blue filtered sections are exposed sequentially.

In an **area array**, high speed is achieved by having multiple outputs that each receive charge from a small area of the sensor, giving frame rates from 1000 to perhaps 5000 per second, depending on the total number of pixels. If 'windowing' is used, with only a portion of the total area being read out, then the frame rate can be 50,000, or more. These tech-



020083 - 11

Figure 1. Linear optical sensor principle.

niques are used in conjunction with an electronic shutter, which freezes the image by first dumping the charge and then integrating it for just the required, very brief, period.

Although high speed sensors are normally CCD types, Stanford University has developed a CMOS **Digital Pixel Sensor (DPS)** which can achieve 10,000 full frames per second. This is made possible by having an 8-bit AD converter in each pixel, which eliminates the analogue bottlenecks. An acceptable pixel size based on DPS requires the use of a 0.18-micron CMOS process; which has produced its own problems due to reduced supply voltages and increased leakage currents. The 9.4-micron square pixels in the 352x288 array use a **photogate detector** (basically a MOS capacitor exposed to light), rather than the more usual p-n junction photodiode detector. Each pixel incorporates 37 transistors, so, not surprisingly, the fill factor is only 15%.

Focal plane processing is also being applied to those sensor applications that normally require an external computer for post-processing of the output. Such things as robotic vision, target acquisition and tracking, car navigation, etc., that rely on edge detection, motion detection, and such like. With each pixel effectively being a tiny computer, the sensor becomes a massively parallel computer, and the need for post processing is either considerably

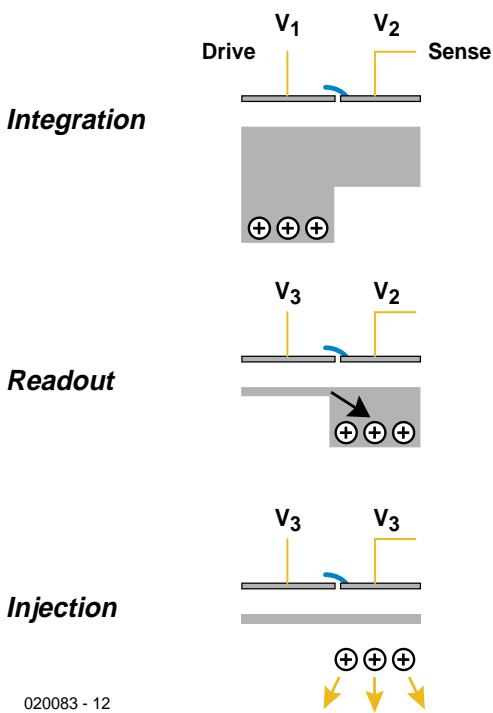
reduced or completely eliminated. The only problem with these 'smart' sensors is, as noted above, the much reduced fill factor.

Advances in focal plane processing

Researchers at CalTech have designed a **focal plane processing** system in which the resolution is enhanced through continuous vibration of the CMOS sensor — filling in the gaps left by the non-sensitive areas of the pixels. Each pixel operates independently, gathering visual information as it scans the scene; and each is read out independently, after in-pixel processing. Having the pixels operating independently eliminates fixed pattern noise because their outputs are not compared. Two means of producing the vibrations have been designed. In one, a 45-degree mirror is used to reflect the image to the lens: the mirror is mounted on a motor shaft slanted at less than 1 degree from the perpendicular so that the image wobbles in a regular circular motion. In the other, the image is irregularly vibrated by the lens being suspended on four springs: the vibrations are either induced naturally — by driving over rough terrain, etc., or by a piezoelectric device.

The Charge Injection Device

One type of sensor that has a high fill factor is the **Charge Injection Device (CID)**. Like the CCD it has been under development for a long time: the concept having been invented by researchers working for the General Electric Company, who announced their first CID camera in 1972 (the same year that researchers at Bell Laboratories announced



020083 - 12

Figure 2. CID pixel dynamics (courtesy Thermo CIDTEC).

the first CCD camera).

The company that is now most associated with the CID technology, Thermo CIDTEC, was established by a management buyout from GEC in 1987.

The CID is more like a CMOS than a CCD, with pixels being individually addressed via row and column electrodes rather than the charges being moved en masse via vertical shift registers. Unlike either, however, each pixel contains two overlapping photogates. Another difference is that the charge is not transferred from the pixel during readout, and so further charge integration can occur — which is particularly useful for adaptive exposure control (selected pixels or groups of pixels can be read several times for real time exposure monitoring during lengthy integration periods). When one photogate is selected by the drive (row) electrode its charge is transferred to the other photogate, and a displacement current proportional to the charge is read by the sense (column) electrode (see **Figure 2**). This is then amplified, converted to a voltage and fed out. The pixel is only emptied when both drive and sense electrodes are switched to ground and the charge is ‘injected’ into an underlying epitaxial layer. This can be at normal field or frame rate, or at any other rate.

The CID has a number of advantages over other imaging devices. The spilling over of excessive charge from a pixel into neighbouring pixels, causing ‘blooming’, is min-

CID Pixel Dynamics

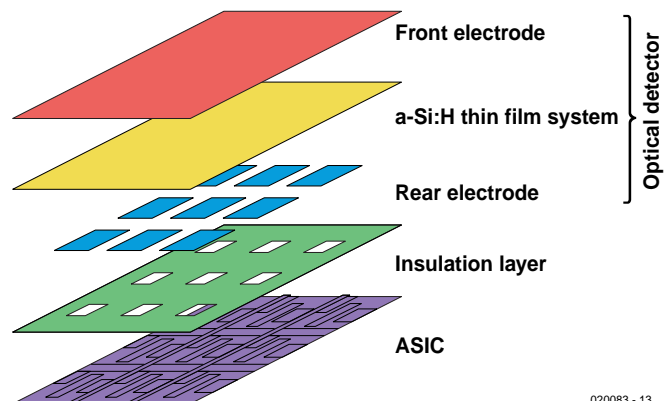
- One or more electrodes inverted
- $|V_1| > |V_2| > |V_3| = 0$
- Change potential on one electrode
- Sense charge transfer (signal) on other electrode. Charge remains within pixel.
- Readout is non-destructive if V_1 is restored to Drive electrode
- Injection occurs when both electrode potentials are collapsed ($|V_3| = 0$). Injected charge diffuses and recombines in underlying collector.

capacitance of the sense line.

The next step: TFA

Another way of achieving a contiguous pixel structure is by vertical integration of the photodiode on top of the pixel transistors, as used by Silicon Vision for their **Thin Film on ASIC** (TFA) technology. This combines the excellent optical properties of hydrogenated amorphous silicon (a-Si:H) with the advantages of crystalline silicon (x-Si) for integrated circuits, to achieve intelligent image sensors. The thin film of amorphous silicon is deposited on the crystalline silicon Application Specific Integrated Circuit (ASIC) in a Plasma Enhanced Chemical Vapour Deposition process; with anything from four to seven layers being successively deposited, in a thickness of less than one micron. **Figure 3** shows the basic layer sequence of a TFA. The insulation layer is patterned in order to provide the contact holes for the pixels between the detector and the circuitry; with the pixel area being defined by its rear electrode which is a patterned metal layer; the top layer is a transparent conductive oxide that acts as a common electrode for all the pixels.

TFA uses row and column addressing of the pixels; and therefore a variety of readouts are possible, including random access when desired. Pixels may also be connected in ways that enable them to communicate with each other — for such things as compression or pattern recognition. Another advantage



020083 - 13

Figure 3. Basic layer sequence of a Thick Film on ASIC. (courtesy Silicon Vision).

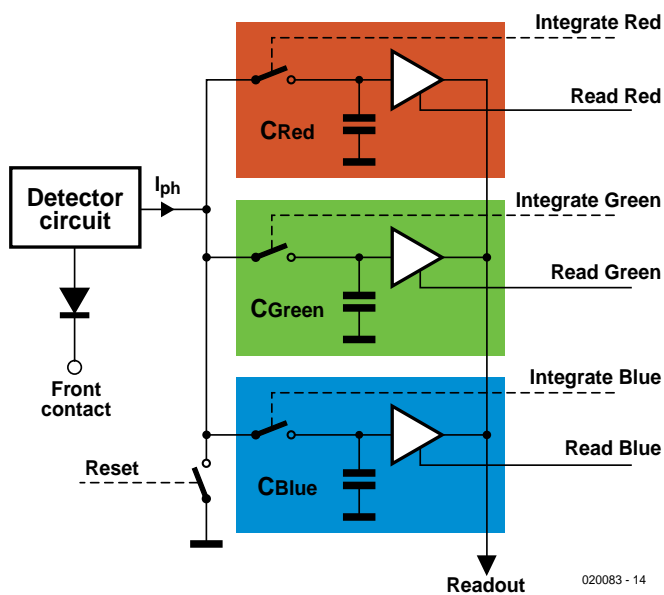


Figure 4. The COSIMA element employs sequential inputting of the colours into their respective integration circuits (courtesy Silicon Vision).

is that the detector and the ASIC can be optimised as if they were separate. Also, the fabrication process is cheaper than that of a CMOS sensor — which is itself cheaper than a CCD.

Silicon Vision has developed three types of image sensor from the basic TFA technology. They are discussed below.

COSIMA, LARS and HIRISE

COSIMA, the Colour Sensor with Integrated Memory Array is, as the name implies, a colour chip; but where it differs from others is that the red, green and blue components are all handled within each individual pixel. Colour recognition is sequential, and is based on the wavelength: blue light is absorbed near the surface of the silicon, green light penetrates deeper, and red deeper still — the actual penetration depths being about 50 nm, 200 nm, and 500 nm to 1 micron. Detection of the three colours is achieved by applying different bias voltages. During the integration phase, the three charges are sequentially fed into their respective colour integration circuits and stored within each pixel (see **Figure 4**). For readout the integrated colour voltages are simulta-

neously applied to the column output line.

The second type of sensor is the **Lokal-AutoadaptiveR Sensor (LARS)** — the company is German). In this, the pixels adapt themselves to the local illumination; and the result is a dynamic range of 120 dB (a normal CCD or CMOS has around 80 dB). Thus suiting it to industrial and automotive vision systems. It can achieve this because it divides the full dynamic range into two signals, each of moderate dynamic range. The integration voltage in the pixel is compared at clocked intervals to a fixed reference voltage, which is slightly below half the saturation value; if it has exceeded that threshold, integration is stopped; if it has not, the integration time is doubled (**Figure 5a** is a diagram of a LARS pixel). Every time the comparison is made a voltage ramp is increased by one step, marking the duration of the integration. When integration is stopped this is sampled and stored in the pixel as timestamp information (**Figure 5b** is a timing diagram of a pixel). When all the pixels have stopped integration, the two voltages — integrated intensity information and timestamp information — are then read out from each; and the original photocurrent is reconstructed by subsequent processing

from a combination of the two signals. Colour can be achieved by sequential exposures through red, green and blue filters. The LARS auto-adaptive function can also be switched off to let the device be used normally.

Thirdly, the high-resolution sensor, **HIRISE**. There are three versions of this. The HIRISE VGA with 640x480 pixels, of 7.4 microns square. The HIRISE HDTV is a 16:9 format sensor with 1920x1040 pixels of 6.1 microns square. While the HIRISE MEGA is a three megapixel chip with 2160x1440 pixels of 5.4 microns square. All three versions are filtered for colour and have two switchable pixel sensitivities, giving high quality or high sensitivity.

Returning to the concept of three colours being detected within each pixel, another company has also announced an image sensor with that facility — **Foveon**. This modified CMOS device is used in the newly announced Sigma SD9 digital SLR camera. The same principle is applied, of the colours being detected at different levels in the silicon. Foveon has also taken advantage of the concept by having what they call 'Variable Pixel Size', using all the pixels for maximum resolution, or combining adjacent pixels for greater sensitivity or flexible video recording (it is both a still and a video sensor); this is not a new concept, it has been used under the name of 'binning' for many years, but the necessity for maintaining the correct colour relationship between filtered pixels has until now limited its use to specialised applications. The F7 sensor used in the Sigma camera measures 20.7x13.8mm, and has a total of 2304x1536 pixels with a 9.12 micron pitch. For video, frame rates can vary from 2 per second at full resolution to 25 at 576x384. A second sensor, the F10, is expected to be launched later this year. This will be 6.4x4.8mm, with a 5 micron pixel pitch, and a total of 1344 x 1024 pixels. With a frame rate of 10 for full array up to 30 for VGA resolution. Unlike the F7 it will also have three integrated 12-bit A/D converters running at up to 20MHz; with red, green and blue multiplexed onto a single 10-bit tri-state output data bus, in addition to the RGB analog outputs. The Foveon sensor is shown in the **introductory photograph**.

FillFactory and TI

CMOS active pixels with their internal transistors can also have their sensitivity improved. FillFactory have developed what they call a **High Fill Factor N-Well Pixel**. In addition to the fill factor, the quantum efficiency has also to be taken into account (this being the number of electrons that are gen-

erated in the pixel for every impinging photon, relative to its spectral response). Photons can be lost by reflection on dielectrics, and by not being absorbed; while those electrons that are generated may not be collected and integrated, or the electron-hole pairs may recombine. As pixels are being made smaller, in order to increase the resolution, the problem is a growing one.

What FillFactory have done is to allow the photodiode to detect the generated electrons in the epitaxial layer beneath the surface of the whole pixel (including under the insensitive areas), electrons that would normally be lost. These are then channelled by electrostatic barriers that shield them from the active pixel circuitry and substrate to the photodiode junction (see **Figure 6**). Apparently, virtually all the escaped electrons will diffuse down that drain; giving a fill factor of 100%, with no other changes to the pixel structure. The only disadvantage is greater pixel crosstalk because of a 16% chance of electrons diffusing into an adjacent pixel (although this can be counteracted).

CCDs have not been left out when it comes to increasing sensitivity, either. Texas Instruments have developed a frame transfer sensor with integral image intensification which they call **Single Photon Detection (SPD)**. In this the charge is multiplied before it is converted to an output voltage. The charge carrier multiplication (CCM) is achieved by creating a high-field region between two adjacent gates, and injecting the charge into this field. When electrons traverse the high-field region, they gain energy and when a certain threshold is exceeded impact ionisation occurs. This happens in the horizontal shift register as the charges are being read out. The register is twice the normal length (see **Figure 7**): the first half is of conventional design that interfaces with the storage area as in any other frame transfer CCD; the second half, however, includes 400 CCM stages. Here, new electron-hole pairs are created by impact ionisation; the new electrons are collected in potential wells where they are added to the original charge, and the holes are drained off to the substrate. This process is repeated for each stage until the greatly increased charge reaches the output amplifier.

The first SPD CCD has just been launched, and has a dynamic range of more than 90 dB. According to Texas Instruments, the SPD technology can be applied to any known image sensor architecture to increase the sensitivity of standard CCD imagers by more than 50 times. Additionally, it extends the spectral range so that it can cover from

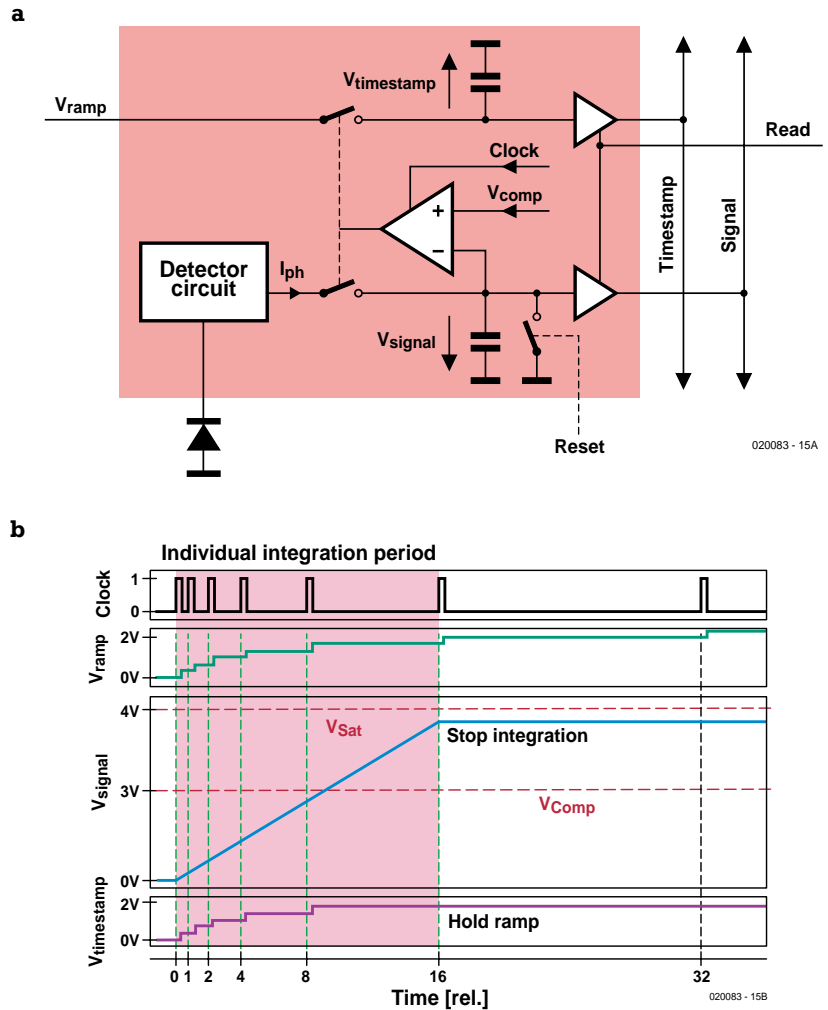


Figure 5. LARS pixel (5a) and its timing arrangement (5b) (courtesy Silicon Vision).

200 nm (deep UV) to 1,100 nm (near IR).

Cyborg vision?

Finally, there is a class of image sensor that borrows from the vertebrate

eye — the **foveal** sensor. This type is being increasingly used for machine vision, such as robots. Instead of the pixels being evenly spread across the surface, there is a central fovea with smaller pixels in which the resolution is greater. In operation, the

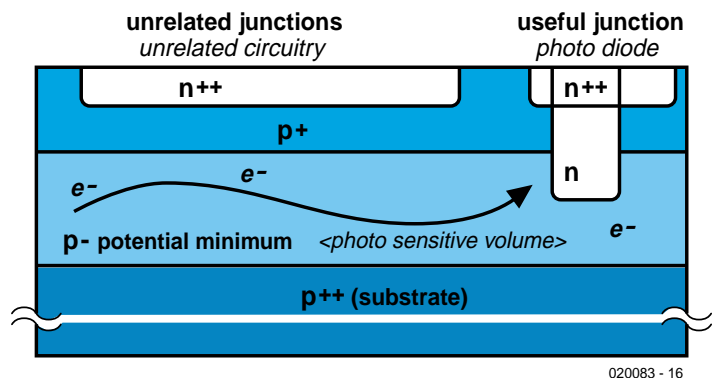


Figure 6. Electron crowding method to improve the fill factor (courtesy Fillfactory).

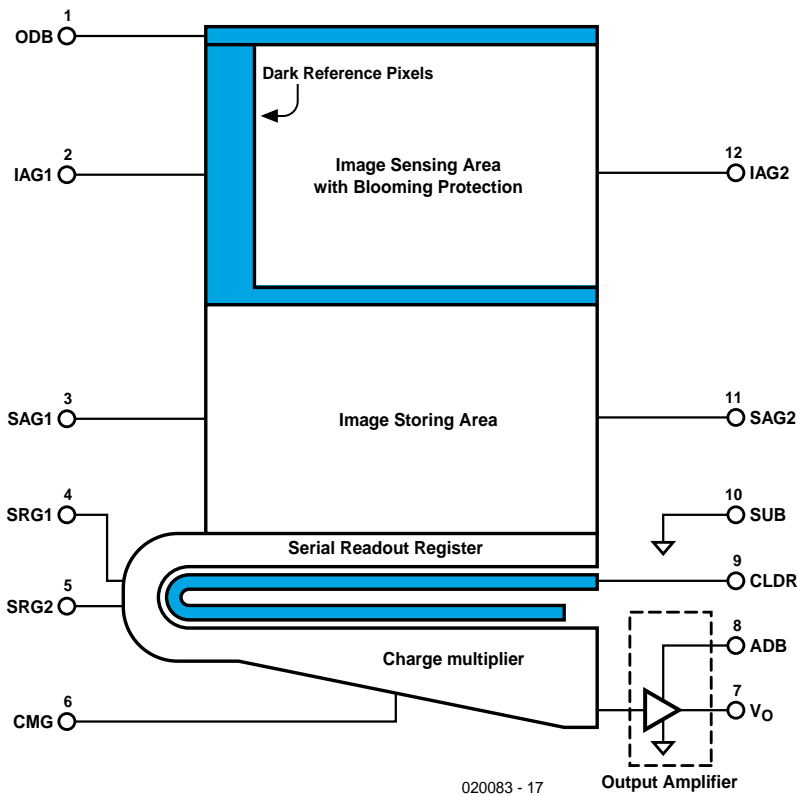


Figure 7. Single Photon Detection (SPD) is expected to make it to commercial CCDs soon (courtesy Texas Instruments).

peripheral area finds something of interest, and then directs the fovea to get a detailed look at it. The field of view can be broad; but because only the fovea provides the details the total number of pixels is much reduced by comparison with a conventional arrangement — as is the focal plane processing, where used. Many designs are circular, with the pixels arranged radially, although square ones have been produced, too. Most of them are CMOS designs: not only to easily incorporate on-chip processing, but also because prototypes can be produced at low cost. The latter being an obvious advantage, particularly as many of the designs are being produced in universities for research purposes.

Conclusion

Solid state image sensors have come a long way since the first cameras in 1972. The initial progress was painfully slow; but now there are genuine alternatives to the CCD and more recent CMOS, and generally the quality is rising in inverse proportion to the cost. And the new 'smart' sensors can perform functions that would formerly have required a lot of off-chip processing to achieve.

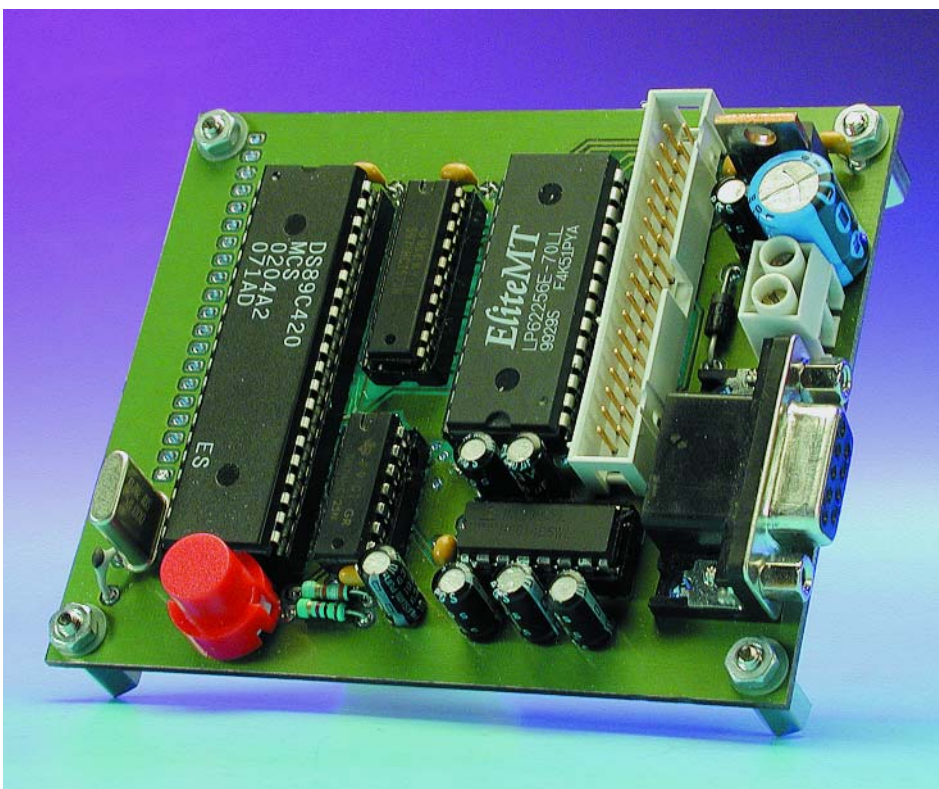
(020083-1)

High-Speed Controller Board

with processing speeds up to 33 MIPS!

Design by L. Lemmens

At first glance, the hardware for this project may appear to be pretty ho-hum: a fairly standard 8051 board, which at most differs from the rest by the absence of an EPROM. The Flash program memory in the microcontroller used here is also not especially radical. But the Dallas Semiconductor DX89C240 is definitely something different: this processor is no less than 12 times faster than the original 8051 at the same crystal frequency, and it can achieve processing speeds of up to 33 MIPS with a clock frequency of 33 MHz!



In December 2001 we published a hugely successful design for a microcontroller board using an Atmel Flash microcontroller. This month it's time to give Dallas Semiconductor a turn. Just more of the same? Yes and no. Yes, this is a Flash microcontroller that bears a strong resemblance to its distant ancestor, the 8051. No, because by modifying the core of the processor to make it much faster and adding various functions to the standard 8051, Dallas has put an 8-bit microcontroller on the market that can easily hold its own against modern 16-biters!

Of course, 33 MHz is already quite fast for a microcontroller, but Dallas was unfortunately not able to achieve the promised 50 MHz (the target value stated in the pre-announcement of the DS89C420). Still, it is a factor of 12 faster than a normal 8051 would be at 33 MHz.

We can also report that a sample of this microcontroller ran at 50 MHz

in our lab at room temperature, but Dallas has to be able to guarantee the maximum frequency over a temperature range of 0 to 70 °C. Overclockers can thus try their luck...

Dallas Semiconductor is certainly not the only manufacturer to embroider on the successful 8051 concept. Over the past years, we have published many projects using microcontrollers derived from this venerable microcontroller. Most of them differ from the 8051 by having more 'peripheral' functions on board, such as A/D converters, watchdog timers, compare-and-capture units and the like. In this regard, the DS89C420 (whose block diagram is shown in **Figure 1**) is something of a non-conformist. The actual core of the processor has been dismantled, improved and extended. All of these modifications are made possible by the architecture of the 8051 processor, in particular the Special Function Registers (SFRs) inside the microcontroller. The RAM region between addresses 80h and 0FFh is reserved for these registers, but in the original 8051 only a small portion of this region is actually occupied. Just like other successors to the 8051, the DS89C420 uses 'free' register addresses to add functions. All of the 'extras' are housed in this memory region, so additional peripherals or functions can be addressed using read or write accesses within the memory space of the microcontroller. For example, an extra serial port has its own register address for the buffer and a register for the port settings. This approach makes it possible to add functions without extending the instruction set.

A glance at **Figure 2** shows that the latest member of the Dallas family adds no fewer than 30 (!) SFRs to the original 21 of the 8051. We don't want to bore you with a full list of all the extra registers or explanations of what they do, so we will limit ourselves to describing the most striking and progressive features. Detailed descriptions can be found in the *User's Guide* (nearly 200 pages long) and the 60-page 'data sheet' for this microcontroller, both available from the Dallas Semiconductor website.

The increased speed is primarily the result of completely new structure for the core of the controller, which allows many instructions to be executed in one clock cycle. The good old 8051 has a machine cycle of 12 clock cycles. At the same clock frequency, the DS89C420 is thus a factor of 12 faster than an 8051 and a factor of 4 faster than other high-speed microcontrollers from Dallas. In addition, the DS89C420 has extra peripherals and features not present in an 8032: 16 kB of Flash program memory, three 16-bit timer/counters, two UARTs, two data pointers, a watchdog timer, five interrupt priorities and 256 bytes of RAM for the stack and variables. The DS89C420 also has a Power Management mode that can be used to dynamically reduce the internal clock rate by a factor of 1024. The power consumption of the processor is proportional to the clock rate, so a considerable amount of energy can be saved in this manner whenever there is little or no activity. The microcontroller can be returned to full speed by an interrupt or activity on the serial port.

The DS89C420 is available in three different packages (DIP, PLCC

and TQFP) and is fully pin-compatible with other 8051-family microcontrollers. It is also fully backwards compatible at the software level, but for many applications it would be a shame not to take advantage of the new possibilities offered by this IC. In this first instalment, we take a close look at these novel features before turning our attention to the circuit board and construction (in the second instalment). Here we assume that the reader is already familiar with the 'standard' 8051 architecture.

Compatibility

The microcontroller can be used as a direct replacement for an 8051 in an existing application, and there are also no changes to the instruction set. As a rule, the circuit should work without any problems, but much faster than with an 8051. However, there are a couple of considerations that must be borne in mind in such a situation.

Timer/counters

The DS89C420 has three 16-bit timers that are clocked in the old manner with twelve clock cycles per machine cycle, so the timing remains compatible with the 8051. All three of them can also be configured to be clocked at one clock cycle per machine cycle, if so desired.

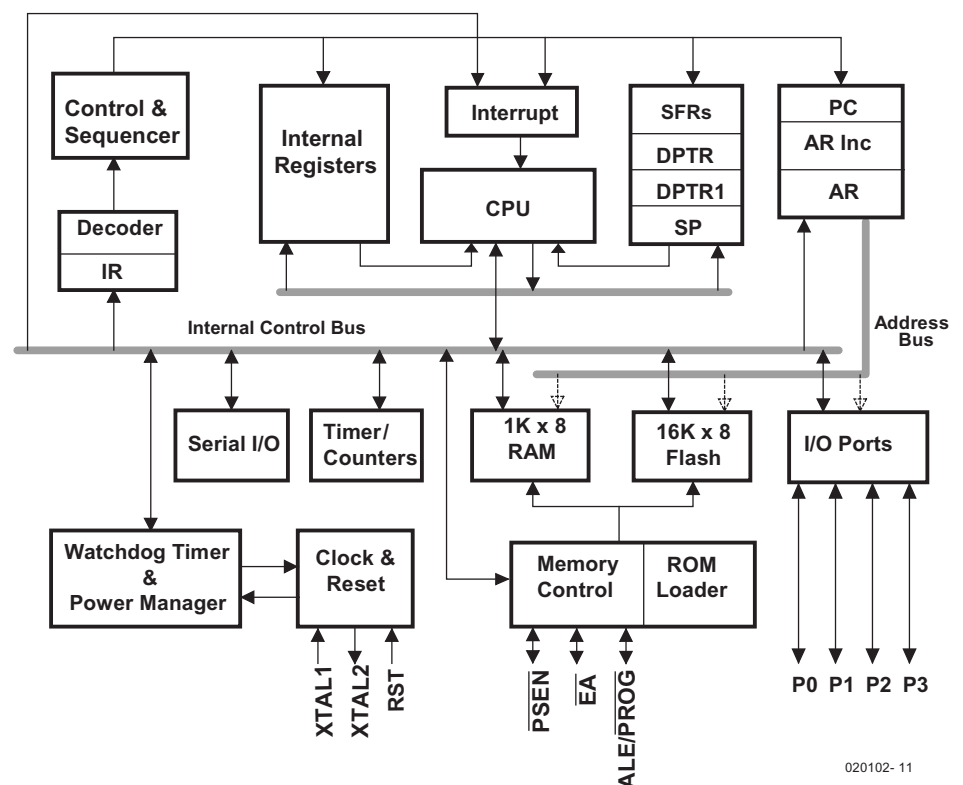


Figure 1. The internal structure of the DS89C420.

8 BYTES

F8									
F0	B	EIP1	EIP0						
E8	EIE								
E0	ACC								
D8	WDCON			BPA1	BPA2				
D0	PSW					FCNTL	FDATA		
C8	T2CON	T2MOD	RCAP2L	RCAP2H	TL2	TH2			
C0	SCON1	SBUF1	ROMSIZE	BP2	PMR	STATUS		TA	
B8	IP0	SADEN0	SADEN1						
B0	P3	IP1							
A8	IE	SADDR0	SADDR1						
A0	P2								
98	SCON0	SBUF0				ACON			
90	P1	EXIF					CKMOD		
88	TCON	TMOD	TL0	TL1	TH0	TH1	CKCON		
80	P0	SP	DPL	DPH	DPL1	DPH1	DPS	PCON	

020102 - 12

↑ BIT ADDRESSABLE

Figure 2. Summary of the DS89C420 Special Function Registers.

Instruction set and timing

The instructions work exactly the same way as their counterparts in the 8051, and there are no changes in the how the bits, flags and processor status are affected. However, the timing of the instructions is different, which can be of considerable importance to time-critical processes.

The relative timing of some instructions is different. For instance, in the original architecture the 'MOVX A, @DPTR' and 'MOV direct, direct' instructions both take 24 clock cycles, or 2 machine cycles, and thus take the same amount of time. In the DS89C420, the first of these instructions takes only two machine (clock) cycles, while the second takes three cycles. If proper timing is essential for the operation of your program, you should thus carefully study the instruction set.

Serial programming

The microcontroller can be programmed 'in circuit' in a very simple manner. As we will see later on in the schematic diagram of the development board, only three tri-state buffers have to be added to the standard hardware to simultaneously put the reset, EA and PSEN signals into a non-standard state. If this is done, a special portion of the ROM is addressed and a monitor program located there is started. After this, the internal Flash memory can be loaded or read out via a serial link to a PC. This is ideal for a development system, as well as for designing and

testing applications that ultimately have to run on a different processor, such as an 8032 — although in that case you naturally can't use any of the splendid new features offered by the DS89C420!

By the way, the microcontroller is also parallel-programmable using a standard Flash programmer or EPROM programmer.

Memory configuration

With the DS89C420, the memory is divided into the same three regions as with the 8051 (see **Figure 3**): registers, program memory and data memory. All registers are located in the microcontroller itself, but the other two regions can be entirely internal, entirely external or a mix of internal and external.

The microcontroller has 16 kB of Flash program memory and 1 kB of data memory. A particularly unusual feature is the ability to switch the data memory over to program memory. This makes it possible to do things such as fetching in a new subroutine while a program is running (via the serial port or from external memory), writing it to data memory and then switching the data memory over to program memory and executing the code. Switching the data memory causes the Flash

memory between addresses 400h and 7FFh to be disabled and 'replaced' by a like-sized block of RAM. Although this RAM is physically internal memory, it is addressed as external memory using MOVX instructions.

Naturally, the size of the address space is 64 KB for both program and data memory. If the address region of the memory inside the microcontroller is exceeded, external memory is automatically addressed. But where can you find static RAM (for instance) that can handle such a lightning-fast processor? No need to worry; the DS89C420 is somewhat more sedate when addressing external memory, and it is even possible to configure the durations of the SR, RD, PSEN and ALE signals to allow the microcontroller to 'talk to' relatively slow peripheral devices. However, this is not especially easy and requires careful study of the timing of both the DS89C420 and the memory coupled to it. Dallas Semiconductor has written a guide that clearly describes how this has to be done, entitled *Application Note 26, Ultra High-Speed Microcontroller Memory Interface Timing*.

The topmost address of the internal program memory can be changed during the execution of an application. This allows a portion of this memory to be disabled in order to (temporarily) make the address region free for use with external program memory.

An additional feature is that external memory can also be addressed in paged modes. This means that rather than having a multiplexed address/data bus on port PO, there is a multiplexed address bus, with the upper address byte being clocked into the latch. As long as this byte remains constant, only the lower address byte is changed. The latch cycle can thus be skipped, which allows the external memory to be read or written faster. Bear in mind that these modes require adjustments to the standard external hardware.

Data pointers DPTR and DPTR1

When executing a MOVX instruction (to read or write external data mem-

ory), an 8051 uses the data pointer register (DPTR), which can hold a 16-bit address. This address can refer to a location in the data memory or can be the address of external hardware. Whenever data must be moved from one address to another, one pointer is needed for the source and a second pointer for the destination. The DS89C420 therefore has two such pointer registers, which allows data to be moved much more efficiently.

There is a Data Pointer Select (DPS) Special Function Register (SFR) coupled to these pointers, which allows the user to have all sorts of operations on the data pointers be performed automatically.

Bit DPS.0 (i.e., the LSB of DPS) determines which pointer is active, which means that no new instructions have been added to the standard 8051 instruction set to allow the new, extra data pointer to be used in processing operations. The default value of this bit is '0', which means that the 'old' data pointer is selected. Another bit in this register (DPS.5, Toggle Select) can be used to cause DPS.0 to be automatically toggled, so that the processor automatically switches back and forth between the two data pointers after each instruction related to DPTR.

In order to make everything easier and faster, the processor also has an automatic increment/decrement function for each data pointer, which can be enabled using Auto Increment/Decrement Enable (bit 4 of the register). In short, if the proper control bits are set, only read and write instructions are needed to move a block of data. One pointer points to a source memory location, while the other pointer points to the destination. The microcontroller ensures that the correct pointer is selected and modifies its content as desired. This concept is undoubtedly familiar to those of you who have worked with digital signal processors, but it is rather unique for microcontrollers.

Hardware

The schematic diagram for this project is not particularly surprising: a microcontroller, an address latch, RAM, a serial interface, a power supply and expansion connectors. All of this has appeared in the pages of

Elektor Electronics fairly often, but you will have to wait until the September issue to take a closer look at the complete schematic. The only exception to the usual hardware configuration is an IC containing buffers with tri-state outputs, which can be used via the DTR line of the RS232 interface to switch the microcontroller into a special mode. If these buffers pull the DS89C420 \overline{EA} and \overline{PSEN} pins Low and RESET High, an internal monitor program is started in the microcontroller. This monitor is located in a special part of the microcontroller ROM that is only addressed when these three pins are held in the states just described, and which therefore does not occupy any program memory.

Software

On the FTP site of Dallas Semiconductor (<ftp://ftp.dalsemi.com/pub/microcontroller/>) you will find two free downloads: Microcontroller Toolkit (MTKbeta.ZIP) and Loader420 (loader420.ZIP). These

can be used to switch the controller board into the monitor mode and communicate with the microcontroller. The first of these programs is fitted into a modern Windows 'jacket', but otherwise the two programs are functionally equivalent. The most important function is programming the internal (Flash) program memory of the DS89C420, so that we can easily install our own applications in the microcontroller and modify them without a lot of bother. It is also possible to view and modify memory locations, ports, registers and so on – all in all, a complete development system!

The program memory is reprogrammable and can be very easily modified in the prototyping phase of a project, even if a normal 8051 (or derivative) microcontroller will end up being used in the production phase.

(020102-1)

In the following instalment (which will appear after the Summer Circuits double issue, and thus in the September issue), we will discuss the circuit diagram of the high-speed controller board in more detail.

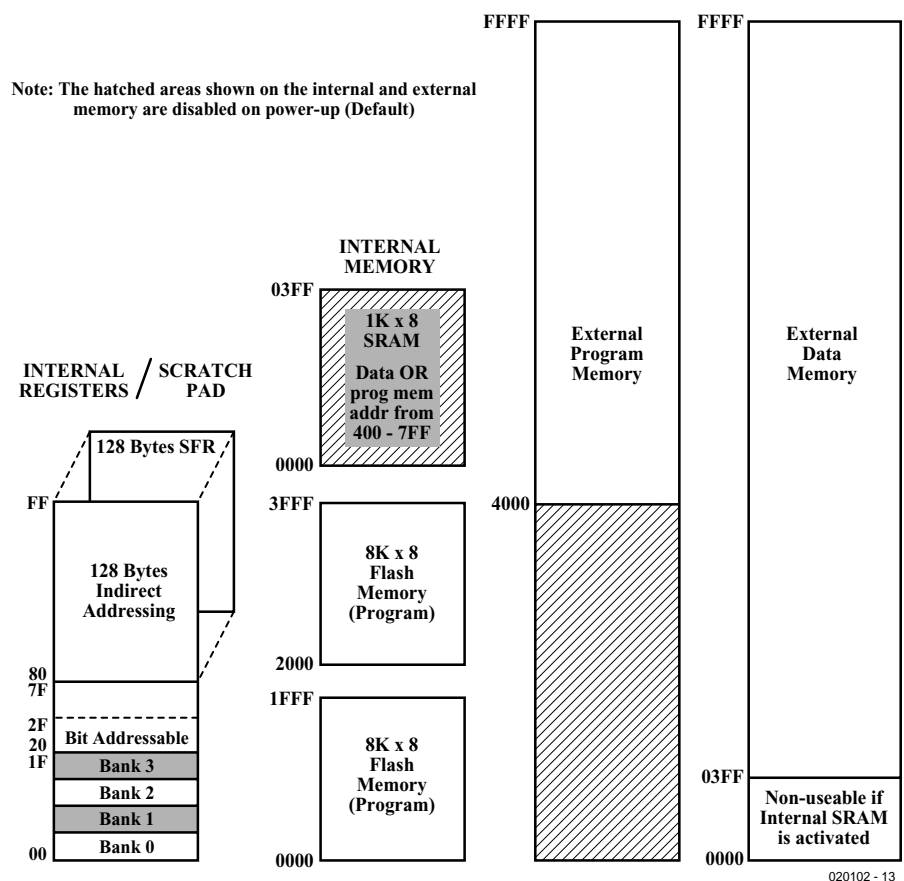


Figure 3. The 89C420 has the same memory configuration as the original 8051.

Portable DMX Tester

everything under control

Design by B. Bouchez

It is frequently necessary that a DMX-compatible device or a complete DMX installation has to be tested when faults have occurred while it is in use. With the tester described here we avoid the need to have to take over the DMX master (PC or console) for this purpose. This tester can be used in every situation, thanks to its handy size and built-in rechargeable battery. And as an added benefit, this circuit can also send and receive DMX data.

Anyone who has ever installed or built DMX-compatible equipment has, in all likelihood, experienced problems when it came to the operation thereof.

It is impossible to describe the wide variety of possible faults and their symptoms

here, because of the enormous scale of the subject! Depending on circumstances, it is possible that a simple piece of equipment (scanner, dimmer, etc.) doesn't respond to a command, or that a complete instal-

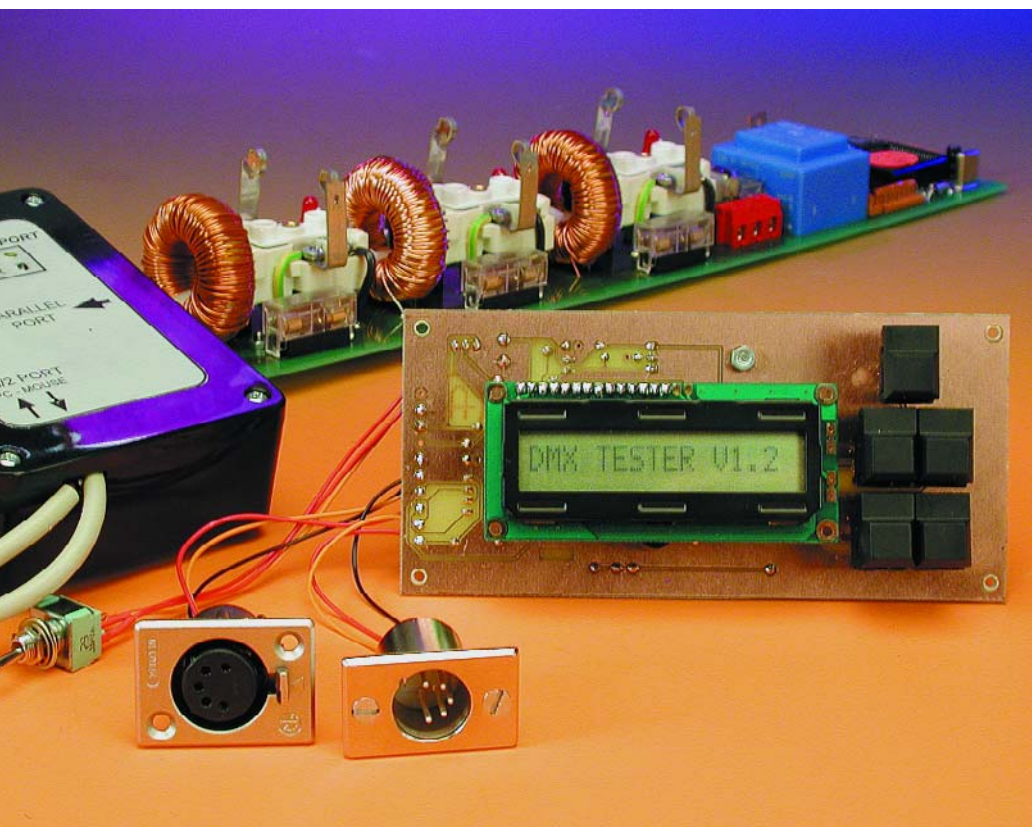
lation has suddenly gone haywire and is carrying out programs that only it seems to be familiar with...

When the installation consists of a simple 0 to 10-V control system, a simple multimeter is usually sufficient to trace the problem and work out a solution.

When DMX512 is concerned however, fault finding with the aid of only a multimeter or oscilloscope is equal to searching for a needle in a haystack. When seriously tackling a fault in DMX512 equipment or an entire installation, a tool is necessary that can send valid commands (according to the DMX512 standard) and also interpret and display whatever is happening at any given instant along these connections.

It is certainly possible to use a DMX interface that is connected to a PC, but this solution requires a considerable investment in a device that is used only for testing purposes. In addition, it is not very practical to carry a PC (including a portable) to a height of several meters, the location of the equipment to be tested.

The tester proposed here provides the facility to solve various problems in a very simple manner. It is sufficient to glance at the specifications, listed in **Table 1**, to be convinced of this.



The Schematic

Only a few years ago, the building of a tester with all these features would have required a circuit with considerable complexity. But thanks to the use of a modern microcontroller, practically everything that is required fits on a single chip. Therefore, the schematic shown in **Figure 1** appears to be simplicity itself. The trade-off however, is that a significant amount of effort has to be invested in the software.

All the work is carried out by IC1, an Atmel microcontroller from the AVR-family. It has everything we require on board: 8 kBytes of flash-memory for the program, 512 bytes of RAM, two timers, a serial interface and even 512 bytes of EEPROM (which is not actually used here).

The whole system is clocked by an 8-MHz crystal, which results in a throughput of 8 MIPS (MIPS = Million Instructions Per Second), plenty of computing power for the present application.

IC1 is an AT90S8515 and it even has its own programmer on board. The only things we need in order to load our program into flash memory, are an appropriate cable that connects to the parallel port of a PC and a program that Atmel has made available free of charge. This cable is connected to K2, which need not be mounted if you decide to purchase a pre-programmed controller from *Elektor Electronics*.

The reset circuit around transistor T1 appears a little strange at first. However, this makes it possible to not only reset the circuit during normal use with the combination of R2/C3, but also during the programming stages of the Atmel program.

The interface for the LCD has been implemented as straightforward as possible. Port A of IC1 is configured for bi-directional operation and takes care of the exchange of data. The control signals are managed by lines on ports C and D. The program ensures the correct timing for the LCD controller.

The five control buttons are connected directly to the inputs of port B.

The interconnection with the DMX512 world is realised with a chip that will be familiar to many

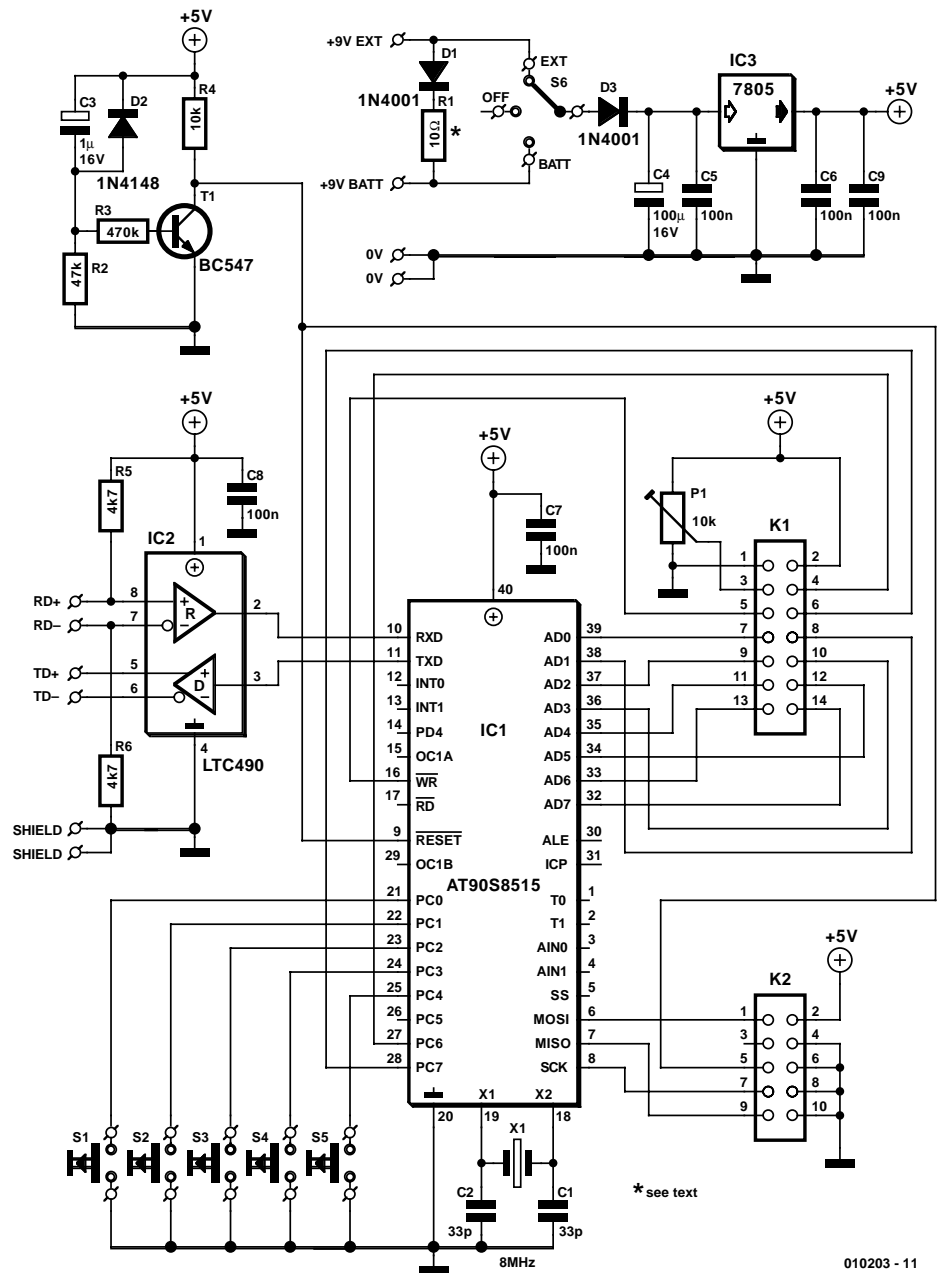


Figure 1. The schematic for the portable DMX tester is not very complicated, despite the fact that this is a complete microcontroller system.

Table I. Specifications for the Portable DMX Tester

- Portable tester with modest dimensions
- Compatible with DMX512-1990
- Transmitted and received data visible on an LCD
- Very straightforward operation (5 buttons)
- Operates from rechargeable battery or mains adapter
- Two functions: DMX transmit and receive
- Transmits on 512 DMX channels (480 are adjustable, the others remain 0)
- Start Code during transmission can be adjusted as desired
- Receipt of 480 channels, the values of which are indicated from 0 to 255
- Indication of the received Start Code
- Indication of received data, so that a break in the cable can be detected immediately
- The option of storing the received DMX-values in the memory of the tester and re-transmit them again at a later time

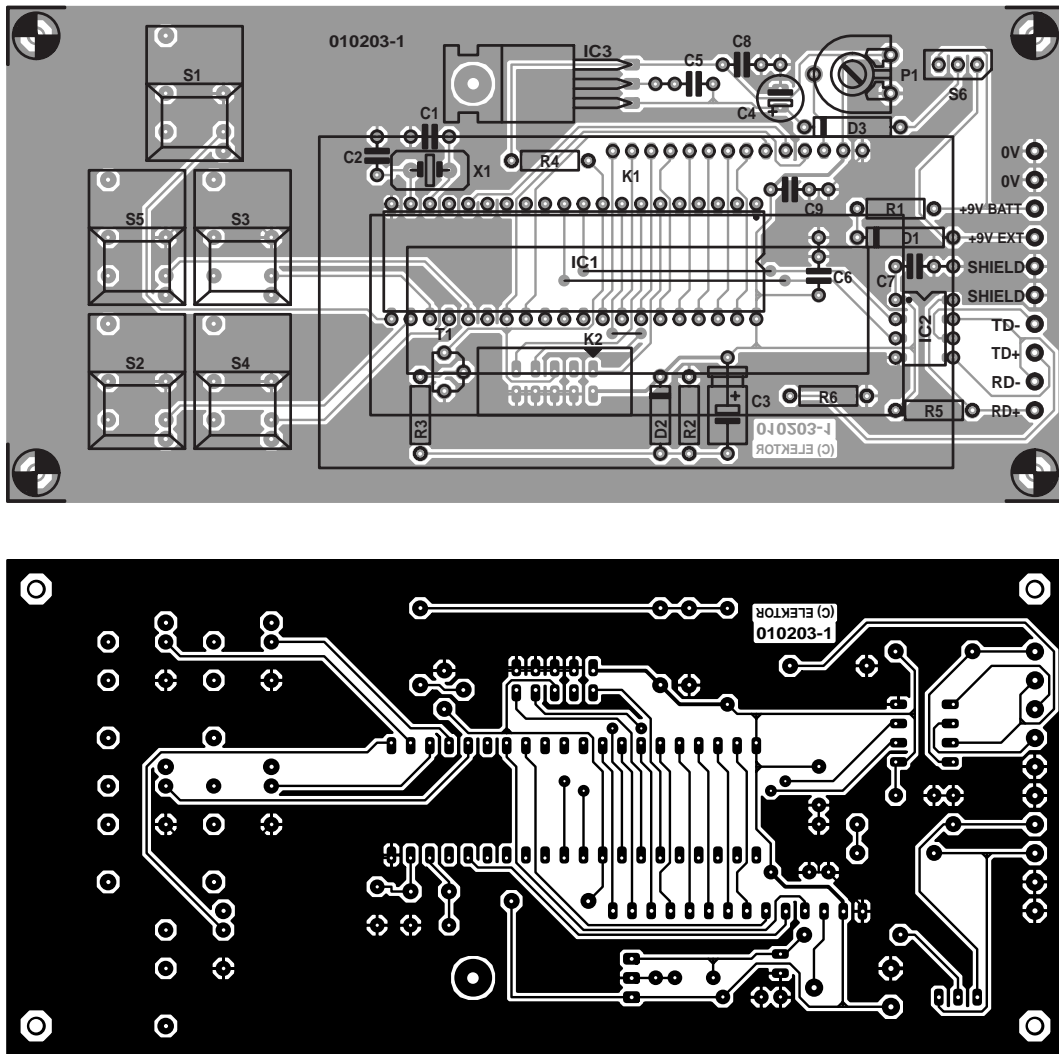


Figure 2. PCB layout and component overlay for the portable DMX tester.

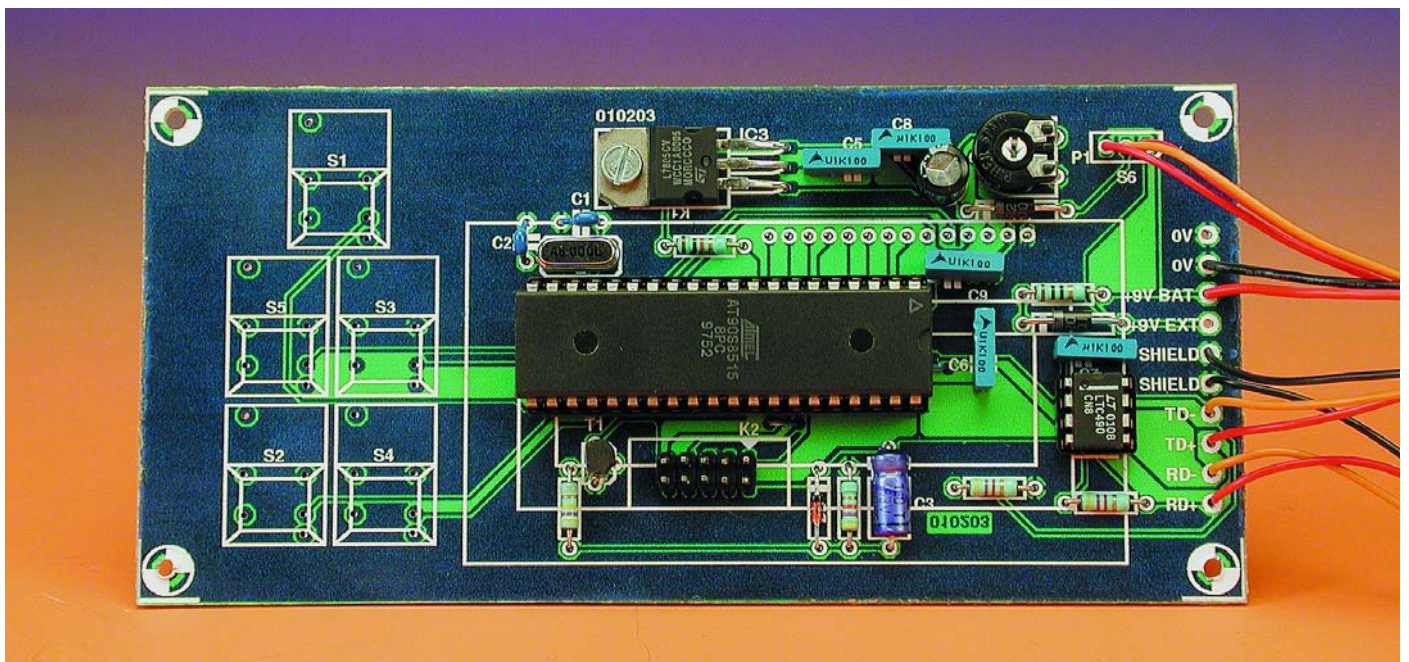


Figure 3. Completely assembled example of the circuit.

readers: an LTC490 (an equivalent of the SN75179). It takes care of the conversion from TTL to RS485. Keeping in mind the purpose of the tester, and the fact that it is battery powered, optical isolation between the interface IC and the processor was not considered necessary.

The tester can be powered via two different means: a simple mains

COMPONENTS LIST

Resistors:

R1 = *
R2 = 47k Ω
R3 = 470k Ω
R4 = 10k Ω
R5,R6 = 4k Ω 7
P1 = 10k Ω preset

Capacitors:

C1,C2 = 33pF
C3 = 1 μ F 16V
C4 = 100 μ F 16V
C5-C9 = 100nF

Semiconductors:

D1,D3 = 1N4001
D2 = 1N4148
T1 = BC547
IC1 = AT90S8515, programmed,
order code **010203-41**
IC2 = LTC490-CN8 (Linear Technology)
IC3 = 7805

Miscellaneous:

S1-S5 = pushbutton, 1 make contact
S6 = single-pole changeover switch with centre-off position
X1 = 8MHz quartz crystal
K1 = socket, 1 row of 14 contacts (+ 14-way header for display)
K2 = 10-way pinheader
LCD, 1 line of 16 characters, HD44780 compatible, e.g. NLC-16x1x07 (Conrad Electronics #183 261)
Optional:
5-way XLR socket, chassis mount
5-way XLR plug, chassis mount
PCB, order code **010203-1** (see Readers Services pages)
Floppy disk, source and hex-code files, order code **010203-11**

* = see text

PCB layout and disk contents also available from Free Downloads section at www.elektor-electronics.co.uk

wall adapter with approximately 9 V output or an internal NiCd battery. The selection between these two power sources is achieved simply with a three-position switch (S6). The power supply is disconnected in the centre position.

Diode D3 protects the tester against an incorrectly connected power supply.

D1 and R1 together form a simple battery charger. This makes it possible to charge the internal battery when an external power supply is connected to the tester. The correct value for R1 depends partly on the capacity of the battery and partly on the output voltage of the mains adapter. If you are using a 9.6-V battery, then you will need to use a mains adapter that is able to provide at least 14 V, to ensure that the battery will be properly charged. The 7805 will tolerate a maximum input voltage of 18 V (this depends on the exact model), so we have plenty of margin.

The value of R1 is determined with the following formula:

$$R1 = (U_{\text{adapter}} - (1.2 U_{\text{battery}}) - 0.7) / I_{\text{charge}}$$

In principle, assume for I_{charge} a value equal to 0.1 of the capacity of the battery, expressed in Ah.

To charge a battery rated at 9.6 V/500 mAh with a mains adapter that has an output voltage of 14 V, the value of R1 will be:

$$R1 = (14 - (1.2 \times 9.6) - 0.7) / 0.05 = 35 \Omega$$

(select 33 Ω from the E24 series).

The power dissipated by R1 amounts to about $33 \Omega \times (0.05 \text{ A})^2 = 0.1 \text{ W}$. A 0.25-W or 0.5-W resistor is therefore entirely satisfactory.

The construction

The practical realisation of a circuit built around a microcontroller, such as this one is almost of proverbial simplicity. In **Figure 2** you will find the component overlay of the matching printed circuit board.

Nonetheless, a number of aspects of the construction deserve some extra attention. A number of parts are mounted on the copper side of

the PCB: the buttons and the display.

First fit all the parts at the component side, once this is done, proceed with the parts at the copper side, starting with the pushbuttons. If you use Digitast-pushbuttons, keep in mind that these are too low in relation to the display, so they will end up recessed in the front panel. In addition, it is very difficult to make the solder connections when the pushbuttons are flush with the copper side of the PCB.

The following solution provides a means to raise the pushbuttons somewhat. First solder individual PCB pins onto the pads intended for the pushbuttons. These PCB pins are available from many electronics retailers, but if you can't find any you can use an alternative approach by using an old IC socket with turned pins. You only need to remove the pins from the plastic housing. The pushbuttons can then be inserted into the pins, and Bob's your uncle.

Once the pushbuttons are in place you get a better impression of the position of the circuit board with respect to the front panel of the enclosure. It is now easier to determine the position of the display. The mounting of the display can be done in two different ways, individual wires or with connectors. We chose the former option, since it doesn't require special parts.

We start by soldering 14 wires to the pads on the display, in such a way that they do not protrude on the display side. We then insert this assembly into the PCB and adjust the distance so that the front of the display is flush with the front of the enclosure. Everything can then be soldered to the main circuit board.

You may also decide to use a 14-way female header that fits in a corresponding male header, which is soldered to the display terminals.

Switch S3 is a single pole change-over type with centre-position. It can be mounted on the side or the front of the enclosure.

Voltage regulator IC3 is mounted horizontally to the PCB and fastened with an M3 bolt and nut. The PCB functions as the heatsink.

The external power supply is connected to a special low voltage connector, which is mounted directly to the PCB. Don't use a connector that can cause a short circuit when inserting or removing the plug.

When everything is finished, your circuit board should look the same as our completed prototype shown in **Figure 3**.

The dimensions of the enclosure are mainly responsible for determining the size of the 9.6-V battery (500 mAh is usually sufficient). If you do not consider portability a necessity then you can omit the entire battery

altogether.

A final remark regarding the construction: the DMX connections. In principle, our tester should be provided with two XLR connectors, one for receive (male connector) and the other for transmit (female connector). Because there are two standards within the DMX world, namely XLR3 and XLR5, you will have to choose between these two connectors and make some adapter cables if necessary. It should be noted that the XLR3 types are more common than the XLR5 version — they are also cheaper.

There are two possibilities when attaching the connectors. Either mount them directly on the enclosure or on the end of a short length of flexible wire that protrudes from the enclosure. The latter solution is much more convenient (in particular between lighting fixtures). The circuit board can accommodate either method.

Operation

To have a DMX tester is one thing, to know how to actually use it is another. When we are several meters up, among the lights, it would be nice to have a device that is easy to use, and in this respect the author has excelled himself.

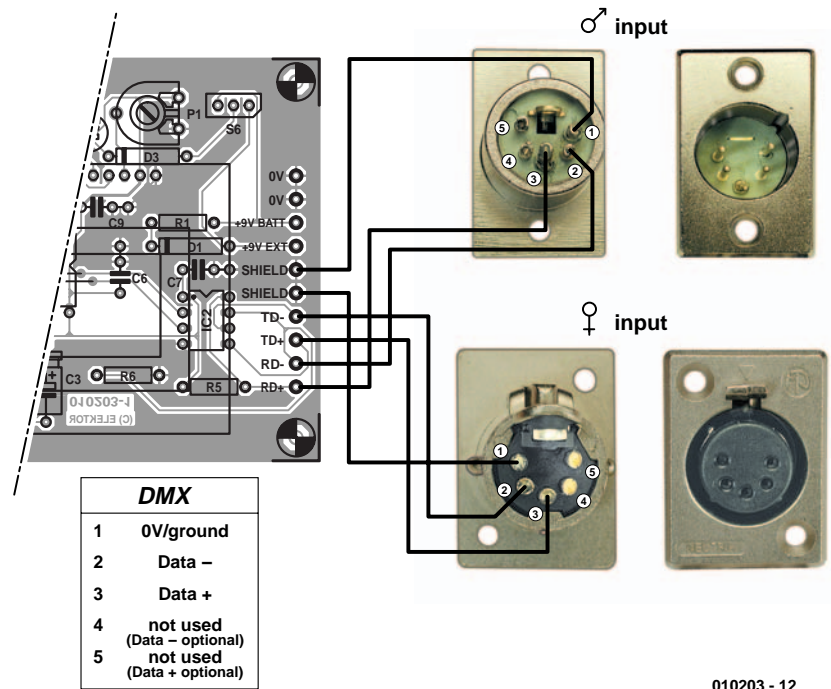
After switching on the power, the device identifies itself with the message 'DMX TESTER Vx.y' (x.y indicates the version of the program).

The tester can function as either a transmitter or a receiver, but not both at the same time. You first have to select the operating mode. The MODE button is used for this purpose. Every time this button is pressed the operating mode is changed. The display indicates the selected mode while the button is held down.

To send data from the tester the mode '* TRANSM. MODE' is selected. To display the data on the DMX line we select 'RECEIVE MODE *'. Note that you will have to connect to the correct DMX-line corresponding to the selected operating mode.

In transmit mode, the tester can generate data on 512 DMX channels, but only the values of the first 480 are selectable. Before you can transmit a value you first have to select the channel. Channel selection is achieved with buttons CHAN+ and CHAN-. If you press and hold a button the repeat function will activate which lets you rapidly step through all the channels. The selected channel is indicated with 'C:xxx'.

It is also possible to select the DMX Start Code to be transmitted. To do this, push the channel selection buttons until the display indicates 'C:S/C' (S/C is the abbreviation for



010203 - 12

Figure 4. Connection details for the XLR5-connectors and wiring diagram for the connections between the PCB and male and female XLR-chassis components.

Start Code).

To change the value of a channel or the Start Code it is enough the push the DATA+ and DATA- buttons. These buttons have a repeat function as well, activated by holding the button down.

Note that the selected values are retained in memory, even of another channel is selected.

In receive mode the operation of the tester is even simpler. As soon as the tester is connected to a DMX line, the values of the first 480 channels and the Start Code are stored. The values remain in memory, even if the connection is broken,

To indicate the proper operation of the DMX line a small animation is visible on the right of the display. When the parts move in a regular pattern this indicates that the tester is receiving valid DMX frames (detection of the Mark Time). If the character on the right doesn't change then the DMX line is not working properly or the line is interrupted somewhere.

To display the values that have been received on the various channels we only have to select the channels (just as in transmit mode) with the CHAN+ and CHAN- buttons.

The receive mode has two interesting properties. The first one causes all values in memory to be completely erased when switching to receive-mode. This is in order to avoid confusion with the in transmit-mode selected values (since the same memory is used for both transmitting and receiving). If you notice that certain channels continue to have the value 0, it is possible that they have not been written to (the transmitter may be limited to 256 or 384 channels). Secondly, there is the built-in function 'BlocNote DMX'. When the tester is in receive mode, the values in the different DMX-channels are stored in memory. This memory is not erased when the tester is switched back again to transmit mode (this is opposite to the behaviour when switching to receive mode). This makes it possible, for example, to store the configuration of the DMX-channels at a particular instant and subsequently replay them at a different installation.

As you can see, this tester is bursting with features. Your mission now, is to go hunt down the problems in your own installation.

(010203-1)

Tube Box

that authentic valve sound — using diodes

Design by M. Radler

The Tube Box lends to a solid state amplifier that characteristic valve sound required by any self-respecting guitarist.

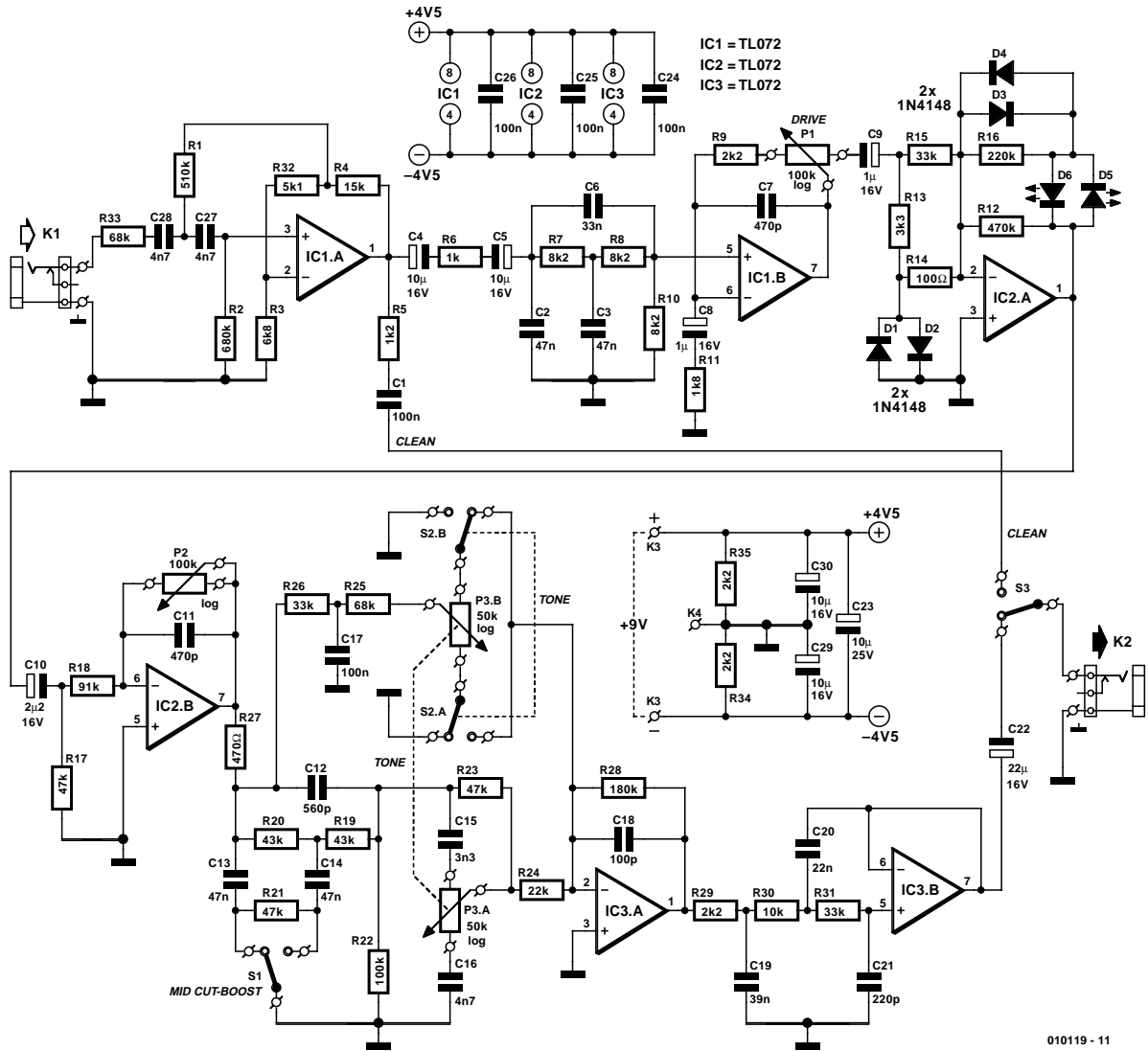


Guitar valve (or 'tube') amplifiers, as used on stage or in the studio, derive their characteristic sound from the clipping behaviour of the valves when overdriven. Whereas the effect of clipping in a solid state amplifier is very unpleasant (and for many this alone is reason enough not to touch them), it is common to drive valve amplifiers into clipping. But with a disadvantage: if a valve amplifier is to be overdriven, the volume control must be turned all the way up. This does not always go down well with the other band members (or with the neighbours!). With the Tube Box

circuit described here, which sits between the guitar and the valve amplifier, this is not necessary. The tiny unit applies the desired distortion to the input signal of the amplifier. The controls on the Tube Box are two potentiometers and two switches, which allow the user to choose from a wide range of possible settings, making the unit suitable for the whole spectrum of guitar music from smooth, warm blues to screaming heavy metal.

Before and after the diodes

The heart of the circuit, the distorter itself, is built around IC2.A. Two pairs of diodes, connected in anti-parallel, are responsible for creating the distortion. D1 to D4 clip the signal gently in a similar way to valve amplifiers, not suddenly as in solid state amplifiers. When the signal amplitude becomes very high, LEDs D5 and D6 also come into play and



010119 - 11

Figure 1. Several filters and a distortion stage: the Tube Box circuit.

reduce the gain of the op-amp. The combination of these two distortions simulates fairly accurately the distortion typically introduced by valves, since the clipping diode adds odd (and therefore pleasant-sounding) harmonics to the notes.

We now come to the circuitry before and after the distortion stage. In order for the distortion stage to work as 'naturally' as possible, the input signal must be suitably pre-processed. The signal from the guitar is first taken through a high-impedance input circuit that forms a filter, and then to operational amplifier IC1.A. The op-amp functions as a buffer-amplifier and prevents too high a load being presented to the high-impedance guitar pickup.

From the output the signal goes two ways: first, via a filter to

footswitch S3, and second, via a filter to IC1.B. This op-amp amplifies the signal by a factor of about 5. The footswitch allows the distortion circuit to be bypassed, taking the guitar's signal practically unchanged to the output socket.

On the way to the distortion stage the signal goes via a band-pass filter, and then to another buffer-amplifier. The band-pass filter has the effect of boosting the important part of the frequency spectrum. The gain is adjustable via potentiometer P1. Note that this affects not the volume, but rather the degree of distortion. The further the potentiometer is advanced, so the more distortion is applied to the signal before it arrives at IC2.B. Here, we have a further potentiometer with which the volume can be

adjusted so as to make the signal level at the output the same whether it goes through the whole circuit or whether it bypasses the circuit via S3. This ensures that there are no sudden jumps in volume when the guitarist switches between the distorted and the clean sound. Of course, P2 can also be adjusted to make the distorted signal louder than the undistorted, so that the guitarist's sound comes more into the foreground during a solo, for example.

There follows a fairly sophisticated tone control circuit with a range of possible functions. Switch S1 allows the user to choose between boosting and attenuating the middle-frequency range. Attenuation is especially suitable for 'harder' music, such as metal, while for the 'softer' blues solos the middle-frequency range should be boosted.

The tone adjustment is unusually constructed, but is nevertheless effective. Double-gang potentiometer P3 simultaneously

adjusts the treble and bass, while the position of S2 determines whether the bands are adjusted in the same or in opposite directions. Thus in one position the treble and bass are either boosted or attenuated together, while in the other position the bass is attenuated while the treble is boosted, and vice versa.

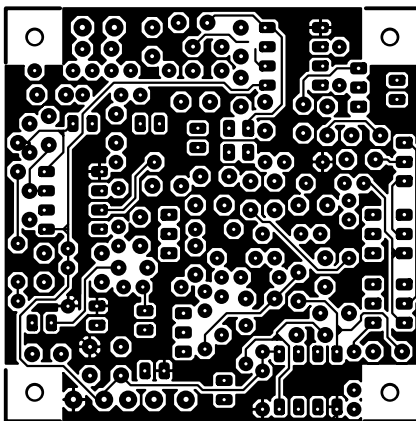
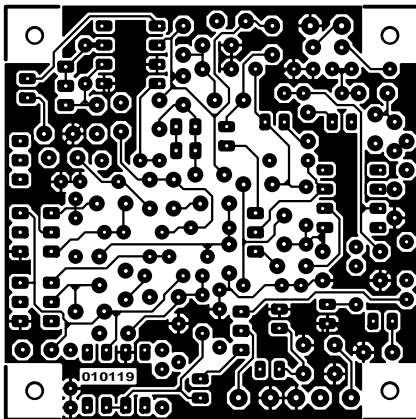
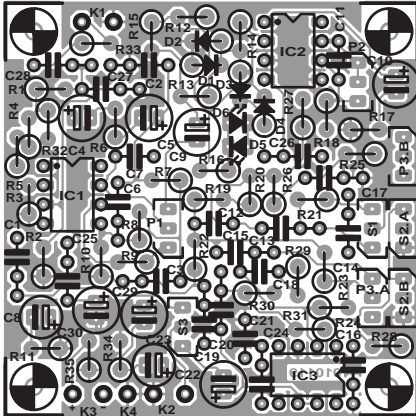
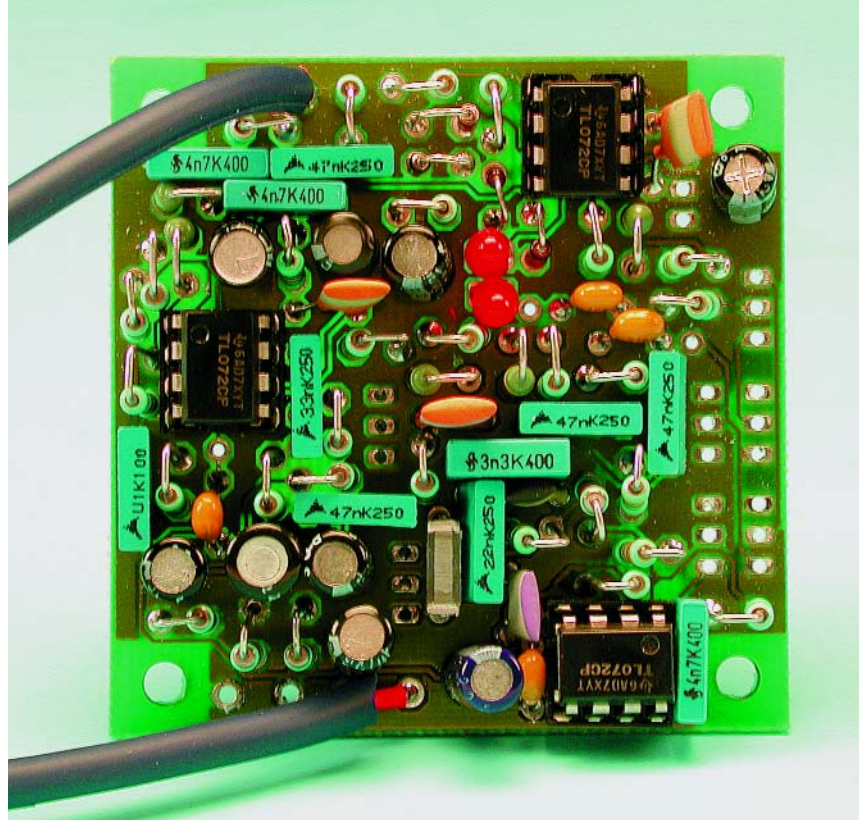


Figure 2. Layout and component mounting plan for the tiny printed circuit board (board available ready-made).



COMPONENTS LIST

Resistors:

- R1 = 511k Ω
- R2 = 680k Ω
- R3 = 6k Ω 28
- R4 = 15k Ω
- R5 = 1k Ω 2
- R6 = 1k Ω
- R7,R8,R10 = 8k Ω 2
- R9,R29,R34,R35 = 2k Ω 2
- R11 = 1k Ω 8
- R12 = 470k Ω
- R13 = 3k Ω 3
- R14 = 100 Ω
- R15,R26,R31 = 33k Ω
- R16 = 220k Ω
- R17,R21,R23 = 47k Ω
- R18 = 91k Ω
- R19,R20 = 43k Ω
- R22 = 100k Ω
- R24 = 22k Ω
- R25,R33 = 68k Ω
- R27 = 470 Ω
- R28 = 180k Ω
- R30 = 10k Ω
- R32 = 5k Ω 1
- P1,P2 = 100k Ω potentiometer, logarithmic law
- P3 = 50k Ω potentiometer, stereo, logarithmic law

Capacitors:

- C1,C17,C24,C25,C26 = 100nF
- C2,C3,C13,C14 = 47nF

- C4,C5,C29,C30 = 10 μ F 16V radial
- C6 = 33nF
- C7,C11 = 470pF
- C8 = 1 μ F 16V radial
- C9 = 1 μ F 16V radial
- C10 = 2 μ F2 16V radial
- C12 = 560pF
- C15 = 3nF3
- C16,C27,C28 = 4nF7
- C18 = 100pF
- C19 = 39nF
- C20 = 22nF
- C21 = 220pF
- C22 = 22 μ F 16V radial
- C23,C29,C30 = 10 μ F 16V radial

Semiconductors:

- D1-D4 = 1N4148
- D5,D6 = LED, red
- IC1,IC2,IC3 = TL072-CP*

Miscellaneous:

- K1,K2 = jack socket, 6.35mm, chassis mount*
- K3 = solder pin
- S1 = rocker switch, 1 x c/o
- S2 = rocker switch, 2 x c/o
- S3 = pedal switch
- Enclosure: Hammond type 1590B*
- PCB, order code 010119-1 (see Readers Services pages)

PCB layout available from Free Downloads section at www.elektor-electronics.co.uk

The output of the tone control circuit is connected via a buffer-amplifier. The signal now passes through a further high-pass filter and buffer, before being taken to the output connector via footswitch S3.

The distortion circuit can be powered from an external regulated mains supply, connected via low-voltage jack K1. Alternatively, a 9 V battery can be used to power the circuit. For this option, the type TL072 op-amp should be avoided in favour of low-current quad op-amps such as the pin compatible rail-to-rail OP470.

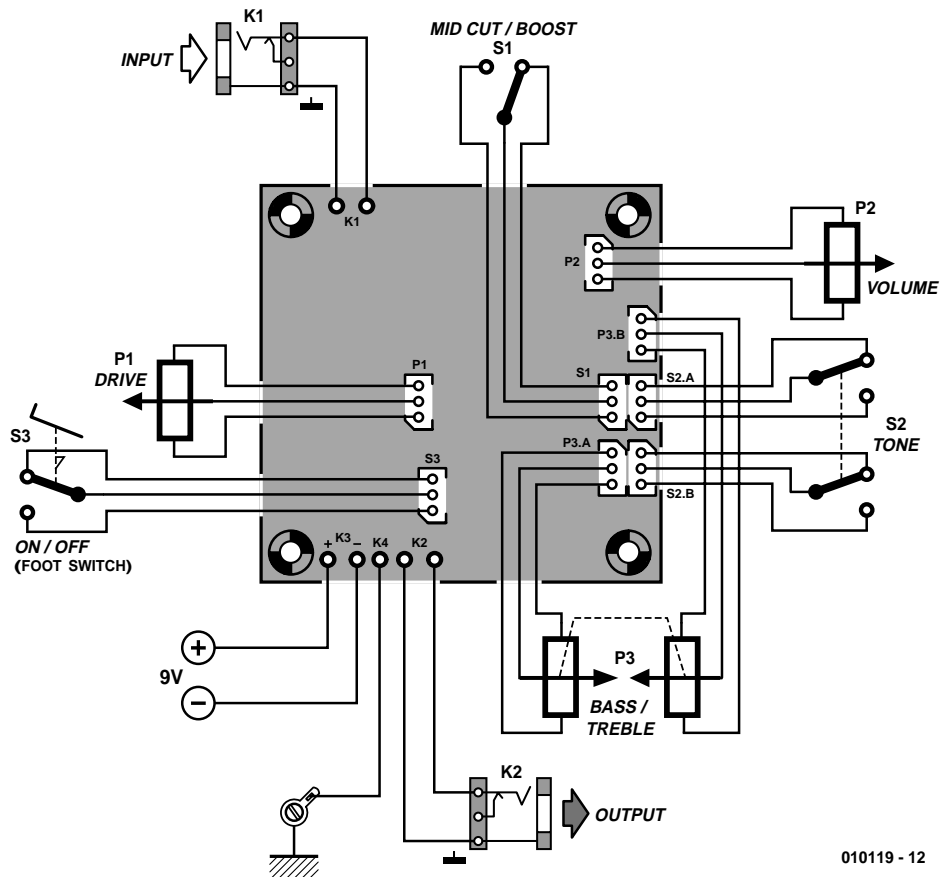
Construction and Test

Given the small dimensions of the circuit board (Figure 2), the component density is very high. The majority of components are mounted vertically, and so it is particularly important to fit the smaller components first and the taller ones later. So, first fit the diodes, the LEDs, the IC sockets and capacitors (with the exception of the electrolytics), the wiring to the potentiometers and switches, and finally the resistors, electrolytics and solder pins for the signal inputs and outputs, power supply and ground (screen).

Figure 3 shows how the controls are connected. The circuit board should be fitted in a suitably-sized metal enclosure to screen the electronics from interference. For the same reason, the circuit ground (on K4) should be connected to the enclosure. This can be done with a solder tag to the base of the enclosure. For our prototype we used a Hammond enclosure type 1590B, which is very small and does not have space for a battery. To save space, instead of chassis-mounted jack sockets we used a short length of screened audio cable to connect the inputs and outputs to in-line jack sockets. Strain relief is essential for these cables.

If you would prefer to use chassis-mounted jack sockets, a larger enclosure will be required. Then no solder tag ground connection to the enclosure will be required, since jack sockets which are not isolated from the enclosure will do the job instead.

As well as screening the electronics, the metal enclosure has another advantage: it is very robust



010119 - 12

Figure 3. The connections at a glance.

and so can stand up to rough treatment on stage.

To test the unit, connect up the Tube Box and set volume control potentiometer P2 to its minimum position. Strike a chord on the guitar: if nothing can be heard, press the footswitch to bypass the unit. Press the footswitch again, and the distortion circuit is switched in and P2 can be adjusted to set the desired volume. Finally, set the degree of distortion using P1 and adjust the tone as required using S1, S2 and P3.

(010119-1)

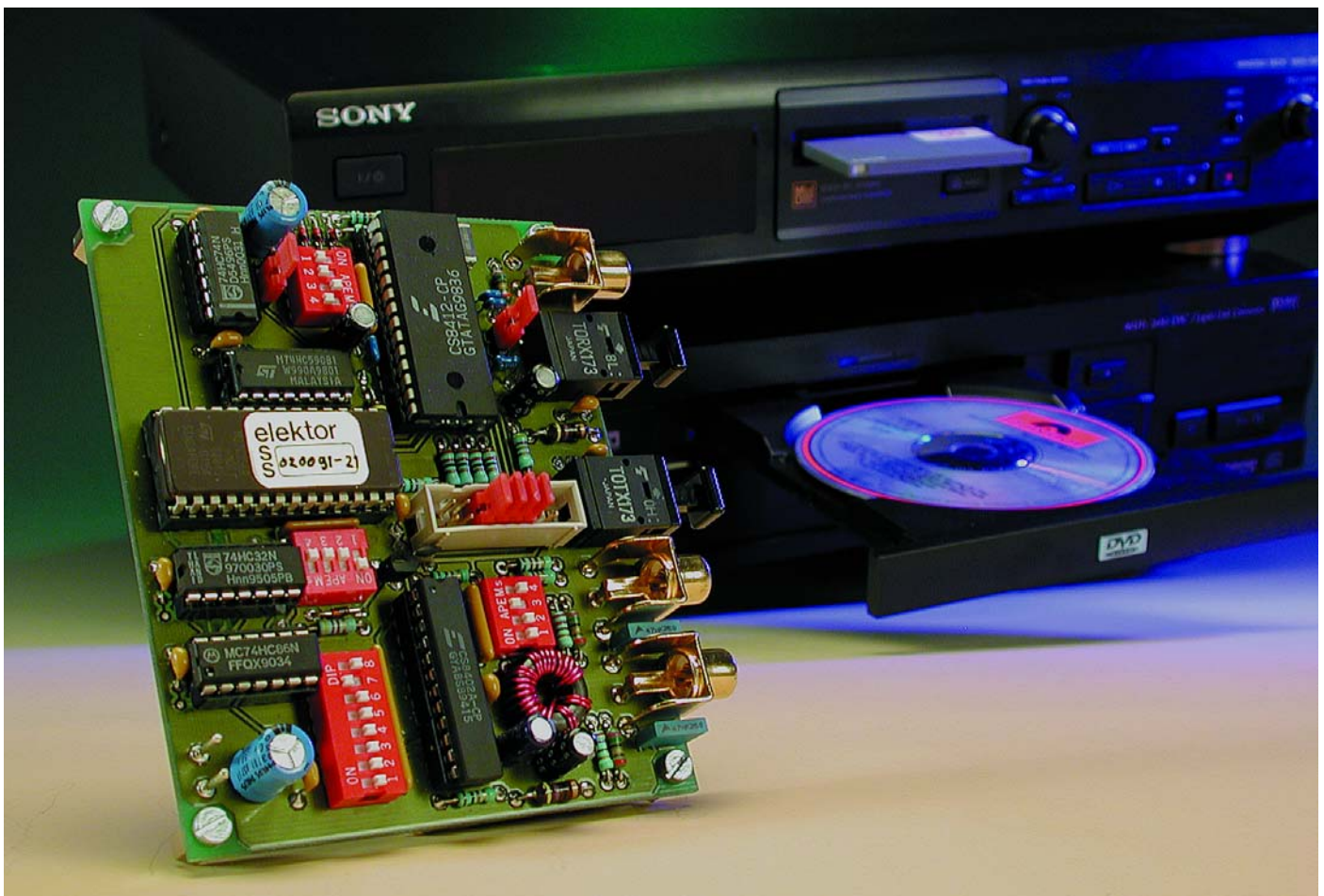


DASP-2002 Digital Audio Signal Processor

not just for the copybit

Design by T. Giesberts

This circuit can be included in every S/PDIF link between two digital audio devices (CD player, DVD player, CD recorder or MD recorder). Besides allowing the notorious copybit to be modified, it can be regarded as a sort of universal processor for digital audio signals.



The circuit described here is exclusively intended to be used for the digital recording or processing of personal musical works. The editorial staff dissociate themselves from any unlawful use of this circuit involving the infringement of copyrights resting on audio media such as CDs, MDs or DVDs.

Modern copy protection systems, such as Cactus Data Shield, SafeAudio and Key2Audio, generally exploit the characteristics of the drive and thus cannot be affected by the circuit described here.

Unlike a similar circuit design previously published in *Elektor Electronics*, this new design is thus truly more than just a 'copybit killer'. Naturally, this application is the key feature here — certainly since we have become aware that the DVD Serial Copy Management System often makes it impossible to make the permitted single copy. For audiophiles who want to compile and process their own versions of digital audio signals, the copybit is thus always a

major hindrance. However, the circuit described here has more to offer. For instance, the audio data can also be processed, possibly using a DSP, and the circuit can also convert a coax signal to an optical signal and vice versa, which is a handy extra feature that makes this device quite a bit more universal in use.

As far as manipulating the digital data is concerned, we can note up front that not only is it possible to modify the copybit, it's also possible to replace nearly the complete content of the channel status register (which includes the copybit). Only the data related to the sampling rate, emphasis and word length are always passed through unchanged. The user bit and validity bit can also be modified. With the user bit, by the way, the most that can be contemplated is to totally clear the bit. Since both channels are used in the consumer format, the total user-bit data stream amounts to 88,200 bits/s for a CD.

The most important task of this circuit is to modify the channel status bit, which involves separate bits for subframes 1 and 2. However, in practice the same information is placed in both data blocks. Most receivers usually check only one of the two subframes, so the received data for the two subframes are set or modified identically. The only limitation of this circuit is that the modifications are made per channel status block (192 frames), since the user channel data is not tied to the size of this block. For more information, you are referred to the consumer format specification IEC 60958-3. The validity bit is also present in each frame and can be modified, should this be desired.

Design

The design of this circuit has intentionally been kept as universal as possible in order to provide avid experimenters a broad range of options. Readers who always take a quick peek at the full schematic (**Figure 3**) will have noticed that although the schematic is reasonably extensive, most of it is contained in a limited number of ICs. At the risk of oversimplifying things, we could say that the circuit consists of an integrated S/PDIF receiver (IC1) and an integrated S/PDIF transmitter (IC2) with a binary counter (IC6) and an EPROM (IC9) fitted between them (between the channel status outputs CI, UI and VI of IC1 and the channel status inputs VO, CO and UO of IC2). The EPROM can be regarded as the actual heart of the circuit. A four-way DIP switch for the address inputs of the EPROM allows 16 different tables to be selected. The default settings of the four DIP switches to enable the circuit to function as a copybit killer are listed in **Table 1**. Presently only the first three tables are used.

S/PDIF receiver and transmitter

For IC1 and IC2 we have selected a set of standard Crystal ICs (www.cirrus.com), consisting of a CS8412-CP receiver and a CS8402A-CP transmitter. Thanks to these ICs, the circuit is suitable for use with sampling rates ranging from 32 kHz to 48 kHz. We have used these two ICs fairly often in past projects, so for more detailed information about them we refer you to the manufacturer's data sheets and the articles 'Digital VU Meter' (April 1996) and 'Sampling Rate Converter' (October 1996). Here we can suffice with a brief description.

The CS8412 is a CMOS IC specially designed for receiving and decoding audio data in the usual standard formats (AES/EBU, IEC958, S/PDIF and EIAJ CP340). This IC, which has been given the handsome name 'digital audio interface receiver' by its maker, receives the signal via an RS422 serial interface and derives the clock and synchronisation signals from the received signal. There is support for 256× oversampling, since the clock frequency of the output signal is 256 times the frequency used for sampling.

The audio and digital information is also demultiplexed in an effective manner. The CS8412 demultiplexes the channel, user and validity data directly to the serial outputs, with dedicated pins for the most important channel status bits (C, U and VERF). The audio data are output via a special serial audio port that supports 14 formats. The data are available on the SCK, FSYNC and SDATA

Table 1.

The default settings of all the switches and jumpers.

S1 :	S1-1 OFF	
	S1-2 OFF	
	S1-3 ON	
	S1-4 OFF	
S2 :	S2-1 OFF	
	S2-2 OFF	
	S2-3 ON	
	S2-4 N.C.	
S3 :	S3-1 OFF	
	S3-2 OFF	
	S3-3 OFF	
	S3-4 OFF	
	S3-5 OFF	
	S3-6 OFF	
	S3-7 ON	
	S3-8 OFF	
S4 :	S4-1 ON	
	S4-2 OFF	
	S4-3 OFF	
	S4-4 OFF	
JPI :	coax	
JP2 :	256	
K2 :	5-6	jumper
	7-8	jumper
	9-10	jumper
	11-12	jumper

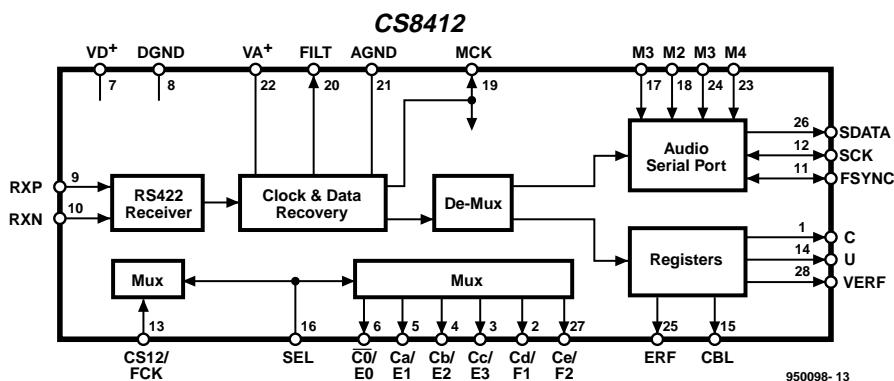


Figure 1. Block diagram of the S/PDIF receiver CS8412.

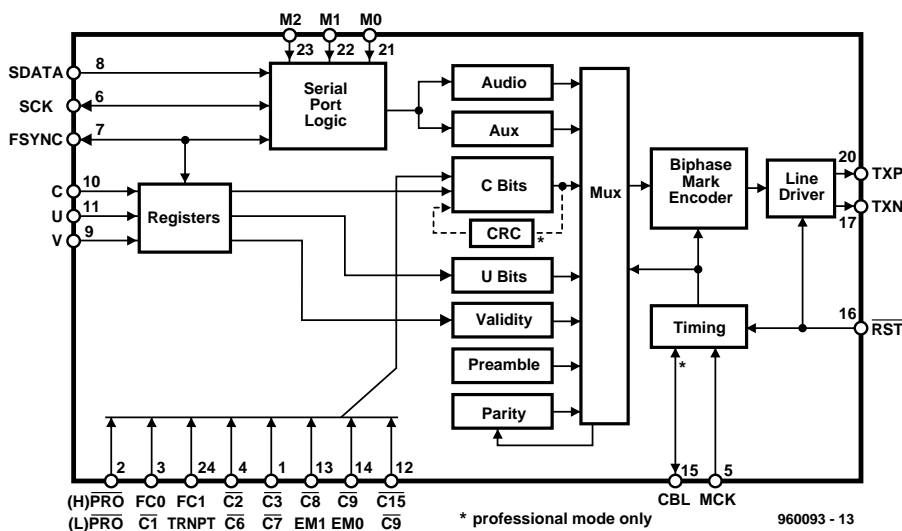


Figure 2. Block diagram of the internal structure of the CS8402A.

pins, and these output pins can be configured using the four control pins M0–M3. As can be seen in the schematic diagram, in our case a four-way DIP switch (S1) is connected here for this purpose. **Figure 1** shows a simplified block diagram of the CS8412.

Next we have the CS8402A, a ‘digital audio interface transmitter’. As you have doubtless already guessed, this IC is specially intended to be used to encode and transmit audio data in accordance with the previously mentioned interface standards. It allows the values of the most important channel status bits to be set using seven inputs. These can be seen at the lower left of the internal block diagram of the IC (**Figure 2**). If you look again at the full schematic diagram in **Figure 3**, you will see that they can be set using an eight-way DIP switch (S3). All seven inputs also have dual functions, depending

on the state of pin 2 (PRO). This input (which can be switched using S3-8) determines whether the IC operates in the ‘professional’ or ‘consumer’ mode. In both cases, the audio data are encoded using the associated applicable standard. In the professional mode (S3-8 open), a CRC code can also be generated (channel status bit 23), as indicated by the dashed outline in the block diagram.

The serial input (pins 6, 7 and 8) can process seven different formats and audio samples with lengths of 16 to 24 bits. The format can be specified using M0, M1 and M2, and in **Figure 3** you can see that here again we use a DIP switch (S2) for this purpose. The serial inputs for

channel status (C), user data (U) and validity (V) are connected to the EPROM (IC7) via several gates (IC8 & IC9) – we’ll say more about this shortly.

Figure 3 also shows that the symmetrical TXP/TXN output of the CS8402A is converted into two standard S/PDIF outputs K3 and K4 (0.5 V_{pp} / 75 Ω) using a (home-made) transformer Tr1. The electrical isolation provided by the transformer has the additional advantage of preventing earth loops. An optical output is also generated using IC4.

Juggling bits

Using jumper JP1, you can select whether the coax input signal or the optical input signal is to be fed to the receiver. Beside the audio data, IC1 also decodes the U, C and V bits. The VERF output represents the received V bit OR’ed with the internal error flag ERF, which is active in the event of a parity error, biphasic coding violation or unlocked PLL receiver. An active V bit means that there is something wrong with the associated audio sample, in which case the data can be muted by the DAC or recorder. These three bits are connected to a number of gates (IC8 / IC9), by means of which four states can be defined for each bit. For each frame (using the same option for each subframe), each bit can be sent to the transmitter unchanged, inverted, as a fixed ‘0’ or as a fixed ‘1’. An OR gate, an XOR gate and two data bits from the EPROM are used to generate each of these four combinations: D0/D1 for the channel status bit, D2/D3 for the user channel bit and D4/D5 for the validity bit.

As an example, let’s look at the combinations of D0/D1 for the C bit. With the combination 0/0 (no change), CI is passed through unchanged by the OR gate (IC8a) and the XOR gate (IC9a). With 1/0 (constant ‘1’), there is a ‘1’ at the outputs of both gates. With 0/1 (inverted), CI is passed through by the OR gate but inverted by the XOR gate. Finally, with 1/1 (constant ‘0’) there is a ‘1’ at the output of the OR gate, which is inverted by the XOR gate.

The outputs of the gates are connected to the transmitter inputs hav-

ing the same designations. In order to be able to use these bits, the transmitter must be set to the professional mode (S3-8 open = OFF) and also be switched into transparent mode (S3-7 closed = ON). The rest of S3 then no longer has any function.

An eight-bit binary counter with an output register (IC65, a 74HC590) is used to address the EPROM. The counter is clocked by the inverted frame synchronisation signal FSYNC.

Since the output register is clocked by the master clock MCK, the address for the next frame only becomes active after the transmitter has already latched the second (right-channel) subframe (the delays of the XOR, counter and EPROM also contribute to the timing). The 'channel status block start' output (CBL) is used to synchronise the counter with to channel status block. A differentiator network composed of R20/C16, T1 and R21 generates a

reset pulse that is applied to the counter clear input of the counter to cause it to resume counting from zero (after 192 frames). Since the transmitter CBL pin can also sometimes be an output, depending on the mode, R22 is inserted in this lead to prevent any problems from occurring.

EPROM data

The most important aspect of the circuit is determining the data for the EPROM. For this we need to know the composition of the

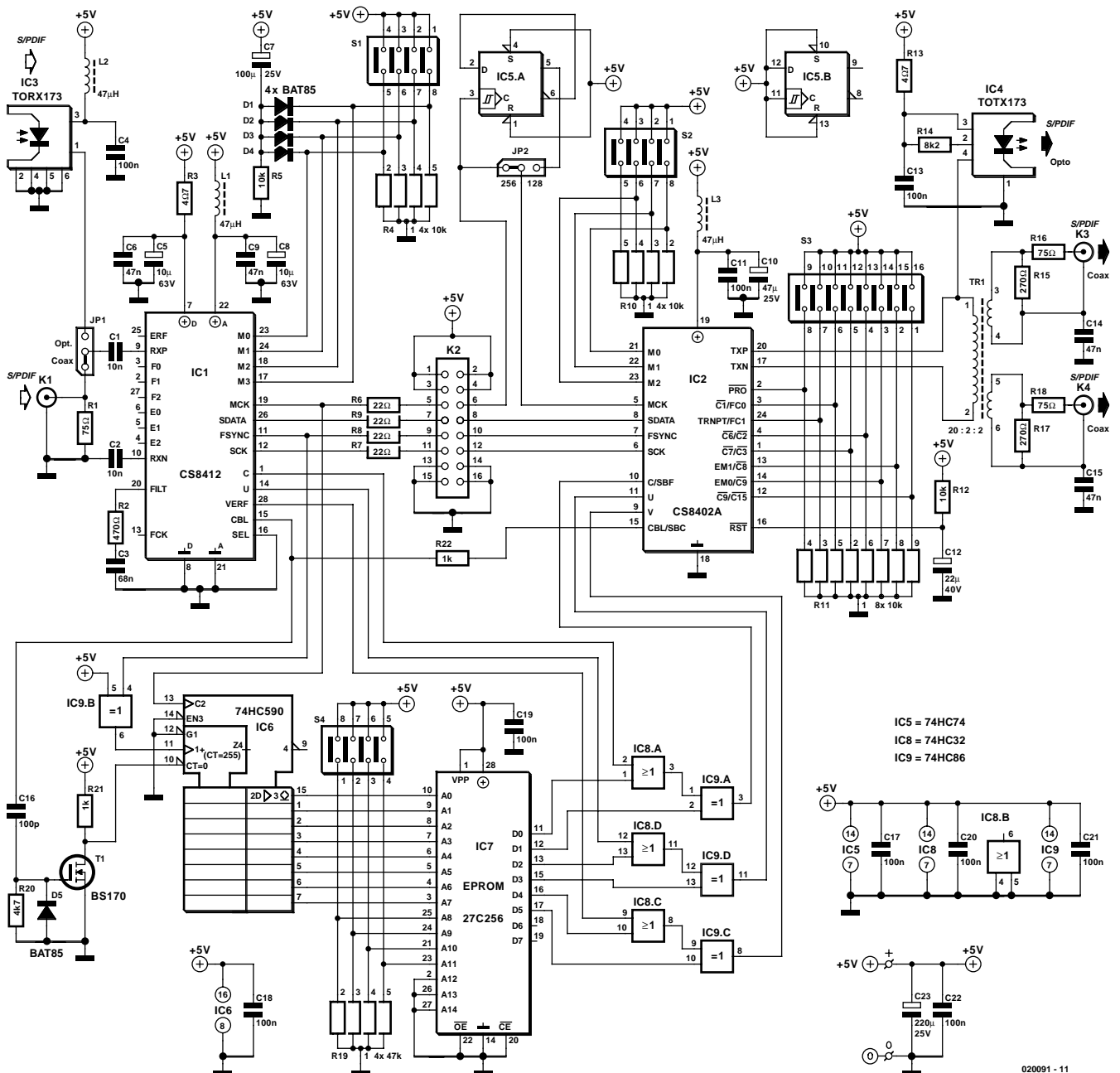


Figure 3. The circuit is designed to be as universal as possible. Practically every possible modification can be realised using the four DIP switches.

channel status block. **Table 2** shows the content of this block for the consumer mode, with brief explanations of the various bits in **Table 3**. Finally, **Table 4** shown what the channel status block looks like after having been processed by the circuit in the default configuration (the second table in the EPROM). In the last of these tables, 'INP' means the original bit in the input signal (INPUT). 'DAT' has been chosen as the category code, since this gave the fewest problems in past experience. The rest is self-explanatory.

If we translate the individual bits in Table 4 into the bit combinations for the EPROM, this (in combination with the choice of U and V bits) yields the data for the EPROM shown in **Table 5** (msb/l sb: U ⇒ 00, 1 ⇒ 01, 0 ⇒ 11).

Table 5 is incorporated in the EPROM as the second table (S4-1 ON). The first table (S4-1/2/3/4 OFF) allows all data to pass unchanged, for which all data bits in the EPROM are '0'. As a small extra, there is also a third EPROM table (S4-1/3/4 OFF, S4-2 ON) that makes the validity bit always '1'. However, we have not tested any recorder that refused the data on this account (the data are otherwise the same is with the second EPROM table). If you have the necessary tools, you can experiment using the remaining 13 tables of the EPROM.

Extra feature

As can be seen from Figure 3, the audio data pass from the receiver to the transmitter via box header K2. This means that it is necessary to fit four jumpers to this header to loop through four signals (see also Table 1).

The presence of K2 also makes it possible to process the audio data if desired, for example using a DSP. In that case, the data format is naturally determined by the settings of the receiver (default: format 2, I2S-compatible).

Soldering

Well, it's about time to pick up the soldering iron. In order to avoid having to insert a lot of wire bridges (one of which is always overlooked, guaranteeing that the circuit won't work!), a double-sided printed circuit board has been developed for this digital audio processor. Figure 4 shows the component layout and the track layouts for both sides. As can be seen, the design of the circuit board is well organised and compact. Where there is sufficient room, the functions of the DIP switches are indicated in addition to their numbers. Be careful with S1, since here S1-4 corresponds to M0. The Cinch sockets and

Consumer format channel status fields							
0	Pro/con = 0	Non-audio = 0	Copyright	Emphasis			Channel status mode = 00
	bit 0	1	2	3	4	5	6 7
1	Category code						
	bit 8	9	10	11	12	13	14 15
2	Source number			Channel number			
	bit 16	17	18	19	20	21	22 23
3	Sampling frequency			Clock accuracy			
	bit 24	25	26	27	28	29	30 31
4	Word length			(Future original sampling frequency?)			
	bit 32	33	34	35	36	37	38 39
5-23	Reserved						
	bits 40-191						

Table 2. The content of the channel status block for the consumer format.

Consumer format channel status field interpretations																				
Bits	label	interpretation																		
0	pro/con	0: consumer; 1: professional format																		
1	non-audio	0: suitable for conversion to analog audio using linear PCM 1: not suitable																		
2	copyright	0: asserted; 1: not asserted																		
3-5	emphasis	000: Emphasis not indicated 100: emphasis—CD-type																		
6-7	channel status mode	00: mode zero; other values reserved																		
8-15	category code	The category code depends on the equipment type. For most codes the MSB of the category code carries information about generation status of the material (refer to SCMS), and is called the L-bit. The following are common codes: <table border="0" style="margin-left: 20px;"> <tr> <td></td> <td>LSB</td> <td>MSB</td> </tr> <tr> <td>CD player</td> <td>1000</td> <td>0000</td> </tr> <tr> <td>DAT player</td> <td>1100</td> <td>000L</td> </tr> <tr> <td>DCC player</td> <td>1100</td> <td>001L</td> </tr> <tr> <td>Mini disc</td> <td>1001</td> <td>001L</td> </tr> </table>		LSB	MSB	CD player	1000	0000	DAT player	1100	000L	DCC player	1100	001L	Mini disc	1001	001L			
	LSB	MSB																		
CD player	1000	0000																		
DAT player	1100	000L																		
DCC player	1100	001L																		
Mini disc	1001	001L																		
16-19	source number	(bit 16 is LSB)																		
20-23	channel number	(bit 20 is LSB)																		
24-27	sampling frequency	0000: 44.1 kHz 0100: 48 kHz 1100: 32 kHz																		
28-29	clock accuracy	10: Level I, ±50 ppm 00: Level II, ±1000 ppm 01: Level III, variable pitch shifted																		
30-31	reserved																			
32	word length (field size)	0: Maximum length 20 bits 1: Maximum length 24 bits																		
33-35	word length	<table border="0" style="margin-left: 20px;"> <tr> <td>000:</td> <td>if bit 32 = 1 not indicated</td> <td>if bit 32 = 0 not indicated</td> </tr> <tr> <td>101:</td> <td>24 bits</td> <td>20 bits</td> </tr> <tr> <td>001:</td> <td>23 bits</td> <td>19 bits</td> </tr> <tr> <td>010:</td> <td>22 bits</td> <td>18 bits</td> </tr> <tr> <td>011:</td> <td>21 bits</td> <td>17 bits</td> </tr> <tr> <td>100:</td> <td>20 bits</td> <td>16 bits</td> </tr> </table>	000:	if bit 32 = 1 not indicated	if bit 32 = 0 not indicated	101:	24 bits	20 bits	001:	23 bits	19 bits	010:	22 bits	18 bits	011:	21 bits	17 bits	100:	20 bits	16 bits
000:	if bit 32 = 1 not indicated	if bit 32 = 0 not indicated																		
101:	24 bits	20 bits																		
001:	23 bits	19 bits																		
010:	22 bits	18 bits																		
011:	21 bits	17 bits																		
100:	20 bits	16 bits																		
36-39	reserved																			
40-191	reserved																			

Table 3. Summary explanation of the bits in Table 2.

Table 4

The channel status block after processing by the circuit (using the default settings).

	LSB							MSB	
Byte 0	0	0	1	INP	INP	INP	0	0	
Byte 1	1	1	0	0	0	0	0	0	
Byte 2	0	0	0	0	0	0	0	0	
Byte 3	INP	INP	INP	INP	0	0	0	0	
Byte 4	INP	INP	INP	INP	0	0	0	0	
Bytes 5-23	0	0	0	0	0	0	0	0	

and there is actually no reason why it cannot be completed in a couple of hours. There are not any SMD components or other 'troublesome' components on the board, the ICs can be simply inserted in sockets and there is no need to fit components on the bottom side of the board.

The only thing that might be considered to be somewhat difficult is winding the transformer for Tr1. Actually, it's dead easy. For this we use a Ferroxcube (formerly Philips) core, type TN13/7,5/5-3E25. The primary winding consists of 20 turns and the two secondary

Table 5

The translation of Table 4 into bit combinations for the EPROM.

Byte 0	0000011	00000011	00000001	00000000	00000000	00000000	00000011	00000011
Byte 1	00000001	00000001	00000011	00000011	00000011	00000011	00000011	00000011
Byte 2	00000011	00000011	00000011	00000011	00000011	00000011	00000011	00000011
Byte 3	00000000	00000000	00000000	00000000	00000011	00000011	00000011	00000011
Byte 4	00000000	00000000	00000000	00000000	00000011	00000011	00000011	00000011
Bytes 5-23	00000011	00000011	00010011	00000011	00000011	00000011	00000011	00000011

(All C bits starting with the most significant nibble of byte 4 are set to '0'.)

optical connectors are all located along one side of the board, which simplifies fitting the board into an

enclosure.

Assembling the circuit board should hardly present any problems,

windings consist of two turns each, all using 0.5-mm (SWG24 or SWG26) enamelled copper wire. Space the 20 turns of the primary winding neatly around the toroidal core, leaving a bit of space in the middle for the two secondaries, which are subsequently wound in between. Figure 5 gives a good picture of what is intended.

Once you have fully assembled the circuit board and carefully checked it against the component layout drawing and components list, you can connect a suitable 5-V power supply to the two pins marked '0' and '+5V'. Any power supply that can deliver a reasonably well regulated voltage at a current of at least 100 mA will be satisfactory.

Once the power supply has been connected, it's a good idea to use a multimeter to check whether the desired 5-V voltage is in fact present across C5 and C10. If this test is successful, there is a good chance that the rest of the assembly is also in order. Should problems nevertheless arise in use, there must be an assembly error, and this can only be found by careful inspection of the entire circuit board. Unfortunately, no measurement points or test voltages can be indicated here, since this is a fully digital circuit with the exception of the supply lines. However, if the board has been assembled with due care, it is highly likely that it will work straight away.

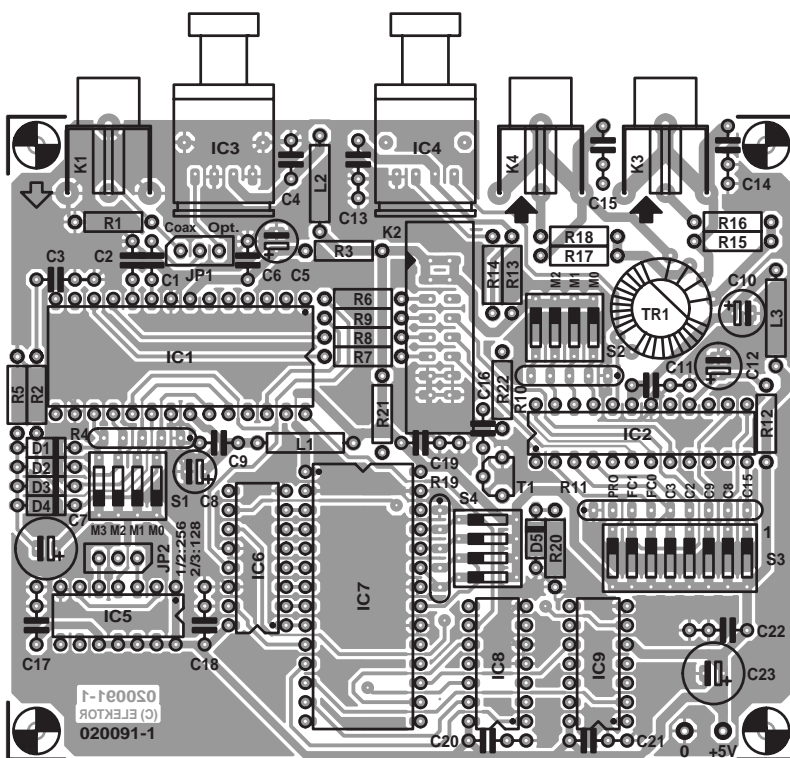


Figure 4. The double-sided printed circuit board is relatively compact and easy to assemble.

(020091-1)

COMPONENTS LIST

Resistors:

- R1,R16,R18 = 75Ω
- R2 = 470Ω
- R3,R13 = 4Ω7
- R4,R10 = 4-way 10kΩ SIL array
- R5,R12 = 10kΩ
- R6...R9 = 22Ω
- R11 = 8-way 10kΩ SIL array
- R14 = 8kΩ2
- R15,R17 = 270Ω
- R19 = 4-way 47kΩ SIL array
- R20 = 4kΩ7
- R21,R22 = 1kΩ

Capacitors:

- C1,C2 = 10nF ceramic, lead pitch 5mm
- C3 = 68nF
- C4 = 100nF ceramic, lead pitch 5mm
- C11,C13,C17-C22 = 100nF ceramic
- C5,C8 = 10μF 63V radial
- C6,C9 = 47nF ceramic, lead pitch 5mm
- C7 = 100μF 25V radial
- C10 = 47μF 25V radial
- C12 = 22μF 40V radial
- C14,C15 = 47nF
- C16 = 100pF
- C23 = 220μF 25V radial

Inductors:

- L1,L2,L3 = 47μH

Semiconductors:

- DI-D5 = BAT85
- T1 = BS170
- IC1 = CS8412-CP Crystal/Cirrus Logic (RS Components)
- IC2 = CS8402A-CP Crystal/Cirrus Logic (RS Components)
- IC3 = TORX173 (Toshiba)
- IC4 = TOTX173 (Toshiba)
- IC5 = 74HC74
- IC6 = 74HC590
- IC7 = EPROM 27C256, programmed, order code **020091-21**
- IC8 = 74HC32
- IC9 = 74HC86

Miscellaneous:

- JP1,JP2 = 3-way pinheader with jumper
- K1,K3,K4 = cinch (RCA) socket, PCB mount (e.g., T-709G from Monarch/Monacor)
- K2 = 16-way boxheader with 4 jumpers
- S1,S2,S4 = 4-way DIP-switch
- S3 = 8-way DIP-switch
- Tr1 = primary 20 turns 0.5 mm ECW, secondary 2 x 2 turns on Ferroxcube core TN13/7,5/5-3E25
- PCB, order code **020091-1** (see Readers Services page)

PCB layout and EPROM contents also available from Free Downloads section at www.elektor-electronics.co.uk

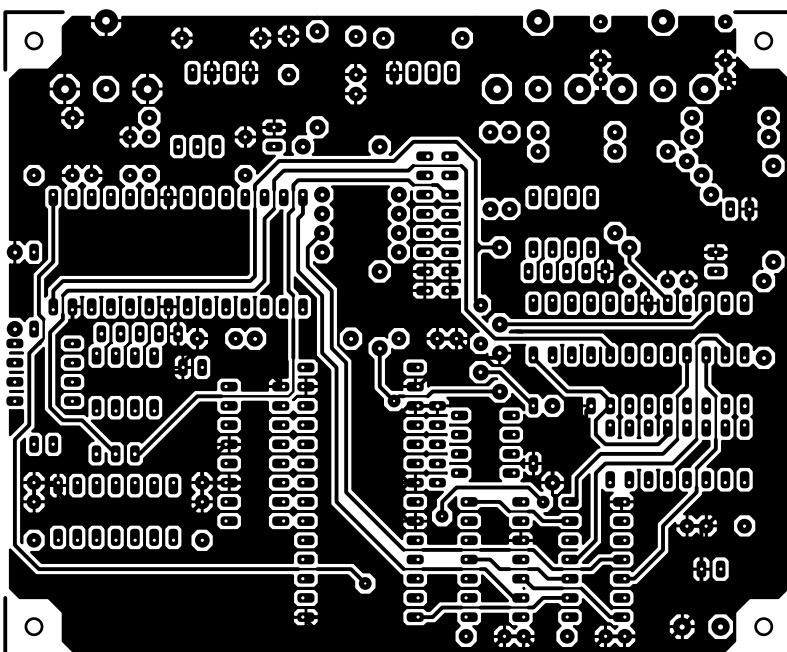
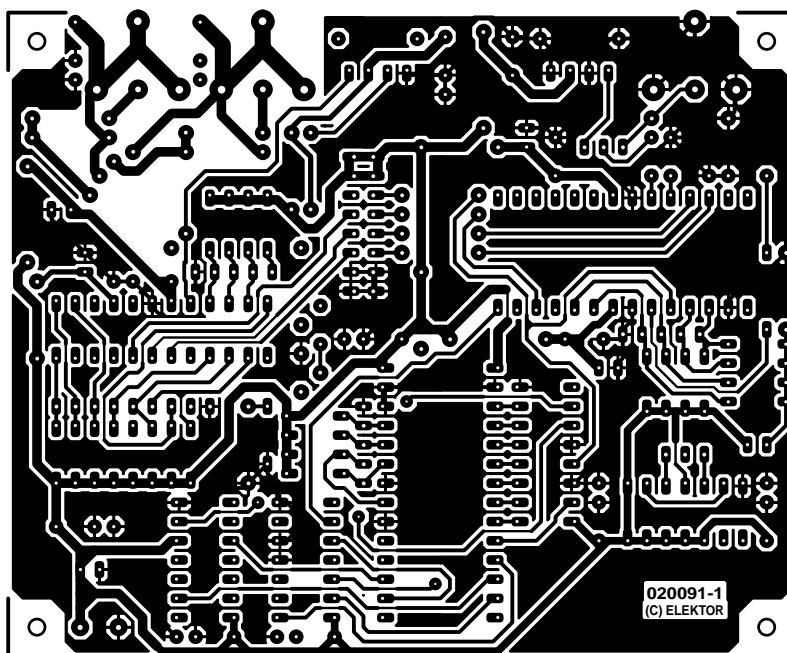


Figure 5. Transformer Tr1 can easily be wound on a small toroidal core.

Microcontroller Basics Course (6)

part 6 (final): driving an LCD

By B. Kainka

Data output from the Flash Board usually takes place via the connected terminal, which means the PC. However, for stand-alone use without a terminal, a display is sometimes necessary.

Using an intelligent LC display with its own display controller in combination with a microcontroller board is very convenient. The display controller already contains its own character generator and can be commanded to output ASCII characters without an undue amount of effort.

Nowadays, almost all intelligent LCDs comply with the same standard. Here we will use a standard model with two lines of 16 characters. The connections to the display are listed in **Table 1**.

Table 1. LCD module connections

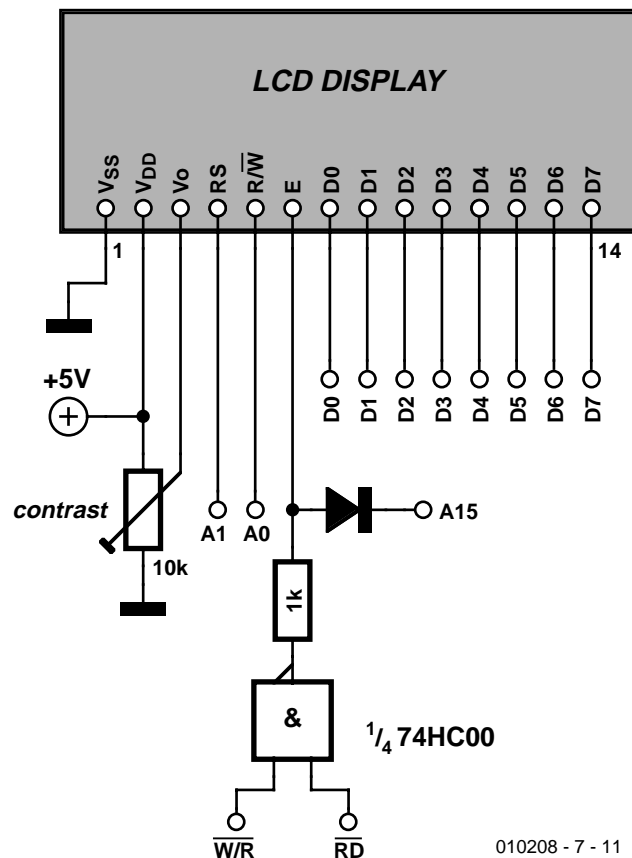
Pin	Signal
1	V _{SS} , 0V
2	V _{DD} , +5V
3	V ₀ , contrast setting (0–2V)
4	RS, 1 = data, 0 = command
5	R/W, 0 = write, 1 = read
6	E, Enable signal, active High
7...14	Data bus, D0–D7

The data transfer follows the bus protocol of a 6800 processor. First the data direction must be set using the R/W line, following which the actual access takes place by means of a positive Enable pulse. With an 8051 processor, it is thus necessary to use a gate to combine the \overline{RD} and \overline{WR} signals. The data direction can be switched using an address line. An additional address line is needed to select the internal registers of the display controller via the RS line. This distinguishes

between data and commands.

The display is connected to the controller by means of a very simple

driver circuit without any address decoding, as shown in **Figure 1**. The display addresses appear above



010208 - 7 - 11

Figure 1. LCD hardware interface

address 8000h and are mirrored several times. Unfortunately, this means that it is not possible to use the board with an EEPROM in the same memory region.

Write accesses are only allowed with A0 = 0, since with A0 = 1 the display places its data on the bus. Since **WR** and **RD** are NANDed (which corresponds to WR OR RD due to the inversion), a write instruction to a read address would result in a bus conflict. Only the following addresses are thus available for driving the display:

The command register of the display can also be read back. It then supplies its Busy flag (BF) and the current cursor position (see **Table 3**). BF must without exception be tested before every write access to the LC display. A command or data may only be written to the display when BF is Low. Otherwise the display controller can be destroyed.

After power has been switched on, a few initialisation bytes must be written to the command register. An example is shown in **Table 4**.

The display has an internal data pointer assigned to the individual

program does without testing the Busy Flag, which does not cause any problems as long as driver execution from a pure BASIC-52 program takes place relatively slowly.

LCD driver for BASIC-52

Outputting individual characters is not particularly convenient in BASIC-52. However, the interpreter has a provision for an extension in the form of a specific driver that can be used to redirect PRINT commands. For this purpose, the user must generate an output routine that reads characters from register R5 (Bank 0) and directs them to the output, in this case the LCD. The user output command U0 1 can be used to redirect the output to a custom driver. When processing a PRINT command, the system jumps to address 4030h once for each character. A jump instruction to the output routine must be located at this address.

Another option for using a custom driver is provided by the PRINT@ command. This jumps to address 403Ch, where again a jump instruction to the output routine should be located. A custom driver routine will in any case only be active if bit 39 of the internal RAM (bit 7 of address 24h) is set. This can be done as part of the display initialisation routine, which is anyhow necessary.

The extension presented here includes the LCD driver along with the command extensions described below. BASIC-52 already provides numerous aids for its external extensions. Machine-language subroutines must obey the following rules:

- all registers except the eight registers in Bank 3 (18h–1Fh), along with the accumulator and the data pointer, must remain unchanged;
- the user may fully use Bank 3 for his own purposes.

Before the driver is used for the first time, the display must be prepared by calling the initialisation routine (CALL 4250h). For such user-generated functional extensions, BASIC-52 allows special calls using CALL 00, CALL 01, CALL 02 and so on up to CALL 127, which are automatically redirected to addresses 4100h, 4104h and so on up to 41FEh. Suitable jump instructions to the actual addresses allow the LCD initialisation routine (CALL 00) and the cursor routine to be called in a simplified manner. The cursor must be set using an a supplementary parameter:

CALL 427FH 0

or using the short form:

Function	7	6	5	4	3	2	1	0
Clear display	0	0	0	0	0	0	0	1
Cursor home	0	0	0	0	0	0	1	x
Shift	0	0	0	0	0	1	ID	S
	(ID= 1/0: right/left, S= 1/0: without/with text)							
Display & cursor	0	0	0	0	1	D	C	B
	(D,C,B= 1/0: Display, Cursor, Blink on/off)							
Shift	0	0	0	1	SC	RL	x	x
	(SC= 1/0: text/cursor to RL= 1/0: right/left)							
Initialisation	0	0	1	DL	N	x	x	x
	(DL= 1/0: 8/4-bit bus, N= 1/0: both lines/one line)							
Character generator	0	1	character			space		
Cursor position	1	memory address						

- 8000h: write command
- 8001h: read command
- 8002h: write data
- 8003h: read data

This memory range is mirrored as far as address FFFFh. This means that you can (for example) use the range F000h to F0003h. The display has a large number of commands, with a distinction being made between different types of commands, each of which has a characteristic number of zeros in the more significant bit positions (see **Table 2**).

character positions. The following relationship applies to a 2 × 16 display:

- Line 1: addresses 00h through 0Fh
- Line 2: addresses 40h through 4Fh

A command to set the cursor position consists of a set bit 7 (80h = 128) together with the address (for example, 80h + 40h = C0h = 192 for the first character in the second line).

The small BASIC-52 program shown in **Listing 1** represents our first example of a simple driver. The

Ready?	BF	memory address (=cursor position)
--------	----	-----------------------------------

Initialise with 8-bit data bus and two display lines	0011 1000 = 38h = 56
Enable display, disable cursor	0000 1100 = 0Ch = 12
Clear display	0000 0001 = 01h = 1

CALL 01 0

As can be seen in **Listing 2**, the cursor routine evaluates the expression following the CALL address, which may also be an arithmetic expression such as CALL 01 (64+4*N).

The display driver must be located in RAM starting at address 4030h. This is possible, since the entire RAM of the 89S8252 board also serves as program memory. However, the Basic RAM region must be reduced, for instance by using an MTOP=8191 statement, in order to avoid a conflict with the system's own memory management. The Basic program LCD2.BAS makes the LCD driver available in RAM (see **Listing 3**).

(010208-7)

Downloads

The download list for this issue (June 2002) can be found under 'Free Downloads' on the Elektor Electronics website. In this list, you can select the following for downloading:

- the program listings for this final instalment of the course (number **010208-17**)
- the complete set of all downloads for the course (number **010208-19**).

Conclusion & Competition

This instalment concludes the Microprocessor Basics Course. The essential elements of the hardware and software have been discussed. During the course, we received many comments and suggestions from readers, and these have frequently resulted in changes to the originally planned content of the course. We would like to cordially thank the readers for their responses. In spite of all of this, it was naturally not possible to fully cover this subject in the course. There are still many ideas and application areas left to be explored.

It is planned to have the 89S8252 Flash Board serve as the basis for new articles to appear in Elektor Electronics at irregular intervals. It has already proven itself as a platform for a wide variety of developments. If you have already implemented applications using this board or would like to do so in the near future, you can participate in an **Elektor Electronics readers' competition** to be announced in the coming issue (Summer Circuits issue, July/August 2002).

Listing 1. Driving the display in BASIC-52

```

1   REM LCD data output (LCD.BAS)
2   REM data 8002h, commands 8000h
10  STRING 80,16
20  GOSUB 1000
30  $(0)="Elektor 89S8252 "
40  GOSUB 1300
50  $(1)="LCD 2 * 16      "
60  GOSUB 1400
70  END
1000 REM LCD-Reset
1010 XBY(8000H)=56
1020 XBY(8000H)=12
1030 XBY(8000H)=1
1040 RETURN
1100 REM cursor position 0
1110 XBY(8000H)=128
1120 RETURN
1200 REM output
1210 XBY(8002H)=A
1220 RETURN
1300 REM line 1
1310 XBY(8000H)=128
1320 FOR I=1 TO 16 : XBY(8002H)=ASC$(0),I) : NEXT
1330 RETURN
1400 REM line 2
1410 XBY(8000H)=192
1420 FOR I=1 TO 16 : XBY(8002H)=ASC$(1),I) : NEXT
1430 RETURN

```

Listing 2. The display driver

```

;Basic 52 extension LCD driver (Basic52_LCD.asm)
4030 .org 4030H
4030 02 42 00 ljmp LCD ;UO 1
403C .org 403CH
403C 02 42 00 ljmp LCD ;PRINT@
4100 .org 4100H
4100 41 50 ajmp LCDInit ;CALL 0
4102 41 7F ajmp CURSOR ;CALL 1

4200 .org 4200H
4200 C0 83 LCD push DPH
4202 C0 82 push DPL
4204 C0 E0 push ACC
4206
4206 51 2E acall Busy
4208 E5 1C mov A,28 ;Cusor position
420A 44 80 orl A,#128
420C 90 80 00 mov DPTR,#8000H
420F F0 movx @DPTR,A ;set Cursor
4210 51 2E acall Busy
4212 E5 05 mov A,05 ;get char
4214 B4 0D 02 cjne A,#0DH,J1 ;= CR?
4217 80 1D sjmp CR
4219 B4 0A 02 cjne A,#0AH,J2 ;= LF?

```

```

421C 80 09          sjmp End
421E 90 80 02      J2      mov DPTR,#8002H
4221 F0           movx @DPTR,A      ;output
char
4222 E5 1C          mov A,28          ;bank 3,
R4, cursor pos.
4224 04           inc A
4225 F5 1C          mov 28,A          ;inc cur-
sor
4227 D0 E0          End      pop ACC
4229 D0 82          pop DPL
422B D0 83          pop DPH
422D 22           ret
422E
422E 90 80 01      Busy     mov DPTR,#8001H
4231 E0           movx A,@DPTR
4232 20 E7 F9          jb ACC.7,Busy
4235 22           ret
4236
4236 51 2E          CR      acall Busy
4238 74 20          mov a,#32
423A 90 80 02      mov DPTR,#8002h
423D F0           movx @DPTR,a
423E E5 1C          mov A,28
4240 04           inc A
4241 F5 1C          mov 28,a
4243 54 3F          anl A,#63
4245 B4 28 EE          cjne A,#40,CR
4248 E5 1C          J3      mov a,28
424A 54 C0          anl a,#192
424C F5 1C          mov 28,a
424E 80 D7          sjmp End
4250
4250
4250 C0 83          LCDInit push DPH
4252 C0 82          push DPL
4254 C0 E0          push ACC
4256
4256 51 2E          acall Busy
4258 90 80 00      mov DPTR,#8000H
425B 74 38          mov A,#38H
425D F0           movx @DPTR,A
425E 51 2E          acall Busy
4260 90 80 00      mov DPTR,#8000H
4263 74 06          mov A,#06H
4265 F0           movx @DPTR,A
4266 51 2E          acall Busy
4268 90 80 00      mov DPTR,#8000H
426B 74 0C          mov A,#0CH
426D F0           movx @DPTR,A
426E 51 2E          acall Busy
4270 90 80 00      mov DPTR,#8000H
4273 74 01          mov A,#01H
4275 F0           movx @DPTR,A
4276 D2 27          setb 027H ;PRINT@ enable
4278
4278 D0 E0          pop ACC
427A D0 82          pop DPL
427C D0 83          pop DPH
427E 22           ret
427F
427F C0 E0          CURSOR push ACC
4281 74 39          Mov A,#57
4283 12 00 30       lcall 030h
4286 74 01          Mov A,#1
4288 12 00 30       lcall 030h
428B E9           mov A,R1
428C F5 1C          mov 28,A
428E D0 E0          pop ACC
4290 22           ret

```

Listing 3. A loader program for the display driver

```

3999 REM LCD driver          (LCD2.bas)
4000 MTOP=8191
4029 REM output jumps
4030 DATA 002H,042H,000H,000H,000H,000H,000H,000H
4038 DATA 000H,000H,000H,000H,000H,000H,000H,000H
4039 FOR N=0 TO 15 : READ D : XBY(04030H+N)=D :
NEXT N
4099 REM CALL jumps
4100 DATA 041H,050H,041H,07FH,061H,000H,000H,000H
4101 FOR N=0 TO 7 : READ D : XBY(04100H+N)=D :
NEXT N
4199 REM LCD
4200 DATA 0C0H,083H,0C0H,082H,0C0H,0E0H,051H,02EH
4208 DATA 0E5H,01CH,044H,080H,090H,080H,000H,0F0H
4210 DATA 051H,02EH,0E5H,005H,0B4H,00DH,002H,080H
4218 DATA 01DH,0B4H,00AH,002H,080H,009H,090H,080H
4220 DATA 002H,0F0H,0E5H,01CH,004H,0F5H,01CH,0D0H
4228 DATA 0E0H,0D0H,082H,0D0H,083H,022H,090H,080H
4230 DATA 001H,0E0H,020H,0E7H,0F9H,022H,051H,02EH
4238 DATA 074H,020H,090H,080H,002H,0F0H,0E5H,01CH
4240 DATA 004H,0F5H,01CH,054H,03FH,0B4H,028H,0EEH
4248 DATA 0E5H,01CH,054H,0C0H,0F5H,01CH,080H,0D7H
4250 DATA 0C0H,083H,0C0H,082H,0C0H,0E0H,051H,02EH
4258 DATA 090H,080H,000H,074H,038H,0F0H,051H,02EH
4260 DATA 090H,080H,000H,074H,006H,0F0H,051H,02EH
4268 DATA 090H,080H,000H,074H,00CH,0F0H,051H,02EH
4270 DATA 090H,080H,000H,074H,001H,0F0H,0D2H,027H
4278 DATA 0D0H,0E0H,0D0H,082H,0D0H,083H,022H,0C0H
4280 DATA 0E0H,074H,039H,012H,000H,030H,074H,001H
4288 DATA 012H,000H,030H,0E9H,0F5H,01CH,0D0H,0E0H
4290 DATA 022H
4291 FOR N=0 TO 144 : READ D : XBY(04200H+N)=D :
NEXT N
4292 CALL 00

```

Listing 4. LCD driver test

```

100 REM driver use (LCDDEMO.BAS)
110 UO 1 : REM User Output enable
120 CALL 01H 0 : REM Cursor to line 1
130 PRINT " PORT P1 = "
140 CALL 01H 64 : REM Cursor to line 2
150 PRINT PORT1
160 GOTO 150

```

Listing 5. The LCD.C module

```

// ----- READS51 generated header -----
// module : C:\Rigel\Reads51\Work\LCD\LCD.c
// created : 10:46:46, Tuesday, March 05, 2002
// -----

#define data_write 0x8002;
#define data_read 0x8003;
#define cmd_write 0x8000;
#define cmd_read 0x8001;

#include <Sio51.h>

void LCDinit(void){
//
//
#asm
    lcall Busy
    mov DPTR,#cmd_write
    mov A,#56
    movx @DPTR,A
    lcall Busy
    mov DPTR,#cmd_write
    mov A,#12
    movx @DPTR,A
    lcall Busy
    mov DPTR,#cmd_write
    mov A,#0x0C
    ;movx @DPTR,A
    lcall Busy
    mov DPTR,#cmd_write
    mov A,#1
    movx @DPTR,A
#endasm
}

#asm
    Busy:
    mov dptr, #cmd_read
    movx A, @dptr
    jb ACC.7, Busy
    ret
#endasm

void LCDwrite(unsigned char dat){
//
//
#asm
    lcall Busy

    mov a, BPL ;load dat to a
    add a, #0xFA
    mov dpl, a
    mov a, BPH
    addc a, #0xFF
    mov dph, a
    movx a, @dptr

    mov dptr, #data_write
    movx @dptr, a
#endasm
}

void LCDcursor (unsigned char pos)
{
#asm
    lcall Busy

    mov a, BPL ;load pos to a
    add a, #0xFA
    mov dpl, a
    mov a, BPH
    addc a, #0xFF
    mov dph, a
    movx a, @dptr

    mov dptr, #cmd_write
    orl a, #0x80
    movx @dptr, a
#endasm
}

main()
{
    char dat;
    unsigned char pos;
    unsigned char n;

    InitSerialPort0(DEF_SIO_MODE);
    LCDinit();
    while (1)
    {
        pos=0;
        LCDcursor(pos);
        for(n=0; n<16; n++)
            LCDwrite (32);
        LCDcursor(pos);
        while (pos < 16)
        {
            dat=getc();
            if (dat == 13) pos=16;
            else LCDwrite(dat);
            pos=pos+1;
        }
        pos=64;
        LCDcursor(pos);
        for(n=0; n<16; n++)
            LCDwrite (32);
        LCDcursor(pos);
        while (pos < 80)
        {
            dat=getc();
            if (dat == 13) pos=80;
            else LCDwrite(dat);
            pos=pos+1;
        }
    }
    while (1);
}

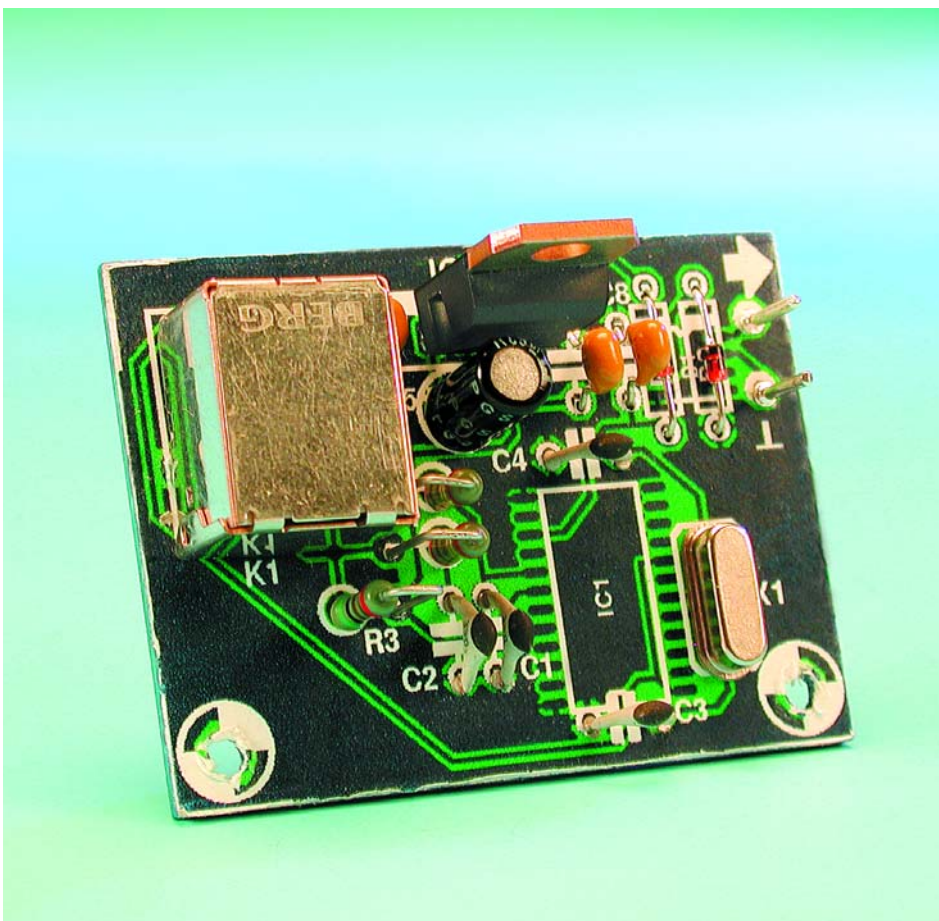
```


USB Interface for the I-Wire Bus

from four to two wires

Design by L. Lemmens

The I-Wire bus from Dallas Semiconductor is very suitable for use in a small (home) network with various switches, sensors and actuators. The simplicity of the hardware is in sharp contrast to the complexity of the protocol on this bus, but fortunately this problem has been solved by the manufacturer with dedicated interface ICs and software that simplifies the communication between the PC and I-Wire devices.



Last April we published a design for a serial interface for the PC, which made it possible to communicate with devices on the 1-Wire bus using development software supplied by Dallas Semiconductor. This month we have an almost identical circuit, but for use with the USB port (USB = Universal Serial Bus). This port is beginning to be used more frequently for connecting peripherals to PCs and Macs. The serial port has now fallen out of favour in that respect. Some people are of the opinion that the trusty old RS232 interface will soon disappear from the PC and certainly from modern laptops. The future will tell if they're right.

The USB does have several major advantages compared to the serial port. Just the fact that several devices can be connected to a single USB port via a hub is a huge improvement. In the past, every device required its own serial port, or we had to make use of clumsy switch boxes (which sometimes introduced problems of their own). It is also a boon that many peripherals can draw their supply from the USB

port or hub, removing the need for separate power supply adapters and cables. The final advantage is that USB devices can be plugged in even when the PC is running; the operating system on the computer detects this immediately and automatically installs the appropriate driver for the device. This is a huge enhancement for the computer world, and justifies the eventual demise of the RS232 interface.

Communications via the USB interface tend to be much more complex than via the old serial interface, even if that often caused a headache when trying to set it to the correct baud rate, data bits etc. Luckily the blow is softened by the fact that more ICs are introduced that take care of the USB protocols, making the USB completely transparent in use. Together with the drivers that the manufacturers of these ICs make freely available on the Internet, they make a complete USB interface, so we don't need to worry about what happens on the USB. And in this case the IC also takes care of the 1-Wire bus.

1-Wire devices are parts that are very suitable for a small network. Two wires are sufficient to power and communicate with these ICs. The range includes switches, thermostats, memories, potentiometers, clock ICs and so on. For a full overview of the range you should refer to the article in the April issue or the website of Maxim/Dallas Semiconductor. Rumour has it that the range will soon be extended to include a humidity/temperature sensor, which could find use in an air-conditioning system. Most of the questions we're asked about this bus come from people who would like to set up a network at home for measurement and control. We'll take a look at the requirements for connecting these devices to the PC via the USB port.

Hardware

Figure 1 shows the circuit diagram of the interface. It couldn't really be any simpler. IC1 is the most important part, doing all the work in the interface: the DS2490. On one side it takes care of the USB interface, on the other it handles the 1-Wire pro-

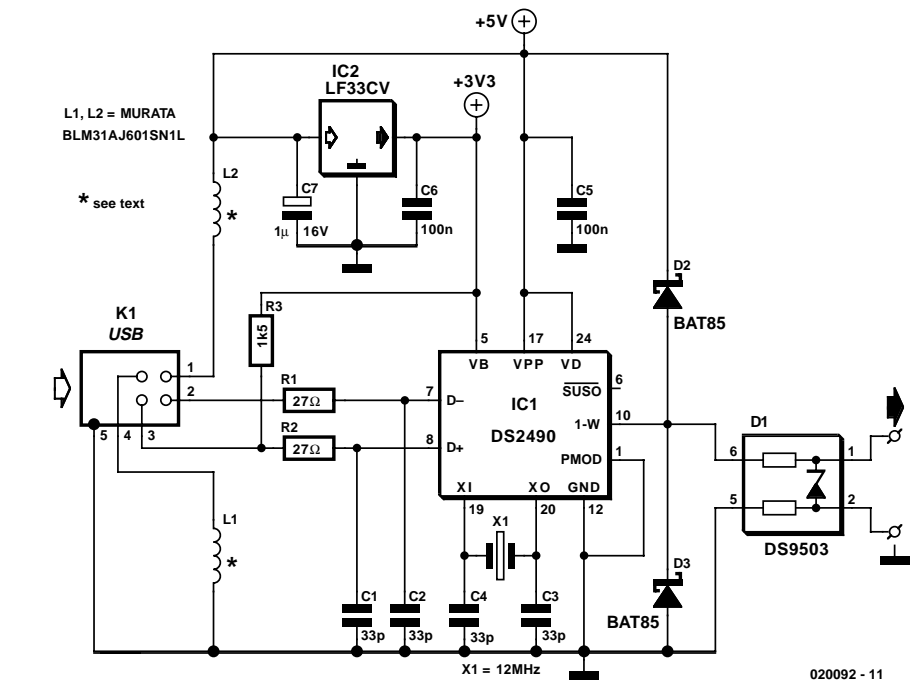


Figure 1. Circuit diagram for the 1-Wire interface.

col. This IC handles all timings and other details that could otherwise make life a misery.

The first component on the USB side is R3, a pull-up resistor that takes the D+ line to the supply voltage, indicating to the USB host (the PC) that a high-speed device is connected to the bus. The presence of this pull-up is also a signal to the host that a driver should be loaded for the USB device just plugged in.

R1 and R2 provide for the correct termination of the USB data lines, whilst C1 and C2 suppress high frequencies and thereby decouple the inputs (EMI suppression). L1 and L2 provide a similar function for the supply lines on the USB connector.

IC2 is a 3.3V voltage regulator. If necessary, you could use any other regulator in a TO220 case that has the same pin-out as an 'ordinary' 78xx series voltage regulator.

IC1 has several supply pins. VD is used for the supply of the 1-Wire bus. The Vpp connection is for the programming voltage for any possible programmable devices (ROMs) on the 1-Wire bus and needs to be at a higher potential than the supply voltage of the IC fed to VB. In this application the programming of any devices is not possible since the voltage on Vpp would need to be

12 V. It's not too difficult to change the layout of the circuit such that a 12 V connection can be made to this pin, but that should be done before IC1 is mounted! Just as for the serial interface in April issue, the same warning applies here: during programming, only one EEPROM device may be connected to the interface, using a short cable. You should also never execute a programming command on a bus that has non-EEPROM devices connected to it; this could damage these devices or the interface!

The two diodes D2 and D3 protect the 1-Wire bus from excessive voltages. D1 has been specifically designed to protect the interface from electrostatic discharges on the 1-Wire bus. It consists of a very fast zener diode with two low-value resistors. These resistors don't affect normal 1-Wire communications, but have a high resistance compared to the zener when it is conducting. This causes an electrostatic discharge to be dissipated in the zener rather than find its way into the interface.

Construction

We have designed a PCB for this circuit, but this won't be made available via the Readers' Services due to its small size. The layout of Figure 2 can be downloaded from our website www.elektor-electronics.co.uk.

The construction of the circuit shouldn't cause problems for those of you who have soldered SMD parts before. Start with these

parts, which have to be mounted on the track side of the board. First tin one pad on the PCB and solder the SMD to that pad only. Then check that all other pins are lined up properly, making any adjustments as necessary. Only then should the other pins be soldered. Take care with L1 and L2; they are on the track side underneath the USB connector. Double check that all joints on IC1 and D1 make a good connection and that there aren't any solder bridges! After the SMDs it's the turn of the ordinary components. When that is finished, the circuit is ready for connecting to a USB port on the PC and its first test.

Installation

We start with the interface without any 1-Wire devices connected to it. Those of you who constructed and used the serial interface from the April issue won't have much more to do since the correct USB driver should already be on the system. Otherwise the software has to be downloaded from www.ibutton.com/software/tmex/index.html, where we find the TMEX with iButton Viewer (with drivers) and, if required, the 1-Wire Software Developer's Kit. In any case, the first-named software package should be installed, which is currently TM320_32.EXE (32-bit, version 3.20 for Windows). This also stores the driver for the USB in the correct directory. This doesn't always go faultlessly, so make sure that you carefully read the instructions

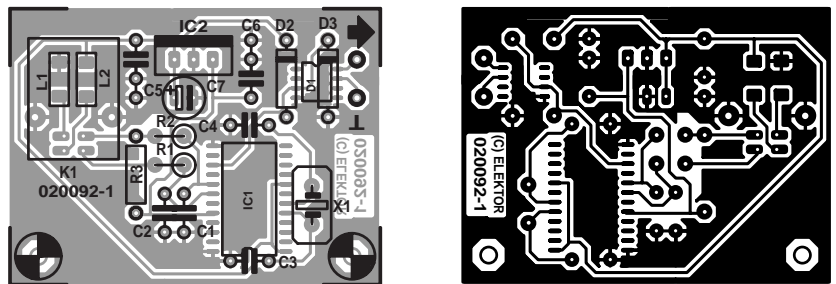


Figure 2. The PCB layout (also obtainable from www.elektor-electronics.co.uk).

COMPONENTS LIST

Resistors:

R1, R2 = 27 Ω
R3 = 1k Ω 5

Capacitors:

C1-C4 = 33pF
C5, C6 = 100nF
C7 = 1 μ F 16V radial

Semiconductors:

D1 = DS9503

D2, D3 = BAT85

IC1 = DS2490

IC2 = LF33CV (Farnell # 302-4520)

Inductors:

L1, L2 = BLM31AJ601SNI (Murata)
(Farnell # 581-094)

Miscellaneous:

K1 = USB connector, type B, PCB mount
X1 = 12MHz quartz crystal

for USB that come with the installation software! If you do encounter any problems you should refer to the README and HELP files that have been included by Dallas. Usually

Windows has to be restarted once the installation has completed.

Now it is — as long as everything is in order — a matter of 'plug-and-play': plug the USB plug into the interface and some rattling of the hard disc tells you that the interface has been detected and that Windows is loading the appropriate driver. In Windows *Device Manager* you should be able to see the driver under the heading *USB*, with the name 'USB host for 1-Wire microLAN'. Next you should run the *iButton Viewer* application from the Start Menu. The first this will ask for is the port it should use for the interface. In our case this is the USB interface as shown in **Figure 3**. Note that this program calls the adapter a DS1490 and not, as you would expect, a DS2490. The DS1490 is a generic name given to USB interfaces such as the DS2490. If you are unable to find the USB interface manually, you should run the *Default 1-Wire Net* application and select the Auto-Detect option. You should make a note of the settings when the DS1490 adapter has been found, because the details are not stored and will have to be entered by hand when the Viewer is started again.

We are now ready to play and can

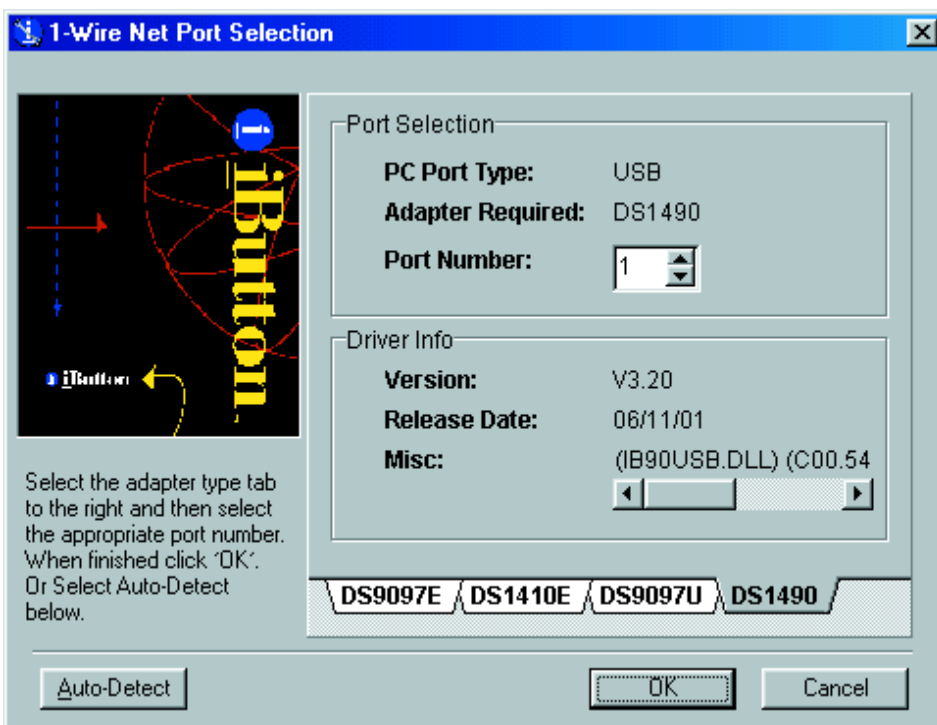


Figure 3. Selecting the USB interface in the iButton Viewer.

connect one or more 1-Wire devices to the bus. The Viewer should immediately show the unique serial number of each device in the left-hand column and, depending on the settings of the program, open a window that shows the properties of the device and (where appropriate) any settings that can be adjusted. **Figure 4** shows what could be expected on the PC's display.

And finally

This circuit is more or less the same as that of the serial interface described earlier; it is just a more modern version using a different port on the PC. All observations made in the previous article regarding the 1-Wire bus, the iButton Viewer, the Software Developer's Kit and the devices that can be connected to this bus, also apply to the use of this USB interface.

(020092)

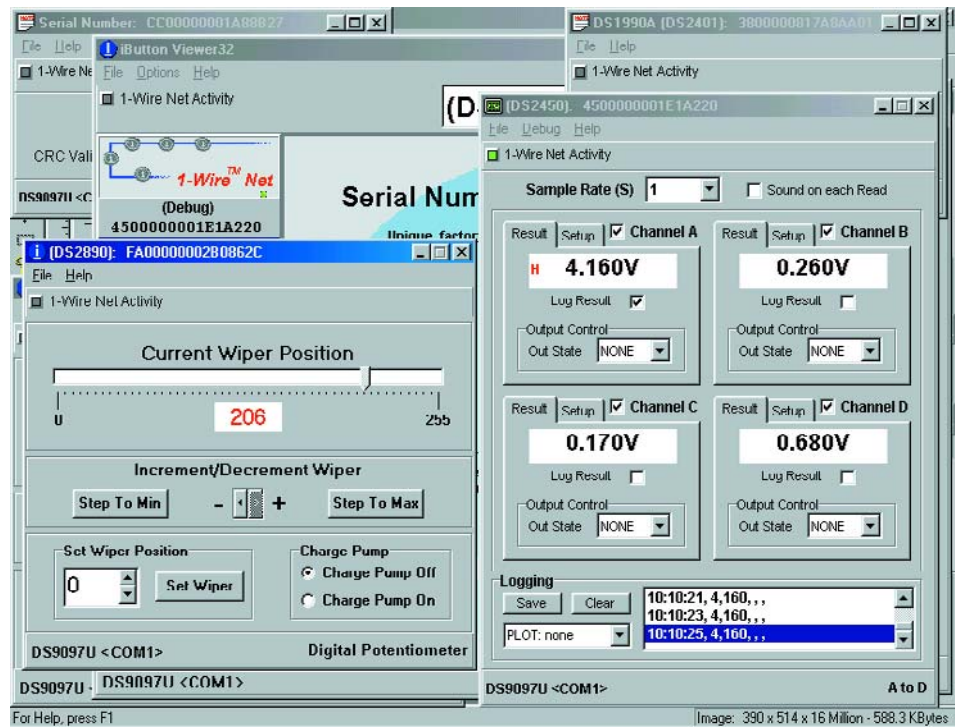


Figure 4. The iButton Viewer in full swing.

LED Torch

semiconductor white light

Design by B. Kainka

White light LEDs have been a long time in the making. This design (as part of our Mini Project series) employs a simple circuit to make the best use of the properties of these devices in a neat key-fob torch design.



White light LEDs are an attractive alternative to the traditional tungsten lamp. They offer far greater reliability and efficiency but also have a much higher forward conduction voltage compared to red or green LEDs. This means that if you want to build a small key-fob sized torch powered by just one battery cell then it will be necessary to resort to a little electronic wizardry to increase the voltage to a level that will cause the LED to conduct.

Pump up the volume

A voltage converter circuit (**Figure 1**) is all that is needed to drive the LED. You may recognise that it is based on the familiar astable multivibrator configuration. To explain its operation, when S1 is pressed a

base current is applied to T1 via resistors R3 and R2 and causes T1 to start conducting. Resistor R2 will ensure that the collector voltage of T1 will be slightly above its base voltage. T2 will therefore also begin conducting and current flows through L1. Electrical noise on the base of T1 will be sufficient to make it start conducting harder, this in turn causes the collector voltage of T1 to fall to ground potential and switch T2 fully off. Current through inductor L1 will be interrupted and the voltage at T2 collector will rise above the supply voltage. LED D1 will now light when this rising voltage exceeds its forward conduction

voltage (3.6 V). C1 couples this positive voltage pulse to the base of T1 to reinforce its ON state. The base current charge will now decay until T1 begins to turn off. Its collector voltage rises and with it the base of T2. T2 will now start conducting and current flows through L1 again. The negative-going signal will be coupled to the base of T1 to reinforce its OFF condition. The circuit continues switching alternately between T1 and T2 until power is removed. An important aspect of the design is to ensure that the circuit switches quickly, otherwise the stored energy in L1 will be dissipated by T2 instead of lighting the LED. After all, an LED is a Light Emitting Diode!

Check it out now

The oscilloscope screenshot in **Figure 2** shows the voltage waveform across the LED (upper trace) and the current through inductor L1 in the lower trace. The horizontal time-base is set to 2 μ s and shows that the waveform has a period of approximately 7.7 μ s giving an operating frequency of 130 kHz. Conventional voltage multiplier circuits require a diode at the output to rectify the waveform but in this design the diode properties of the LED means that no additional diode is necessary.

The complete circuit draws approximately 20 mA from a 1.5 V battery. This is much less than you would expect from a standard torch

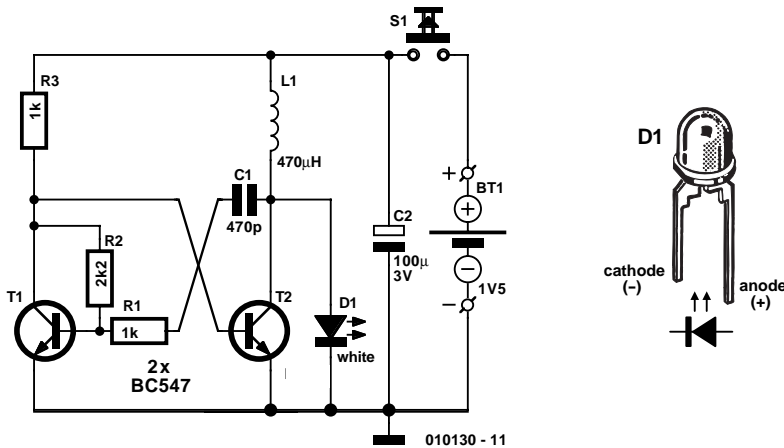


Figure 1. A multivibrator pumps up the voltage across the diode.

using an incandescent light bulb. If this circuit were used with a 2,000 mAh alkaline battery it would

operate for 100 hrs. The circuit is also tolerant of the falling supply voltage so that a useful output light level can

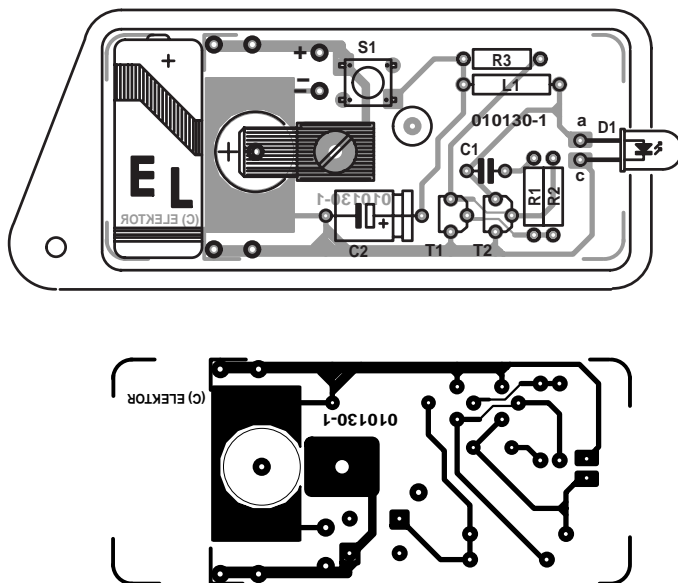


Figure 3. The PCB layout allows fitting of a button cell or LR1 type battery (PCB available ready-made).

COMPONENTS LIST

Resistors:

R1, R3 = 1kΩ
R2 = 2kΩ

Capacitors:

C1 = 470pF
C2 = 100μF 3V

Semiconductors:

D1 = LED, white
T1, T2 = BC548C, BC549C or BC550C

Miscellaneous:

L1 = 470μH miniature choke
S1 = pushbutton with 1 make contact
Battery (see text)
Enclosure (see text)
Battery mounting materials
PCB, order code **010130-1** (see Readers Services page and website)

PCB layout file available from Free Downloads section at www.elektor-electronics.co.uk

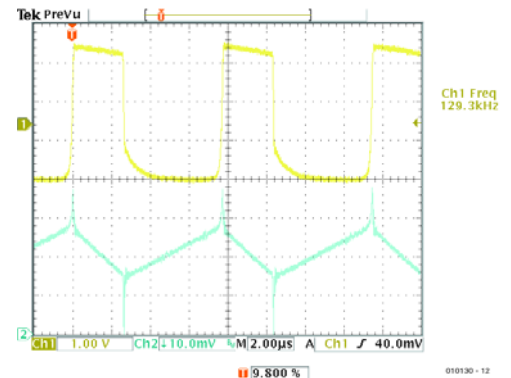


Figure 2. Oscilloscope screenshot of the voltage across the LED. (1 V/DIV).

still be achieved even when the battery voltage has dropped below 1 V. This gives you plenty of time to replace the battery and means that you will not find yourself suddenly left in the dark. One environmentally friendly aspect of this design is that it will operate quite happily with old batteries that have too little energy left in them to power a conventional torch. The circuit can also take a rechargeable battery in which case it should draw just 17 mA from a single 1.2 V NiCd cell. The actual value will be dependant to some extent on the quality and tolerances of the components used.

Little boxes

The layout and construction of the circuit is not critical. A PCB (see **Figure 3**) is available from Elektor Electronics Readers Services. The original PCB was fitted into a UM14 enclosure but if you have difficulty finding this item, Farnell (www.farnell.com) stock suitable alternatives including the similar 1551KBK key-fob enclosure. The PCB provides a fitting for two types of battery, either an LR1 style cell (or any similar cell profile with a diameter less than 12 mm and less than 30 mm long). It may be necessary to modify the housing slightly to accommodate your chosen battery. Be sure that the casing cannot come into contact with any of the PCB tracks, if necessary use insulating material. Alternatively you can use a button cell type 675. This battery is usually fitted to hearing aids and has a useful capacity of 500 mAh at 1.4 V. If you decide to use a button cell it will be necessary to drill a hole through the PCB (see the title photo) for the cell and solder a contact strip to the PCB track-side together with an AMP clip on the component side to ensure a good contact with the battery.

(010130-1)

The content of this note is based on information received from manufacturers in the electrical and electronics industries or their representatives and does not imply practical experience by Elektor Electronics or its consultants.

TRX01

Transceiver for ISM radio applications

By G. Raedersdorf

The TRX01 from Atmel is a single-chip transceiver that has been designed for low-power, wireless applications and is optimised for use in the 433-MHz and 868-MHz ISM bands, where licence-exempt data communication is permitted.



This new IC (type AT86RF211) from Atmel can communicate with any microprocessor via a 3-wire bus. The device can be completely configured (output power, frequency) through this interface. Even the battery voltage and the received signal strength are measured. These parameters are available in the status register. There is also a timer, among other things, that allows for the possibility to automatically start the circuit after some period of time.

Two of these ICs make it possible to build a reliable connection over a distance of several hundreds of meters.

As can be seen in the above photograph, the IC is housed in an SMD package with many connections (48-pin TQFP package). The IC is, nonetheless, quite easy to solder using a soldering iron with a fine tip.

The most important technical details can

Technical specifications:

- All transmit/receive-functionality on board
- Power supply from 2.4 to 5 V; so can operate from batteries
- Operates from 400 to 950 MHz with Digital Channel Selection on the 433-, 868- and 915-MHz bands
- Data transmission with Digital Channel Select up to 50 kbit/s
- FSK modulation, completely integrated modulator
- Data transmission without protocol up to a speed of 100 kbit/s
- Synthesiser oscillator for RX and TX
- Digital fine tuning of the carrier frequency in steps of 200 Hz
- Integrated RX/TX switch
- Short RX/TX change-over time ($< 200 \mu\text{s}$)
- Fast frequency shift ($< 50 \mu\text{s}$ for a shift of 100 kHz)
- 10 dBm (10 mW) output power at 2.4 V with 8 digitally selectable levels, maximum power 25 mW in the 868-MHz band
- Sensitivity -100 dBm
- Energy saving functions: sleep-mode en wake-up mode
- Current consumption less than 60 mA while transmitting and 30 mA while receiving, this drops to 3 μA in sleep mode and 1 μA in power-down mode
- Simple configuration and control via special registers
- Digital readout of RSSI and battery voltage
- Available in a 48-pin TQFP package

be found in the accompanying table. A data sheet for this IC is also available from Atmel in PDF-format. It can be downloaded from:

www.atmel.com/atmel/products/prod281.htm

After perusing the documentation,

you will quickly come to the conclusion that this is a very flexible chip, which is partially explained by the high level of integration.

Typical applications for these ICs are systems related to telemetry, remote control, burglar alarms, radio

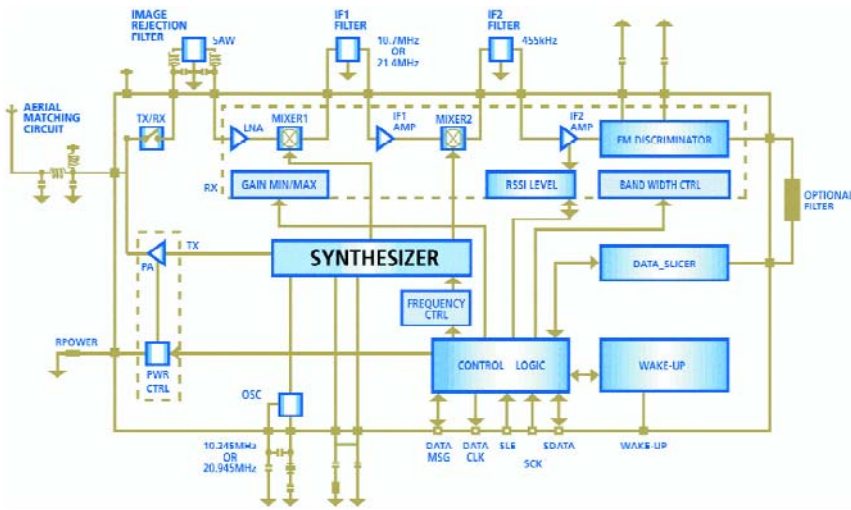


Figure 1. Block diagram of the TRX01 (source: Atmel).

modems, etc. All these application areas are grouped together under the general term ISM (Instrument, Scientific, Medical). This chip makes it possible to equip systems like these with bi-directional communications, allowing the use of commu-

nications protocols with handshaking functionality. In this way, applications such as the remote reading of instruments or handheld terminals becomes much more interesting, both from a technical and an economic perspective.

The block diagram

A glance at the block diagram of the TRX01 (Figure 1) shows that we are dealing with a chip which is both complex and flexible. The various circuits encompass several electronics disciplines, such as the digitally adjustable synthesiser and related parts, control logic, RF-circuitry for, among others, the discriminator section and filters of various kinds, even SAW filters (SAW = Surface Acoustic Wave).

Synthesiser

The fast, multiple-loop synthesiser with high resolution can be tuned to two different bands: the band that occupies the region from 400 to 480 MHz and the band from 800 to 950 MHz. The individual channels within each band can be selected in software. With the exception of the PLL filter, all the synthesiser electronics are integrated on the chip. Phase detection is achieved with charge pump technology.

Power amplifier

The power amplifier is capable of delivering up to +10 dBm (10 mW) in one of the three popular bands reserved for ISM communications: 433 MHz, 868 MHz and 915 MHz (only the first two are freely available in Europe). Under certain conditions the output can even rise to above +11.5 dBm.

There is also a system to automatically regulate the output power (ALC = Automatic Level Control), so that the amplifier becomes less sensitive to fluctuations in temperature or the power supply voltage.

Receiver

The TRX01 also accommodates a complete receiver, from the RX/TX-switch to the FSK-discriminator. All stages have been designed for operation from 400 to 1000 MHz and on intermediate frequencies of 10.7 MHz, 21.4 MHz or 455 kHz. The gain of the first stage is adjustable.

Selection of IF1

Because of sensitivity reasons, the designers choose for a classical super-heterodyne topology with a double IF. The input- and output impedances of the mixing stages are internally matched to the impedances of commonly available ceramic filters. For the intermediate frequency two typical values are proposed: 10.7 MHz (the most frequent option) and 21.4 MHz. In the latter case the image frequency is far enough away from the carrier frequency to permit the use of a ceramic filter instead of a SAW-filter. It should be noted that 21.4-MHz ceramic filters usually have

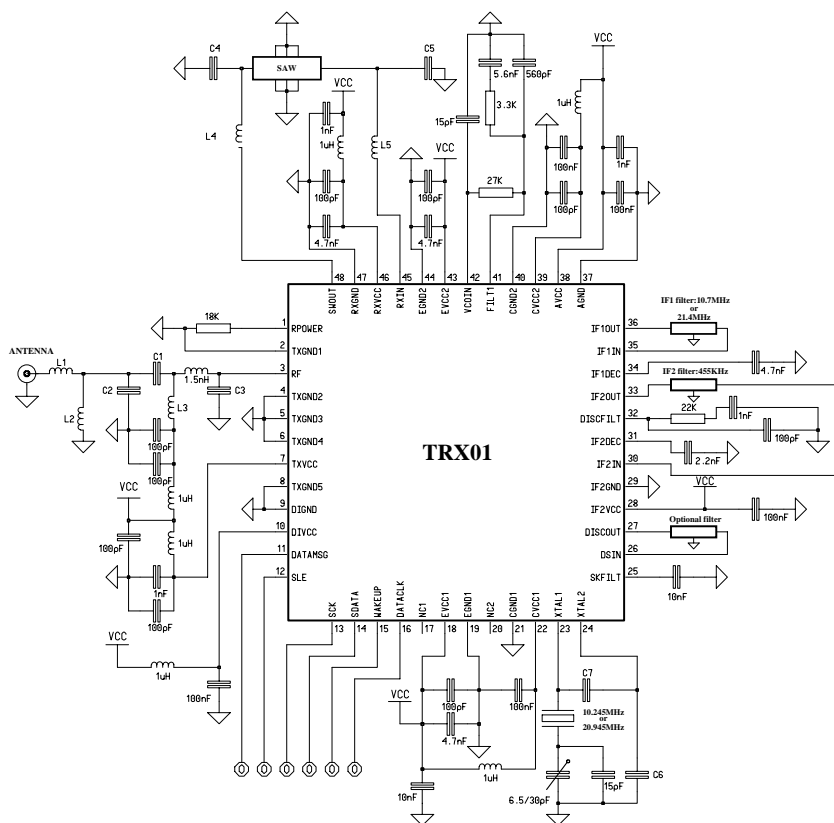


Figure 2. Schematic of a practical realisation containing a TRX01. Note the presence of a substantial number of coils.

steeper slopes than 10.7-MHz ceramic filters.

FSK-modulator

The structure of the modulator is based on an oscillator. The nominal voltage of the demodulated signal is 100 mV_{pp}.

TRX01 pinouts

Pin	Name	Function
1	RPOWER	Full scale output power resistor
2	TXGND1	GND
3	RF	RF Input/Output
4	TXGND2	GND
5	TXGND3	GND
6	TXGND4	GND
7	TXVCC	VCC
8	TXGND5	GND
9	DIGND	GND
10	DIVCC	VCC
11	DATAMSG	Input/Output digital message
12	SLE	Serial interface (enable)
13	SCK	Serial interface (clock)
14	SDATA	Serial interface (data)
15	WAKEUP	Wake-up output
16	DATACLK	Data clock recovery
17	-	Test pin; do not connect
18	EVCCI	VCC
19	EGND1	GND
20	-	Test pin; do not connect
21	CGND1	GND
22	CVCCI	VCC
23	XTAL1	Crystal input
24	XTAL2	Crystal output
25	SKFILT	Threshold for data slicer
26	DSIN	Data slicer input
27	DISCOUT	Discriminator output
28	IF2VCC	VCC
29	IF2GND	GND
30	IF2IN	IF2 amplifier input
31	IF2DEC	2.2 nF to ground
32	DISCFILT	Discriminator bypass
33	IF2OUT	IF2 mixer output
34	IF1DEC	4.7 nF to ground
35	IF1IN	IF1 amplifier input
36	IF1OUT	IF1 mixer output
37	AGND	GND
38	AVCC	VCC
39	CVCC2	VCC
40	CGND2	GND
41	FILT1	Synthesizer output
42	VCOIN	Synthesizer input (VCO)
43	EVCC2	VCC
44	EGND2	GND
45	RXIN	LNA input from SAW filter
46	RXVCC	VCC
47	RXGND	GND
48	SWOUT	Switch output

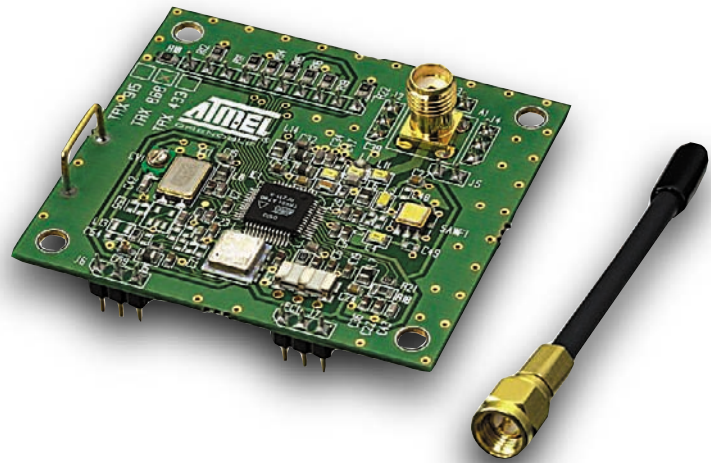


Figure 3. Daughter board with the AT86RF211 at its heart.

Crystal reference oscillator

This is an oscillator of the Colpitts type with two external capacitors. Any crystal with a parallel resonance frequency of 20.945 or 10.245 MHz is suitable.

Serial data interface

The application's microprocessor can control and monitor the TRX01 through the synchronous, bi-directional serial interface comprising 3 wires: SLE, SCK and SDATA.

Final remark: the operating frequencies of this circuit require a well thought-out PCB layout.

Practical circuit

Figure 2 shows the schematic of a practical circuit around the TRX01, the prototype of which can be seen in Figure 3. Note the presence of a number of

RF components, such as ceramic filters and a SAW filter. Fortunately, with the exception of trimmer CV1, there is nothing to be adjusted.

Development kit

In conclusion we would like to point out to those who are interested that a development kit exists which can operate on 433, 868 or 915 MHz and consists of two autonomous systems. The kit contains an AT86RF211 daughter board, an antenna, an AVR motherboard and all the necessary pieces to create a stand-alone application: batteries, LCD, ISP functionality (In System Programming) and a remote lightmeter prototype that can be built. The kit also contains a CD-ROM with programs (in C), a user's manual and, before we forget, three samples of the AT86RD211.

(020025-1)

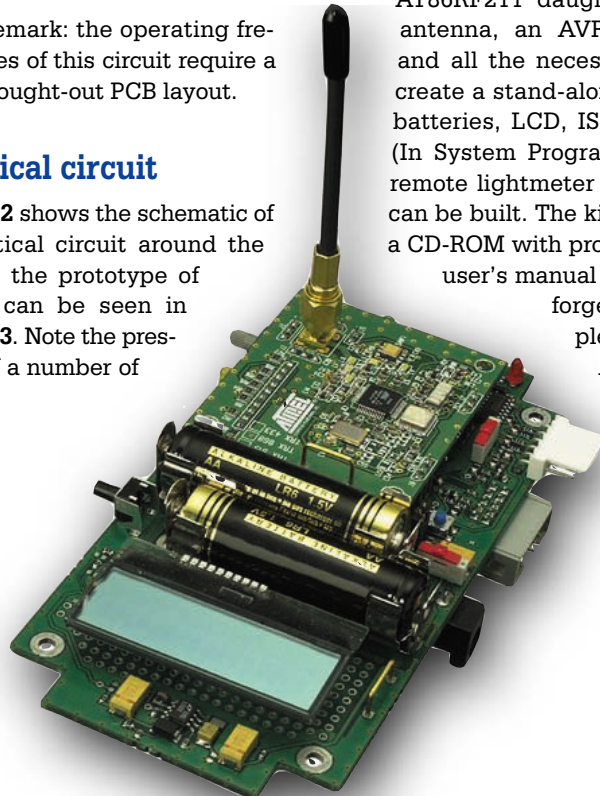


Figure 4. The complete development kit.

Oscilloscope and Function Generator for the PC

test equipment with Centronics interface

Review by Harry Baggen

Many readers are undoubtedly familiar with the company name Velleman, because of their electronics kits. Their range of products encompasses a wider range however; several different types of test equipment are also available. We subjected two such instruments to closer scrutiny: a digital storage oscilloscope and a function generator for the PC.



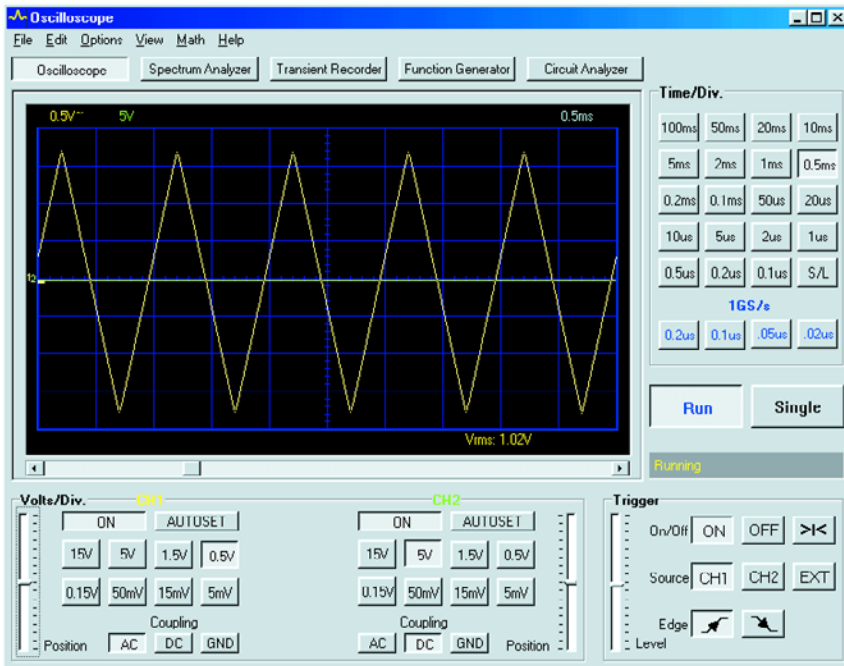


Figure 1. The oscilloscope window offers all the adjustment options of a real two-channel scope.

As already mentioned in the introduction, the name Velleman is practically synonymous with well thought out electronics kits distributed through a wide network of electronics retailers. But the product range hasn't been limited to kits for

a considerable time now. The assortment is very extensive and just about anything that is remotely related to electronics can be supplied, from disco mirror balls to right up to advanced test equipment. It is from the latter category that we will

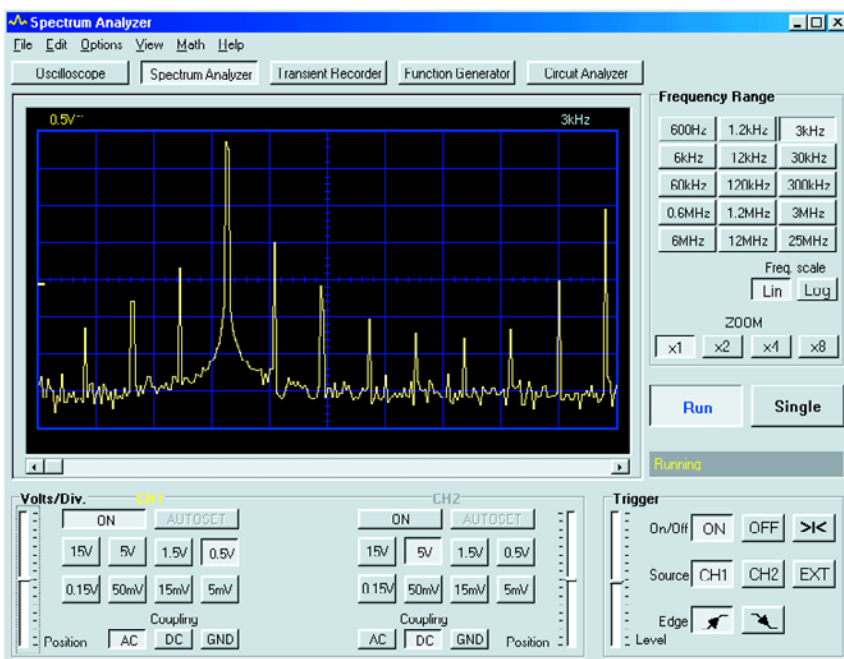


Figure 2. The spectrum analyser shows the frequency components of the input signal.

examine a couple of instruments a little bit closer.

The equipment under evaluation is a **Function Generator PCG10** (also available as kit K8016) and a **Digital Storage Oscilloscope PCS500** (a single-channel version comes as kit K8031). Both instruments are intended for use in conjunction with a PC. Consequently, they are not much more than small grey boxes with a few connectors. Operation and read-out takes place entirely on the computer display. For this purpose, both devices are fitted with an optically isolated Centronics interface. In order to be able to use both instruments at the same time (which is rather likely) the function generator is fitted with a pass-through connector, so that both devices can be connected to a single Centronics port.

First, the most important specifications:

PC Function Generator PCG10

- frequency range 0 to 1 MHz
- direct digital synthesis (DDS) with 32 k waveform-memory, sampling frequency 32 MHz
- accuracy of selected frequency: 0.01%
- output amplitude: 0.1 to 10 V_{pp} (50 Ω output impedance)
- offset adjustment -5 to +5 V
- waveform resolution: 8 bits
- waveforms: sine, square, triangle and user-defined
- output filter can be deactivated

Digital Storage Oscilloscope PCS500

- time base 100 ms to 10 ns/div
- input sensitivity 5 mV to 15 V/div
- sampling frequency 50 MHz
- sampling frequency for repetitive signals: 1 GHz
- extensive triggering capabilities (edge, level, source)
- autoset and pre-trigger function
- markers for time, frequency and voltage
- linear or smoothed interpolation
- record length 4,096 samples/channel
- additional functions: spectrum analyser and transient recorder.

In practice

Both instruments were connected to a rather old Pentium PC in order to examine their capabilities in actual use. Since you need to have a spare Centronics port available, you will either have to connect the printer to the USB port, or fit an additional PCI expansion card with a second Centronics port. It is a pity that this test equipment does not make use of the USB port. This would have been much easier (perhaps a suggestion for the next generation?).

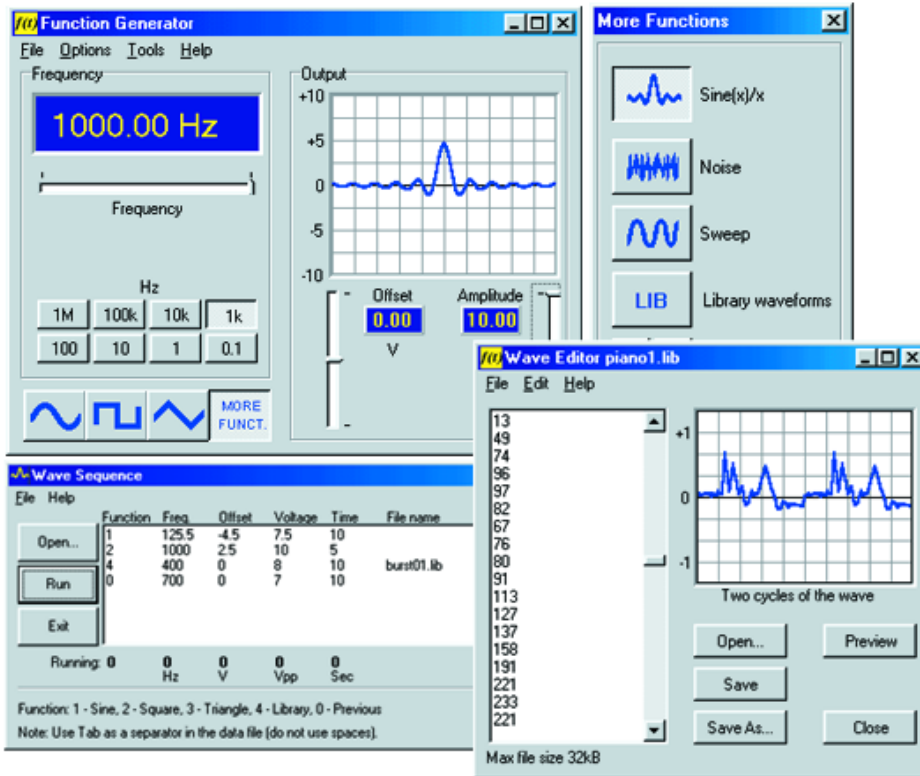


Figure 3. The generator has several extras, such as a number of pre-programmed waveforms, a waveform-sequencer and a waveform-editor.

The instruments may now be connected. The signal generator is connected to the PC first. Next, the oscilloscope is connected to the signal generator. All the necessary cables are supplied. Pay attention when connecting the mains adapters. The oscilloscope operates from 9 V and the signal generator from 12 V! We didn't dare to find out whether or not something fails if they are reversed!

The accompanying PC-Lab 2000 program can now be installed. This program is compatible with most versions of Windows and the installation on our test computer was completed without problems. Also, the most recent version can always be obtained from the Velleman website.

After starting the program a setup window appears. Here you have to tick the boxes for the equipment that is connected and indicate the address of the printer port that has been used. Once this is completed, the oscilloscope window appears on the screen.

The test cables that were supplied with the unit will suffice for an initial evaluation. However, for 'real' measurements we would like to suggest that you obtain some authentic oscilloscope probes, because the supplied test cables are not much more than a piece of cable with two croc clips.

After connecting a signal and clicking the

Autoset button, the 'scope immediately produced a usable picture. Both the input sensitivity and the time scale are automatically adjusted with this function, resulting in a good readable signal that is displayed over several periods. Naturally, many things can also be adjusted by hand, just like the buttons on a normal oscilloscope. Because of the storage function, single-shot signals can easily be recorded and displayed. The markers are very useful in practice, as well as the ability to display the effective value or dBm value of the signal in the oscilloscope window.

The four fastest time settings, 200 ns/div to 20 ns/div, are unfortunately only of limited use, because a method is used where a periodic signal is sampled at different points. In this way a pseudo sampling rate of 1 GHz is obtained. Note, however, that this method is only useful if the signal does not change. And who can be sure of that?

Using the normal sampling frequency of 50 MHz, the scope is usable to about 5 or 10 MHz,

depending on the degree of accuracy required to make a proper judgement of the waveform.

With the click of a button, a change can be made to the spectrum-analyser window. This provides an impression of the frequency components of a signal, so that, for example, distortion components can be examined. Regrettably, there are several details that make this feature less user-friendly. The division of the frequency scale is rather strange (multiples of 3 and 12, while one would expect 3 and 10, because there are actually 10 divisions displayed on the screen). The vertical scale is even more awkward. It cannot be changed to a logarithmic scale, which is particularly useful in an FFT plot. It is, however, possible to select a logarithmic scale for the horizontal axis. Despite all this, there are many nice features, such as the choice of FFT window and very useful markers (which do show the level in dB!).

The transient recorder is another function that can be invoked. This is very similar to the oscilloscope window, but the time scale is much longer (up to 2000 s/div). This way, very slowly varying processes can be traced (more than a year is possible).

The measured oscilloscope samples can be stored in a text file and may be retrieved later for viewing on the display.

A separate window is opened for the operation of the function generator. This not only provides the opportunity to adjust the output amplitude, shape and frequency, but also shows a preview of the waveform. The controls are conveniently arranged and the frequency can be adjusted quickly with a slider or by typing in the exact value. The output amplitude and offset are adjusted in a similar manner. In addition to the three waveform buttons, there is the button 'More funct.' This offers a selection between sin(x)/x-function, noise, a frequency sweep and a number of waveforms from the library. With the help of a separate editor, the user can also define waveforms for themselves.

Unfortunately, the frequency range of the generator is rather limited; the maximum value is only

1 MHz. This is caused by the technique used for generating the waveforms. The direct digital synthesis implemented here requires a relatively high sample frequency (32 MHz in this case). At higher output frequencies this also needs to be proportionally higher. The advantages of this instrument are unquestionably the high accuracy of the output frequency, the flexible output signal with many waveforms and the programmability.

Users will have to be aware that the generator window cannot be closed during use. If this is done, the signal generator is switched off and the signal disappears. Our tip: keep an eye on the Ready LED on the generator, because it is illuminated when an output signal is present.

A very nice test configuration that can be realised with the combination of the instruments described here is a Bode Plotter. It is very easy to measure the transfer function of a filter or amplifier by simply connecting the output of the generator to the input, and the input of the scope to the output of the circuit to be measured. From here, having set the frequency range and sensitivity, everything is done nearly automatically. It is possible to select a logarithmic scale for either the amplitude and the frequency, or both — very practical!

An interesting new feature in the latest version of the software is the possibility of controlling the generator with a text file you create yourself or externally via the RS232 input of the computer.

Conclusion

Those of you who would like to use their PC for making electronic measurements will make a significant step in the right direction with the test equipment described here. This equipment is also very suitable for measurements 'in the field' when combined with a Notebook computer. The transient recorder in particular can prove to be very useful. However, there has to be a power outlet nearby to supply the various devices.

The function generator does an excellent job and has many features, despite the fact that the frequency

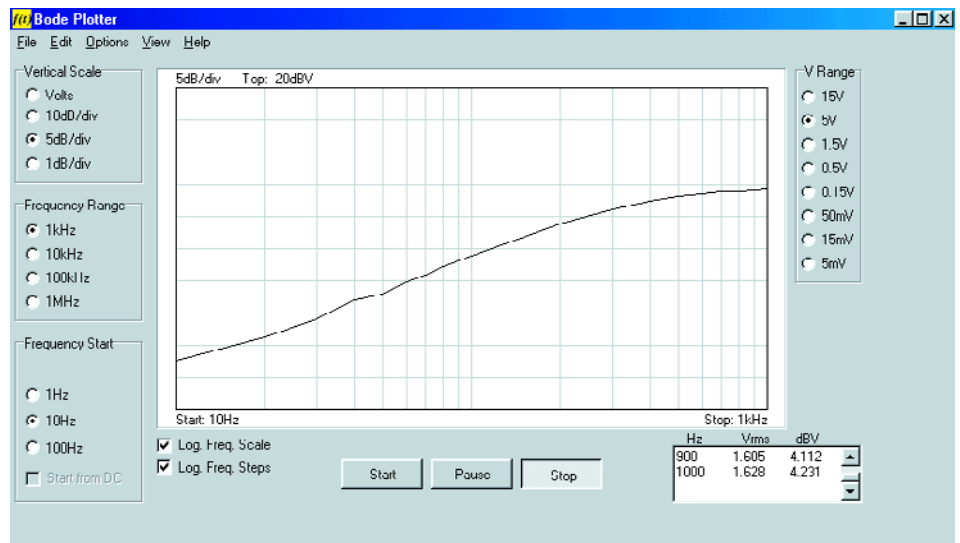


Figure 4. With the aid of the Bode-plotter it is very easy to determine the transfer function of a circuit.

Prices (E&OE):

PCG10 PC Function Generator:	€ 179.95*
K8016 PC Function Generator (kit):	€ 136.22 / £99.99 (Maplin).
PCS500A 2-Channel 50 MHz PC Oscilloscope:	€ 495.00*
K8031 1-Channel 12 MHz PC Oscilloscope (kit):	€ 119.95 / £89.99 (Maplin).

* item not listed by Maplin, see www.maplin.co.uk.

range is rather limited. It will depend on the application whether this is sufficient.

On the other hand, the bandwidth of the oscilloscope will probably be sufficient for most applications, but we would wish for some improvements in the spectrum analyser software. Velleman informed us that improved versions of the software are being developed, also as a consequence of user requests.

Overall, this is quite an attractive set of test equipment. Unfortunately, the price of the oscilloscope in particular is fairly high. Not so much in comparison with competing PC-scope products, but this amount of money will also buy you a nice 'hardware' oscilloscope. For the current price of the PCS500 we would really have expected to see two real oscilloscope probes included in the package. For those with lesser demands, the single-channel 'scope K8031 is available. This one is much cheaper

but also has a much lower sampling frequency. And finally, dear developers from Velleman, perhaps use the USB port next time? This provides much greater flexibility and leaves the sole Centronics port on the PC available for the printer. Finally, please not that at the time of writing this article, the ready-made units PCG10 and PCS500A were not listed by Maplin, the UK distributor of Velleman kits.

(020080-1)

Further information:

www.velleman.be

Updates and a demo of the PC-Lab 2000 program are available from

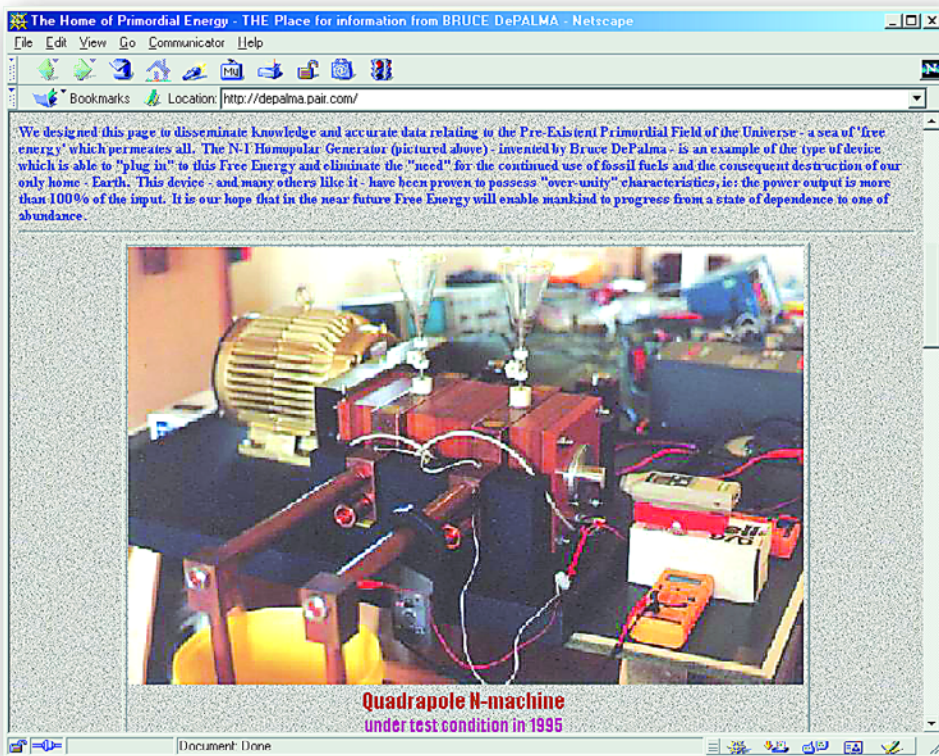
www.velleman.be/company/download.asp

Free Energy

some say it exists

By Harry Baggen

The word 'free' is always sure to trigger reader response but we'd say hold your horses. Here, the word should be taken to mean 'liberated' or even 'from an unknown source'.



Recently, when one of our readers kindly pointed us to a website describing so-called 'free energy devices' we were lead to believe it was either a hoax or a belated April spoof. However on closer inspection of a number of circuits on this website we found the subject intriguing, then fascinating, and quickly abandoned the initial impression of 'a bag 'o joke circuits'. Of course, you are free to your own opinion, but we found the subject sufficiently interesting to cover it on this month's Electronics Online pages.

The overview of free energy devices [1] starts with an explanation of the term. So

what is a 'free energy device'? Well, there are three possibilities:

1. A device that gets its energy from a source not (yet) known to modern science.
2. A newly coined name for a *perpetuum mobile*.
3. A device that gathers, and makes available, energy at no charge whatsoever.

The last option could also include a means of stopping your electricity

meter from ticking but still passing electric energy. That, unfortunately, is illegal (and dangerous) and not meant either. Your thoughts should really go into the direction of a solar panel...

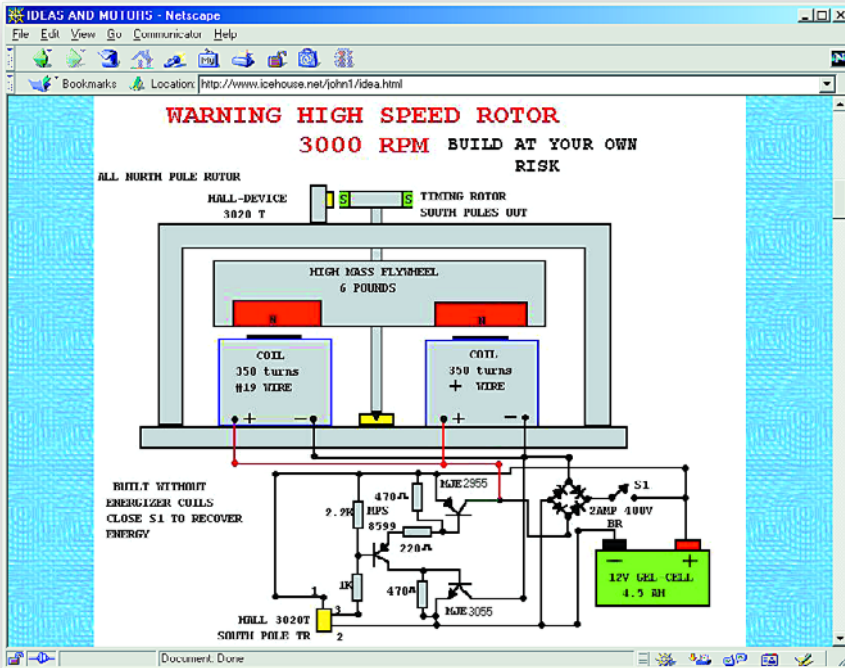
The idea of being able to create a perpetuum mobile has fascinated mankind for centuries. Never, right up to the day of writing this article, has anyone succeeded in building a device that kept moving for ever and ever without consuming any form of energy.

The first option, then, for the explanation of 'free energy device' is the only that is at least within the imagination of the technically inclined.

One way or another, most subjects in this area make use of electromagnetic fields. Permanent magnets, in particular, are frequently employed.

As long ago as the 1920's, free energy was already the subject of many experiments. Today, complete descriptions of the apparatus used in those pioneering times may be found on the Internet. **Hans Coler's** Magnetic Current Apparatus (Magnetstromapparat) may be viewed on [2]. Another remarkable invention of the of the age was **Hubbard's energy coil** [3], which was (said to be) powerful enough to energize a car or boat. The coil was (again said to be) capable of delivering 280 A at 125 volts!

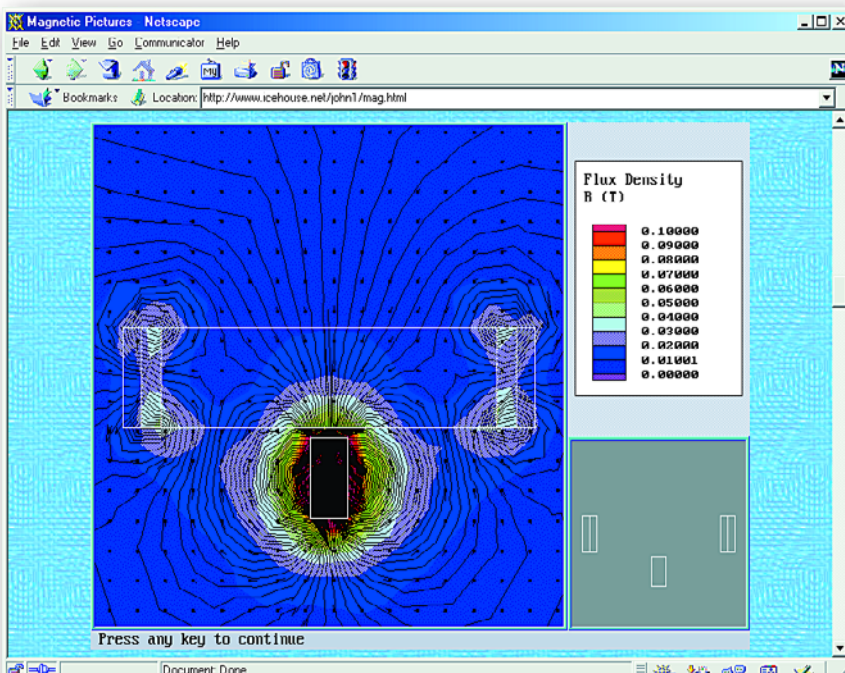
Enough nostalgia, let's return to this day and age where known



energy sources are running out fast and energy conservation is highly topical.

A website with several interesting subject is that of **John Bedini** [4], who has been involved in the subject ever since the 1980's. One of his designs is the free energy generator. The device consists of a motor coupled to a battery. The motor has a huge flywheel with a nearby set of coils. Once the flywheel has enough speed, the battery can be connected to the coils and, yes, it can be

charged in this way. Another circuit capable of generating 'free' energy is the so-called Tesla switch. Admittedly, the theory behind it is as muddy as that of the generator, but the practical realisation is easier to follow! On closer scrutiny, we appear to be dealing with a switching method (originally devised by Tesla) that allows a half charged battery to fully charge another battery. To electronics enthusiast, this a nice subject to tackle because it involves a couple of rather simple electrical and



electronic circuits. In particular, the switching method with a couple of electrolytic capacitors connected in parallel and then in series again, drew our attention and we've actually persuaded our in-house design staff to conduct this experiment once they've finished tweaking the latest PIC software!

The homopolar generator is another machine that draws energy from an unknown source. **Bruce DePalma** [5] has been exploring this generator in depth. His website shows various photographs of prototypes. There is also an in-depth discussion of the technology behind this free energy device. **William Beatty's** experiments with homopolar generators [6] are also well worth looking at. William also provides an explanation of the phenomenon. We do not, however, recommend building the proposed machine because of the large amounts of mercury employed.

In this article we mentioned a number of electricity-related free energy projects. However, we should not forget many other technical achievements like the eternally ticking clock.

In case you get over excited by the prospects of first understanding and then generating free energy, you should keep in mind the stark warning the compiler of the free energy device pages has put at the top of his website:

"Do not give money to people involved in 'free energy'! Legit researchers do exist, but they don't advertize themselves. The people who get publicity are scam artists. If someone is selling plans for 'real' free-energy devices, they are a ripoff. Don't waste your money."

You have been warned!

(025041-1)

Internet addresses:

- [1] Free energy devices:
www.eskimo.com/~billb/freenrg/fnrg.html - hen
- [2] Hans Coler device:
www.algonet.se/~johnnyfg/freenrg/hcoler/hcoler1.htm
- [3] Hubbard coil:
www.amasci.com/freenrg/hubbard1.txt
- [4] John Bedini's energy page:
www.icehouse.net/john1/
- [5] The home of primordial energy:
<http://depalma.pair.com/>
- [6] Homopolar Generator Experiments:
www.amasci.com/freenrg/n-mach.html

WorldSpace Radio (2)

worldwide satellite radio receivers

by G Kleine

A low-cost chipset has been developed for the WorldSpace digital satellite radio system described in the previous instalment of this series. The chipset is already in use in WorldSpace receivers. In this second and final part we will describe several of these receivers, their functions and antennas, and look at the stations that can be received.

In order to ensure the development of low-cost receivers, WorldSpace has commissioned ST Microelectronics and Micronas to produce a million chipsets. The so-called **Starman chipset** consists of the devices whose part numbers and functions are shown in **Table 1**.

Receivers

The first manufacturers of receivers were the well-known Japanese companies Hitachi, Panasonic, Sanyo and JVC. These companies had an exclusive agreement with WorldSpace Corporation until 2001. More recently, other manufacturers have come to the fore, and now 18 companies have signed licence agreements with WorldSpace. Most of the units are portable radios with adjustable antennas attached, and sport at least a mono loudspeaker. Although some of the receivers (from JVC, BPL and Polytron) have the shape of a ghetto blaster and offer stereo loudspeakers, the majority take the form of compact travel radios. All have a socket for stereo headphones, an LCD, often with several rows of characters, and can run from batteries or from the mains, generally via a small mains adaptor. Some units can also receive FM, medium-wave and/or shortwave and long-wave transmissions.

Programmes can be selected by broadcast channel number, service component, language or programme type (see Table 3 in the first part of this series). Intelligent receivers offer programmes in the same language or of the same type as the selected broadcast channel.

Table 2 shows a small selection of

receivers with their characteristics. An overview of known WorldSpace receivers can be downloaded from the *Elektor Electronics* homepage: go to www.elektor-electronics.co.uk, choose the 'Free Downloads' menu, and then select this issue (June 2002) from the downloads index.

It became apparent that at a price of around US\$ 100 the customer base was not as great as had been expected in Africa, where the cost of a WorldSpace receiver is equivalent to about two months' salary. In Ghana, Ethiopia, Kenya and South Africa, WorldSpace receivers are available for US\$ 125 to US\$ 175. Nevertheless, in East Africa alone 40,000 receivers have been sold so far.

In the areas covered by AsiaStar and AmeriStar the units are in relative terms less expensive. There the population can more readily afford the price of a receiver. It is therefore expected that WorldSpace radios

will rapidly be taken up in these regions.

Antennas

A flat, or 'patch' antenna, about the size of a CD, is used to receive the WorldSpace signals. Short helical or Yagi antennas can also be used. The acceptance angle of the WorldSpace patch antenna is around 80 degrees, both horizontally and vertically. This is so wide that exact alignment, as required by TV satellite dishes, is unnecessary. The antennas have an RF bandwidth of around 50 MHz.


The patch antenna is usually detachable and can be situated remotely from the receiver, for example on a window, using an antenna cable fitted with F connectors. The antenna includes an integrated amplifier, which receives its power supply from the receiver over the antenna connection. Typical current consumption for a patch

Table 1 The ST Microelectronics and Micronas Starman chipsets

Manufacturer	Part number	Function
ST Micro-electronics	STA 001	Radio Frequency Frontend IC
	STA 002	Channel Decoder
	STA 003	Source Decoder
Micronas Intermetall	DRD 3515 A	Channel Decoder
	MAS 3506 D	Source Decoder

Table 2a. Some WorldSpace receivers employing the Starman chipset

Note: a complete summary can be downloaded from www.elektor-electronics.co.uk

Receiver	KH-WS 1	RE-WS 10	DSB-WS 1000
Manufacturer	Hitachi (Japan)	Panasonic (Japan)	Sanyo (Japan)
	 HITACHI	 Panasonic	 SANYO
Memories	10	10	32
Other wavebands	FM, MW, SW	none	none
Loudspeaker	Mono, 0.5 W	Stereo, 2x 3 W	Mono, 0.7 W
Headphones	Stereo	Stereo	Stereo
Display	1 row of 8 characters	3 rows of 12 characters	2 rows of 8 characters
Data port	yes	yes	yes
Special features		2-way loudspeaker	remote control, alarm clock
Power supply	4 D cells	4 D cells	2 D cells plus 2 AA cells
Dimensions	241 x 163 x 65 mm	302 x 300 x 135 mm	260 x 85 x 190 mm
Weight	1.5 kg	3.4 kg	1.1 kg
Accessories			5 m antenna cable
Price (Euros)	€ 180	€ 245	€ 190
Website	www.hitachi.com	www.panasonic.com	www.sanyo.com

antenna is around 70 mA. Also, the level of the supply voltage is used to switch the antenna between right-hand circular polarisation (2.8 V to 3.3 V) and left-hand circular

polarisation (2.2 V to 2.5 V).

Antenna cables up to 10 m long can be used without difficulty. If a longer cable run is required between receiver and antenna, a special ampli-

fier can be obtained which is also supplied with power over the antenna connection.




Also available, for around fifty pounds, is a so-called rooftop antenna kit which consists of a Yagi antenna dimensioned for the



Figure 1. Yagi and patch antennas for WorldSpace Radio.

Table 2b. Some WorldSpace receivers employing the Starman chipset

Note: a complete summary can be downloaded from www.elektor-electronics.co.uk

Receiver	FR-DS 100	JSRA-WS 01 10	DAR-WS 2000
Manufacturer	JVC (Japan)	JS Info (South Korea)	JS Info (South Korea)
			
Memories	20	10	10
Other wavebands	FM, MW, LW	none	none
Loudspeaker	Stereo, 2x 3.5 W	Mono, 0.8 W	Mono, 0.6 W
Headphones	Stereo	Stereo	Stereo
Display	1 row of 8 characters	1 row of 10 characters	1 row of 10 characters
Data port	yes	yes	yes
Special features			
Power supply	6 D cells	4 AA cells	2 C cells
Dimensions	450 x 58 x 250 mm	130 x 130 x 40 mm	157 x 139 x 25 mm
Weight	4.2 kg	0.9 kg	0.3 kg
Accessories	8 m antenna cable	3 m antenna cable mains power supply	mains power supply
Price (Euros)	€ 200	€ 190	€ 200
Website	www.jvc.com	www.joyear.co.kr	www.joyear.co.kr

1.5 GHz band and designed for fixed installation. An antenna cable to wherever the radio is situated is then also required.



Figure 2. AfriStar's three beams.

A Yagi antenna is supplied instead of a patch antenna with the low-cost WSSR-11 receiver. This type of antenna typically has a very narrow acceptance angle and must therefore be aligned very accurately. For portable or mobile reception in Europe WorldSpace receivers with patch antennas are invariably the preferred option.

So far only a car antenna with magnetic base has been made available, even though reception is impossible if the satellite is obscured by trees or houses. It was developed by the broadcaster Hit Mix FM and costs around one hundred pounds, and is a modified Sanyo DSB-WS 1000 patch antenna. Methods are being worked on to avoid signal interruptions while the satellite is briefly obscured. One idea is to transmit a channel simultaneously live and delayed by a few (4.32 to be exact) seconds. The receiver can then

reproduce the delayed channel while storing the live channel in a buffer. If the signal is interrupted, the receiver can continue to play for up to another 4.32 seconds. When reception is re-established, the receiver can return to the delayed channel and fill the buffer again from the live signal. A disadvantage of this method is that the system can only carry half as many transmissions.

Also, experiments are being carried out with terrestrial repeaters that receive the WorldSpace signal from the satellites and rebroadcast it in obscured areas. This principle of using fill-in TV transmitters is already well known.

WorldSpace Direct Media Service

The WorldSpace system is also designed for data transmission. The WorldSpace Direct Media Service

(DMS) can send up to 128 kbit/s over one broadcast channel. Of course, it is not possible to provide a fully featured Internet connection, since there is no reverse channel, but editorially-selected Internet content of some 15 websites is provided and made available in the form of regular transmissions to WorldSpace receivers. An up-to-date list of websites available using DMS can be found at www.worldspace.com/productservices/directmedia/contentlist.html.

Every WorldSpace receiver has a data port which can be connected to a PC over the USB interface via an external adaptor. An expansion card is also available for the PC which contains a complete WorldSpace receiver. An external antenna is attached directly via an F connector, and the data services can then be received. Users who also want to listen to the radio stations will not be disappointed: the audio signals can be connected to a stereo system, allowing the PC card to be used as a high quality radio.

The final part of the WorldSpace specification provides for text and small-format TV images (176 by 144 pixels at 8 to 12 frames per second) to be transmitted in a broadcast channel. Top-of-the-range receivers can reproduce these images on a suitable display without a PC.

WorldSpace radio in central europe

After AfriStar was launched Hitachi carried out initial reception experiments which revealed that good reception of WorldSpace radio was possible using the standard patch antenna not only in the target regions but much further afield. The west beam of AfriStar can be received without difficulty as far north as Scotland and southern Scandinavia (Figure 2). The east beam, on the other hand, reaches only as far as southern Europe and reception here is only possible using

Table 3 AfriStar channels

Note: Channels broadcast on the west beam can be received in central Europe.

BCID	Station	Programme Type	Language	West beam	South beam	East beam
543	EMA TEST	Education	various	X		
613	NGOMA	Music	English	X	X	
614	Killa Musika	Music	Arabic	X	X	X
615	Haneen	Music	Arabic	X	X	
627	WRN-1	News	English	X	X	X
628	WRN-2	News	German	X	X	X
700	BOB	Music, Modern Rock	English	X	X	X
701	Ultra Pop	Pop Music	English	X	X	X
702	24x7	Dance Music	English	X	X	X
703	Potion	Urban, Adult Contemporary Music	English	X	X	X
704	Up Country	Country Music	English	X	X	X
705	RIFF	Jazz Music	English	X	X	X
706	RITMO!	Pan African	English	X	X	X
707	Maestro	Classical Music	English	X	X	X
750	ALC	News / Information	English	X	X	X
800	Egypt-1	Music, News	Arabic, English, regional French	X	X	X
801	Egypt-2	Music, News	Arabic, English, regional French	X	X	X
804	RadioVoyager	Adult, Contemporary Music	English	X	X	X
805	KISS 100	Music	English		X	X
806	East FM	Music	English, Hindi, Urdu	X	X	X
H807	KBC	Full Service	Swahili	X	X	X
810	Radio &TV Senegal	Full Service	French	X	X	-
812	WALF FM	Full Service	French	X	-	
814	CNN International	News	English	X	X	X
817	Medi-1	Full Service	English	X	X	X
818	Bloomberg-En	News	English	X	X	X
819	Bloomberg-Fr	News	French	X	X	X
820	Bloomberg-Sp	News	Spanish	X	X	X
821	Bloomberg-It	News	Italian	X	X	X
823	Radio One	Full Service	English	X	X	X
824	Capital Radio	Music	English, Turkish	X	X	X
825	RMC-MO	News	Arabic, French	-	X	-
829	REE	Full Service	Spanish	-	X	-
830	MBC	Full Service	Arabic	-	X	
831	RBC	Music	Hindi	X	-	X
832	Canal EF	Education	French	X	X	X
833	CONGO-BZV	Full Service	French	X	X	
834	Europe-1	News	French	X		
835	KIE	Education	English		X	
837	HITMIX FM	Music	German, English	X	X	
838	CAPITAL FM	Pop Music	English	X		
900	KAYA - FM	Full Service	English	X	X	X
902	RFI-2	News, Music	French, English	-	-	X
903	RFI-1	News	French	-	X	-
904	BBC-AfrW	News	English	-	X	-
905	BBC-AfrS	News	English	-	-	X
906	BBC-AfrE	News	English	-	X	-
907	BBC-Arab	News	Arabic	-	X	-
908	AIR	Full Service	Hindi, Urdu	X	-	-
909	Lusofonia	Full Service	Portugese		X	
942	Jacaranda	Music	English		X	
947	Highveld	Music	English		X	
999	Ch Islam	Education	English	X	X	
1515	Marine T	News	various	X		

a directional antenna, such as a Yagi. The south beam of AfriStar can of course not be received in Europe.

WorldSpace radio programmes

During the construction of the WorldSpace system there were many changes to the satellites' channel allocations. Initially many programmes were produced by WorldSpace itself, in order to provide an incentive for people to buy receivers. Once it was demonstrated that the efficiency of the system was so good that reception was possible well outside the planned target areas, it became possible to find more and more programme providers who were prepared to rent a WorldSpace broadcast channel. Today, alongside internally produced education and light entertainment programming, there are many well-known radio stations on WorldSpace: BBC, CNN International and Radio France International (RFI) to name just a few.

Prospects

WorldSpace is the first satellite radio system available worldwide. The satellite infrastruc-

ture is now in place with AfriStar, AsiaStar and AmeriStar, and the system offers fixed and mobile reception. The number of firms producing WorldSpace receivers is growing rapidly. The prices are still subsidised by the WorldSpace organisation, but will fall as take-up spreads and quantities grow. Work is in progress on in-car mobile receivers: where there is line of sight to the satellite there is clearly no problem; where the satellite is obscured, between buildings in a city for example, fill-in transmitters must perhaps be resorted to.

All in all WorldSpace has a good chance of establishing itself worldwide — in contrast to national projects such as German Digital Satellite Radio (DSR), abandoned after just a few years. It helps that the system is aimed at regions not well supplied with radio stations, rather than trying to introduce a modern transmission system into areas already over-supplied with established stations. Nevertheless, the construction of a EuroStar satellite to

extend WorldSpace signal availability to the whole of Europe is already being considered and is the subject of preliminary contracts with satellite manufacturers.

(021002-2)

References:

- ST Microelectronics STA001 and STA002 datasheets (at www.stmicro.com)
- Micronas DRD3515 and MAS3506 datasheets (at www.micronas.com)

Information

on the World Wide Web

(see also under 'HyperLinks' at

- www.elektor-electronics.co.uk)
- www.worldspace.com
- www.worldspace.org
- www.stmicro.com
- www.micronas.com
- www.alcatel.com/telecom/space
- www.worldspaceradios.co.uk
- www.orbitica.com
- www.hitfm.de/worldspace/main.html
- www.hit-fm.com