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Digital sine-wave generator
In-car ioniser
Electronics Technology

Its master's voice ................................................. 3.19
The razor edge of the excimer laser ....................... 3.25
Flap-effect optocoupler ..................................... 3.37

Projects

Digital sine-wave generator .................................. 3.21
VLF add-on unit for oscilloscopes ......................... 3.27
ROM/RAM card for Electron plus One ..................... 3.32
Software for the BBC computer-3 ......................... 3.35
Micro-squeaker .................................................. 3.38
Battery saver ..................................................... 3.39
MSX extensions - 4 ............................................. 3.40
The Junior Computer as a frequency counter .......... 3.45
In-car ioniser ..................................................... 3.47

Information

News • News • News ........................................... 3.15
Junior Computer facts ......................................... 3.45
New products ..................................................... 3.58
Infosheet .......................................................... 3.67
Licences & letters of intent .................................. 3.70

Guide lines

Switch board ....................................................... 3.63
Classified ads ..................................................... 3.74
Index of advertisers ........................................... 3.74
Corrections ........................................................ 3.74

Selex-21

Charging/Discharging ......................................... 3.50
Phase-shift ......................................................... 3.52
Simple dimmer .................................................... 3.54
Half wattage dimmer .......................................... 3.56
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Range of 'TV' speakers

<table>
<thead>
<tr>
<th>COLOR T.V. SPEAKERS</th>
<th>TYPE/DIMENSION</th>
<th>MM/INCHES</th>
<th>WALL</th>
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<tr>
<td>8x13 LCT 3/5</td>
<td>78x118 (3&quot;x4 1/8)</td>
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<td>CONTEC/TOSHIBA</td>
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<tr>
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<td>(14&quot;)</td>
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and Newman (BBN), which has a contract from the American Defense Department to develop speech recognition technology, compares it with trying to read handwriting in which not only are all words connected, but the shape of each letter depends on the letters that precede and follow it. People do not leave gaps between words in speech as they do on paper. In the chart below, note that the gaps correspond to consonants, not word endings.

Note the less, thanks to the arrival of customized chips and dirtcheap computing power, it is now possible to build a device that can hear each of thousands of words correctly and within half a second in more than 95% of cases. Venture capitalists have got wind of this company's human's ability to make mental pictures of words. In April last year, it did the same on a personal computer, using two chips called digital signal processors developed at IBM's laboratories in Switzerland and France. Dr. Jelinek now says he has gone even further and given a PC a vocabulary of 20,000 words. IBM calls the speech recognizer Tangora, after the computer, the world's fastest typist. It has not yet said how well it will be selling Tangoras. Dr. Jelinek plans to distribute a few dozen to offices in IBM research laboratories next year for evaluation.

Setting limits

Kurzweil, Dragon, and IBM all realize that the only way to tackle speech recognition is to limit the problem in four ways:

- Vocabulary A large vocabulary can be made manageable by teaching a machine elementary grammar. For example, sentences are more likely to begin with "what" than "that". Dr. Susan L. Kurose, a Harvard professor, whose skills of syntax are incorporated into Kurzweil's voice writer, divides speech into about 500 kinds of word and defines which kinds of words follow which in a direct sentence. IBM uses what it calls a "trigram" approach given the two preceding words, it predicts the third.

Most researchers reckon a good dictation machine would have to know 20,000 words. Kurzweil disagrees. The vocabulary of even an educated English speaker is surprisingly small. Shakespeare used about 30,000 words in all his writing, but most people are much less prolific. Dr. Robert Kurose, director of design at Kurzweil, found that he had used 8,000 different words in all his writing during two years (103,000 words in total) and only 4,000 of those were used more than once. IBM has searched 27 million words of office correspondence to glean the 20,000 words most commonly employed for its Tangora. Those 20,000 account for 96% of the total.

- Connected speech. All three machines require each word to be spoken in isolation from its neighbours. Thus greatly facilitates recognition, but it is inconvenient, slow, and is plain not how the human mind works. However, even with gaps between words, it should be possible to dictate to Kurzweil's voice writer at a rate of about 60 words a minute considerably faster than most professionals type though well short of Mr. Tangora's 147 words a minute.

Isolated speech may turn out to be a technological dead-end. Dr. Kurzweil does not think so. He says his voice writer will be able to handle connected speech by 1988. IBM's Dr. Jelinek reckons it will require a ten-fold increase in computing power. But IBM's Dr. Makhoul says that you cannot tackle connected speech without sacrificing performance on other counts.
Speaker dependence To be good, speech recognisers will have to be trained to an individual's voice. Where the ability to recognise any voice is required (eg, dialling telephone numbers), either vocabulary will have to be limited or errors tolerated.

Training the machine to your voice will be tedious: once the vocabulary gets much above 1,000 words, it is impractical to sit down and repeat each word three times. Kurzweil's solution is to get a sample of up to 2,000 words from the speaker and use those to infer how he will speak other words. Then, when it hears him say the real word, it substitutes the real thing for its guess. IBM's Tanga is trained by the user reading a set text of 1,100 words, from which it "accepts" its representations of the other words in its vocabulary.

Background noise Given a high-fidelity microphone and no noise in the background, a computer will make a better job of recognising each word than over a noisy, long-distance telephone line with its narrow range of frequencies and crackles. Again, each designer has to choose whether to sacrifice performance for robustness or vice versa.

Look, no hands
Nobody knows quite what the implications of computers taking dictation will be. One of Kurzweil's best ideas has been to send Mr Kinkead to find out what people want from such a machine and design it accordingly. Mr Kinkead's main discovery was that people do not want to see a keyboard at all. They want not only to dictate their computer, but to correct words, move around the screen and sign off with spoken commands. If they have not learnt to type before, they do not want to start now.

So, although the Kurzweil voice writer will work with any word-processing program, it can be entirely controlled by speech. "Listen-to-me" wakes the computer up; "move-right" moves the cursor right, "next-choice" corrects a wrongly heard word by telling the computer to substitute its second-best guess. Connected words are used in such commands and isolated ones in dictation. Kurzweil reckons that the market for the voice writer will be lawyers, doctors and middle managers, who generate a lot of text. And many disabled people should benefit. Stanford University and America's Veterans Administration are developing a robot with wheels and a mechanical arm that is controlled by a voice system.

Many speakers of Japanese and Chinese have even more reason to welcome speech recognisers than English speakers, as they struggle to design keyboards that can manage many thousands of characters. NEC already makes a 500-word recogniser and Fujitsu a 256-word one.

Such machines need not confine their recognition to words. Kurzweil discovered that one of the customers who bought its voice system was using it to identify the sound of faulty bearings in machinery. In a similar mood, some of Kurzweil's scientists taught the machine to distinguish three different kinds of back by one of their dogs, as "animal in the yard", "somebody at the door", and "let me out!". It worked well.

The machines described in this article mark only the beginning. By the end of the century they will be as obsolete as typewriters. Some of the speech-recognition projects—especially those paid for by defence departments to help fighter pilots do a dozen things at once in dogfights—give a glimpse of what will one day be achieved.

Bolt Beranek and Newman, using enormous computing power (a Symbolics LISP machine or one of IBM's own parallel computers called Bur- teflies), is in no hurry to get a product to market. It searches isolated words and works instead with connected speech. It is still restricted to a small vocabulary and it takes minutes for a long sentence, but it works. To watch it gradually making up its mind about what you said (and puzzling over your English accent) is eerie.

An even more futuristic idea is exciting Mr John Bridge and Dr Roger Moore at one of Britain's defence-research laboratories, the Royal Signals and Radar Establishment in Malvern, Worcestershire. They want to try speech recognition on a new generation of computers called either "Boltzmann machines" or perceptrons. These are networks of microprocessors built to imitate primitive brains.
DIGITAL SINE-WAVE GENERATOR

This simple to build AF generator can output a digitally obtained sinusoidal output signal in the 2 Hz to 20 kHz range.

There are various ways of generating a sine-wave signal in the AF range, and numerous designs to this effect have already been published in this magazine. However, where the main concerns of the user include a high degree of output level stability, low distortion and reliable coverage of the full AF spectrum, quite a number of basic designs fail short of the necessary performance in these and other important respects.

The generator described in this article outputs a sinusoidal waveform obtained from an EPROM, i.e. a digital storage medium. The data stored in the EPROM (Erasable Programmable Read Only Memory) is the template, so to speak, for the output waveform. As shown in Fig. 1, a clock generator, three dividers, and a cyclic address counter cause the data bytes in the EPROM to be fed to a digital-to-analogue converter (DAC), whose output signal is cleaned with the aid of a tracking low pass filter. An output amplifier has been included to ensure a sufficiently low generator output impedance.

Circuit description

With reference to the circuit diagram, Fig. 2, the tunable clock oscillator is composed of monostable multivibrators MMV₁ and MMV₂. Frequency range switch S₅ selects the appropriate output from divider chain IC₃-I₃, while P₆ is used as the fine adjustment for the generator output frequency.

The oscillator circuit with the two MMVs ensures a stable output clock signal over the entire 128 kHz to 1.28 MHz range. The oscillator and the divider chain can supply the following frequency ranges:

- 128 Hz...
- 1280 Hz (IC₄; S₆=1),
- 1280 Hz...
- 12.8 kHz (IC₄; S₆=2),
- 12.8 kHz...
- 1.28 kHz (IC₄; S₆=3),
- 1.28 kHz...
- 128 kHz (MMV; MMV₂; S₆=4).

As each period of the output sine wave is generated in 64 steps, the generator has an output frequency range of 2 Hz to 20 kHz.

The clock pulses at the pole of S₅ are inverted with the aid of MOSFET T₁ to ensure the correct phase relation between FF₁ and IC₅, a Type 4030 binary counter, which drives the address input lines A₀...A₄ of the EPROM containing the digital pattern for one period of the sine wave. It is seen that only 64 from the 8192 bytes available in the Type 3761 EPROM are used (6 address lines A₀...A₅, 2₆=64). This is, admittedly, rather a waste of memory capacity, but it must not be forget-

Fig. 1 Block diagram of the digital sine-wave generator. The cut-off frequency of the low pass output filter is switched along with the frequency range setting.
EPROM.

diagram of the digital sine-wave generator. The output waveform is stored in an EPROM.

ten that, in general, EPROMs in the 27XX series offer shorter access times as their holding capacity increases. The Type 2764 is now widely available, and its price has come down to the level of a 450 ns type 2732. The majority of manufacturers of the 3764 specify a device access time of the order of 250 ns, being the maximum permissible value for the EPROM used in this circuit.

Output Q of cyclic counter ICs goes high after every 32nd pulse transition at the CLK input. This event causes bistable FF1 to toggle and drive data input D0 of DAC ICs low. Latch IC1 is inserted between the data outputs of the EPROM and the data inputs of the DAC to ensure that glitch-free logic levels are transferred during the rising edge of a clock pulse. As counter IC3 addresses all 64 memory locations in the EPROM, each of the successively output bytes represents an instantaneous voltage of the output sine-wave. Table 1 shows the contents of the EPROM. Assuming that IC1 has not yet reached output state 32, its Q output is low, and the Q output of FF1 drives DAC databit D0 high. Therefore, the first 32 hexadecimal values to be converted by the DAC are $0 \times 1H$ $32 \ldots 119$ Then, FF1 toggles, and Ds of the DAC is driven low, causing the next 32 steps to be $0F$ $0E7 \ldots 0CE$ $0E7$. Thus, the positive half period of the sine-wave is written with counter states $0 \ldots 32$ ($D = 1$), the negative half period with counter states $33 \ldots 64$ ($D = 0$). With 64 memory locations, 8-bit conversion values are available for the DAC in phase increments of $5.625^\circ$ ($360^\circ/64$). The attainable resolution for the steps is $U_b/2^8$.

The staircase-like output signal of the DAC is fed to a variable-R.

![Circuit diagram of the digital sine wave generator. The output waveform is stored in an EPROM.]

![Suggestion for a simple power supply. Note that a 5 V regulator is filled on the generator board.]

Table 1. Hexadecimal representation of the contents of EPROM IC1.

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3-22 eléktor 1987
Fig. 4 Track layout and component mounting plan for the sine wave generator

- **Parts list**
  - (generator board, Fig. 4)
  - Resistors (±5%)
  - R1, R2, R3 = 2k2
  - R4 = 10k
  - R5, R6 = 1k
  - R7 = 100k
  - R8, R9, R10, R11 = 100R
  - Re, Rf, R12 = 470R
  - R13 = 15k
  - R14 = 3k9
  - R15, R16 = 10k
  - R17, R18 = 100R, 0.5 W
  - Pt = 100k stereo potentiometer linear

- **Capacitors**
  - C1 = 15p ceramic
  - C2 = 68p ceramic
  - C3, C4, C5 = 100n
  - C6, C7, C8 = 150, 15p, 18 V electrolytic
  - C9 = 22p ceramic
  - C10 = 69p ceramic
  - C11, C12 = 10n
  - C13 = 33n

- **Semiconductors**
  - Diode
  - Transistor

- **Miscellaneous**
  - S1 = 2 pole, 4 way rotary switch for panel mounting
  - Power supply as shown in Fig. 3
  - PDB Type 4701

- **Recommended enclosure**
  - Veroboard type 075.5111D
  - Single hole BNC socket
  - Front panel lid Type 47001 F

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**Notes**

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fixed-C low-pass filter, whose cut-off frequency is arranged to track along with the generator output frequency. The filter is required to smooth the stair-case into a sine-wave, and at the same time to suppress harmonics and spurious DAC output signals. The simple R-C filter offers a skirt steepness of about 6 dB/octave, which is adequate, as the first strong spurious signal has a frequency 64 times that of the fundamental note.

The output amplifier of the sine-wave generator is based around IC91, IC92, T7 and T8. The latter two are medium-power transistors in a balanced power output stage capable of driving relatively low impedance loads (Zout ≈ 50 Ω). The output amplitude of the generator can be adjusted with P5.

The generator board comprises its own 5 V regulator. Therefore, a simple, symmetrical 8 V supply suffices to feed the instrument—Fig. 3 shows a standard design to accomplish this. LED D1 on the generator board is used as the power on/off indicator.

Construction

The sine wave generator is constructed on ready-made PCB Type 8700. With Fig 4 and the parts list (see Fig. 5) to hand, no constructional problems are envisaged. The frequency and amplitude controls are fitted straight onto the board to enable this to be mounted vertically, behind the enclosure front panel. Make sure that you use good quality presets in the P1 and P2 positions, else the stability of the generator output signal will be affected. Power semiconductors T7, T8 and IC8 can do without heatsinks, but due account should be taken of the potential at their metal mounting tabs. The spindles of S3, P1 and P2 are left long enough to protrude through the instrument's front panel. The output of the generator is made with a single-hole type 5NC socket.

As to the power supply, this is constructed on PCB Type 9968—see Fig. 5. The regulators are best fitted onto a metal surface, e.g. on an aluminium plate cut to slide into the slots at the rear of the VEnobox enclosure. Do not forget to fit both the 7810 and the 7910 with insulating washers to preclude short circuits via the cooling surface.

Setting up and filter considerations

To begin with, the ±8 V supply is separately tested by measuring its open-circuit output voltage. Connect the completed generator board, switch on, and see if the LED lights. The precise adjustment of the D/A converter can be carried out by temporarily replacing R16 with a 5 KΩ multturn preset, and connecting a digital multimeter between pin 18 of IC2 and the preset. Make sure that the preset has previously been set to the centre of its travel, and adjust it for a current of 2 mA. Remove it, measure its resistance, and fit an appropriate high-stability resistor in the R16 position. While you have the board lying in front of you to perform this test, it is a good idea to check the measuring points indicated in the circuit diagram.

Should you want to use the generator to provide only one fixed output frequency—e.g. for distortion measurements—, it is certainly worth while to replace the P5-C9 filter with a higher order type to attain an output distortion of about 0.01%. It is readily seen that such a filter is considerably more complex, and also more difficult to track with the generator output frequency, that the proposed single R-C combination, and that is why it was left out of the present design. It is possible to store waveforms other than a pure sine-wave in the EPROM. Do not forget, however, that the simple R-C low pass will cause distortion of sharp points in the signal, for instance, ramps and triangular waveforms. For these applications, a very complex DAC output filter is required, making the digital approach to signal generation cumbersome as compared with conventional analogue techniques.
THE RAZOR EDGE OF THE EXCIMER LASER

by Dr Malcolm C. Gower, Laser Division, Rutherford Appleton Laboratory, Chilton near Oxford

Excimer lasers produce extremely intense bursts of ultraviolet light. Their ability to do so is generating a great deal of interest in areas as diverse as chemical synthesis, defence, surgery, and semiconductor processing and chip manufacturing. The short-wavelength photons they produce have enough energy to break most of the chemical bonds that bind molecules together, thereby fragmenting or stimulating them to change their form. This ability to control the chemical state at matter and change it in a desirable and very selective way is at the heart of many of the most exciting applications of excimer lasers.

The most common type of excimer laser uses molecularly diatomic rare-gas halides such as ArF, KrF, XeF or XeCl as the active species from which the laser light is produced (see Spectrum 198). In their common, unexcited form, atoms of the rare gases Ne, Ar or Xe are unreactive or inert and do not readily form molecules. But if an electron is knocked off an atom to ionize it, the atom can become extremely reactive and form molecules, particularly with negative halogen ions of the F-, Cl-, Br and I types which have an additional electron attached to them.

Rare-gas halide molecules are held together by electrostatic forces, similar to the way alkali halide (salt) molecules are formed, as in the first illustration (a). Because of their transient nature, with a lifetime of a few billionths of a second before falling apart by spontaneously emitting ultraviolet photons, rare-gas halide molecules cannot be bought in a bottle but must be created in the laser vessel as such. It is usually done by high-voltage electrical discharges in gas mixtures of halogen-bearing molecules and rare-gas atoms, as in part (b) of the illustration. The unexcited rare-gas halide molecules which form the lower laser level are unstable, so that at any instant there are very few of them in the laser vessel. Nearly all the rare-gas halide molecules in the vessel are excited and have energy available for extraction as ultraviolet laser photons. The wavelength of the laser light is determined by the type of molecule created and can be selected simply by changing the gas mixture originally added to the laser tube, as shown in the table; the pulsed energies of the light obtainable from typical commercial excimer lasers are also listed. Such devices can produce pulsed bursts of light lasting approximately 2 x 10⁻⁹ second at up to 500 times a second.

Nuclear fusion

Much larger excimer lasers can be built in the laboratory. A KrF laser at the Los Alamos National Laboratory, USA will soon be producing four terawatts (4 x 10¹² watts) of ultraviolet light. This power is several times more than the combined capacity of all the electricity generating stations in the world today, but the laser can produce it for only about 5 x 10⁻⁹ of a second. With the aim of eventually building a laser-driven nuclear fusion power plant for the relatively cheap pollution-free production of energy, this extremely large laser is being used to study the nuclear fusion reactions produced when the focused laser light illuminates, heats and compresses to high density tiny glass microspheres containing deuterium and tritium gas to obtain more fusion energy from the pellets than is put into it by the laser light the plasma created should last for at least 2 x 10⁻³ second and have a temperature close to that on the Sun (10⁸ degrees) while maintaining a density more than 50 times that of solids. Experiments have shown that such high temperatures and densities are more readily achieved by using short-wavelength ultraviolet laser light to iridate and compress the target. Because excimer lasers can efficiently convert electricity to pulsed bursts of ultraviolet photons (conversion efficiencies of over 10 per cent have been demonstrated) and can in principle do so many times a second, they are considered to be the most likely source for any laser induced fusion power plant which may eventually be constructed.

Seminconductors

The ability of ultraviolet excimer laser light to break molecules apart so easily is now being exploited in the semiconductor industry. For example, highly uniform conductive metal coatings can be deposited on the component surfaces of a silicon chip by using the laser to release metal atoms from gaseous molecules above the surface. This step in silicon chip fabrication is called chemical vapour deposition and is conventionally done by means of plasma techniques, which in general are far more destructive to the silicon wafer and less controllable than the laser technique. Thin crystalline layers of silicon can also be grown by depositing atoms of silicon. Furthermore, by simultaneously locally melting the silicon wafer with an excimer laser, the technique can be adapted to implant dopants into the bulk silicon. Such implantation is used to create the p-n junctions which combine to form the semiconductor circuit elements in the chip.

Present non-laser methods of implanting dopants into silicon by ion bombardment or plasmas tend to leave the silicon crystal lattice damaged, so it is essential to recrystallize (anneal) the silicon wafer in a high-temperature area. Apart from adding another slow step to the production process, high-temperature annealing of the whole wafer can also lead to distortions of the circuit elements on the chips. On the other hand, the excimer laser method of implanting can simultaneously locally anneal the silicon wafer as well as achieve very high, supersaturated concentrations of dopant atoms. There is another process, too, in producing silicon chips, that can be improved upon by the excimer laser. Extremely small, complicated circuit patterns to be fabricated on the silicon wafer are initially laid out by reproducing master mask patterns in the circuit on a thin,
light-sensitive plastic polymer film called the photoresist, coated on to the silicon, in a way similar to that in which a camera works, lenses or mirrors project an image of the illuminated mask on to the photoresist. In the exposed, bright regions of the mask pattern, the photoresist is then removed by chemical development. Ions are subsequently implanted into the silicon through the gaps in the photoresist. This process of optical replication of mask patterns on to the silicon wafers is known as photolithography, incoherent lamp sources illuminate the mask. Recently, however, ultraviolet excimer laser light sources have demonstrated several unique advantages over lamps in such work. The most striking advantage is that the laser can produce images which are nearly 10^6 times brighter than those produced by a lamp. This means that the exposure time of the photoresist can be made negligibly small, allowing a substantial increase in the chip throughput of a photolithography machine. Furthermore, because the wavelengths produced by excimer lasers are in general shorter than those produced by high-powered lamps, smaller feature sizes on the mask can be replicated on to the chip. This allows many more, smaller circuits to be packed on to the chip, so that each chip can perform a greater number of operations at a greater speed.

Another advantage of the excimer laser is that the extremely short burst of ultraviolet photons can also directly remove (etch or ablate) the photoresist from the exposed regions without the need for wet chemical development. So the excimer laser source may mean cutting out another processing step in chip production.

Clean etching

Ultraviolet excimer laser light directly etches plastics materials by producing a microexplosion through efficient, rapid breaking of the chemical bonds that hold the polymer together. Unlike lasers working at longer wavelengths, the excimer laser produces no melting and very little heating of the surrounding unexposed material, so that remarkably clean, wallless cuts are produced in the crater left behind. This type of clean etching also applies to biological tissue. The possibility of performing extremely clean cuts without charring and damage to surrounding tissue has aroused a great deal of interest in medical centres around the world.

The first study of a medical application of excimer lasers was to do with cutting and reshaping corneal tissue in the eye. Unlike light of a longer wavelength, ultraviolet radiation does not pass through the cornea layer at the front of the eye. In an operation known as radial keratotomy, pioneered in the Soviet Union, a diamond knife is used to make radial incisions in the cornea. Because the cornea as well as the lens can focus light, a change in its radius of curvature can lead to a permanent correction of defects caused by the lens, such as short sightedness. It has recently been shown that masking techniques enable this type of surgery to be done by means of an excimer laser, with a quality and precision far exceeding that achieved with a knife. Moreover, the laser can reshape the cornea by machining rings and crescent shapes. It can also make the precise incisions necessary for subsequent corneal transplants or removal of cataracts.

Balloon angioplasty

Work is also going on to investigate the use of the excimer laser to unblock arteries, a procedure known as angioplasty. Blockage near the heart by accumulation of plaque, the condition known as atherosclerosis, eventually leads to a heart attack. Most widespread of surgical methods now used to alleviate this condition is extremely invasive open-heart surgery, in which surgeons bypass the blockage by grafting a new artery around it. Less invasive is a recently developed technique called balloon angioplasty, in which a fibre is threaded through the arteries to the blockage and a balloon on the end is then inflated to open it out; the patient remains conscious throughout. But the technique can also damage arterial tissue. An alternative method might be to use light from an excimer laser, passed down through an optical fibre in the artery, to burn through the blockage cleanly. Initial studies have shown that for soft, non-calcified plaque the excimer laser can remove the constricting efficiently and cleanly. Calcified blockages are much more difficult to remove. Among other medical applications being studied are very precise neurosurgical cutting in the brain and spinal column. While most applications of high-power visible and infrared lasers use the laser merely as a sophisticated cutting and welding torch, the most exciting potential applications of excimer lasers make use of the high powers which they are capable of producing and the ability of the ultraviolet photons to induce changes in the chemical state of matter in a most efficient way. Many new applications of excimer lasers may be expected to develop as scientists and engineers become increasingly aware of their tremendous potential.
VLF ADD-ON UNIT FOR
OSCILLOSCOPES

This is a low-cost storage unit enabling oscilloscope users to view signals with very long periods. Where the typical oscilloscope merely shows a slowly travelling spot in response to a VLF input signal, this add-on unit is intended to convert that instrument into a versatile chart recorder.

The bandwidth of an oscilloscope is generally considered one of its main technical characteristics. For obvious reasons, the relevant specification is generally featured close to the oscilloscope type indication on the front panel. Interesting as its bandwidth specification may be, the common oscilloscope can not offer what appears to the user to be a continuously written trace, at input frequencies below some 10 Hz.

The vast majority of oscilloscopes is totally unsuited to study a process with a period time of, say, one minute. Even in the unlikely event of the instrument offering a timebase setting of 0.01 Hz/div, nothing would be visible on the screen, other than an apparently stationary, bright spot. In this example, a usable curve can only be obtained from a special chart recorder, or a storage oscilloscope, both of which are relatively costly instruments.

The VLF add-on unit described in this article considerably extends the lower end of the bandwidth of any oscilloscope, having a timebase setting of 500 µs/div, an external trigger input, and a positive edge trigger selection. Its input impedance must not be less than 1 MΩ. Actually, there should not be too many oscilloscopes around which do not meet these requirements.

In essence, the oscilloscope extension is an 8-bit wide memory block inserted between an analogue-to-digital converter (ADC) at the input, and a digital-to-analogue converter (DAC) at the output. Its wide range of available timebase settings—see the Technical Specifications Table—enables the storage unit to be used for applications like studying the thermal behaviour of systems, analysing subsonic movement, or establishing charge and discharge curves of batteries. In the former two examples, a suitable sensor (temperature-to-voltage converter; strain gauge) plus associated amplifier could be used to drive the storage unit.

After the measuring process is completed, the user can view a neat curve on the oscilloscope screen for closer analysis. During the measurement, the writing of the curve can be observed without a trace of display flicker, as the oscilloscope is set to a sufficiently high display rate.

If you are now under the impression that the present storage unit incorporates a fair number of costly components in a highly complex circuit, it is time to proceed reading the next section.

Block diagram

Fig 1 shows the basic operation of the circuit during its two alternating states of digitizing \( U_m \) (CONVERT) and outputting the sampled data to the oscilloscope (DISPLAY). Digitizing of \( U_m \) is essentially done on the basis of ramp and compare. The output of an 8-bit counter, \( I_C_1-I_C_2 \), is translated into an analogue voltage by a DAC (digital-to-analogue converter), which produces a ramp output signal for comparison with \( U_m \) in \( I_C \). As soon as \( U_{out} \) from the DAC rises above \( U_m \), \( I_C \) toggles, and the last present data from \( I_C-I_C \) is written into the RAM location ad-
dressed by ICj. In this manner, the stored databyte is the digital equivalent of the instantaneous level of Um. Note that ICj addresses one RAM location only during the CONVERT mode, as its CLK input does not receive address count pulses. During the DISPLAY mode, ICj is arranged to successively address all the 256 bytes in the RAM, whose contents are fed to the DAC providing the scope with the restored analogue level of Um. The cost-effective use of ICj as a DAC and—along with the 8-bit counter and the comparator—as an ADC requires a rather particular circuit timing, which will be examined below.

Circuit description

The circuit diagram of the VLF storage unit, and its basic internal timing arrangement, are shown in Figs. 2 and 3, respectively. Assuming the circuit to operate in the CONVERT mode, gate network Nj-N*N* disables address counter IC3 from receiving 50 kHz clock pulses from Nj. The address inputs of RAM (random access memory) IC3 are, therefore, held at a fixed logic configuration, causing the rising 256-increment binary value from counter and latch ICj-IC3 to be written to one memory location only. Note that IC3 is a 2048-byte RAM, whose memory capacity has been restricted to 256 bytes by grounding its A0...A7 inputs. The Type 6116 was chosen because it is much cheaper and easier to obtain than, for instance, a 5101 256 × 8 RAM. The Type 2N4268 8-bit DAC thus outputs the analogue equivalent of the output states of ICj, i.e., a ramp is obtained to drive the + input of comparator IC. (see Fig. 3, curve IV), while Um is applied to the protected — input. As already explained, the opamp output remains low as long as Uom from the DAC is lower than Um. Output Q of bistable FFj drives the WE (Write enable) input of IC2 low, so that each binary value from counter ICj is stored and overwritten again at the current address obtained from IC3. Only that counter state from ICj that causes Uom from the DAC to be higher than Um, is left at the rel-
relevant address, as WE goes high immediately afterwards, disabling the writing of further data in the RAM—see Fig. 3, curves IV and V. Obviously, the lower the instantaneous level of WE, the sooner IC₁ toggles, and the lower the value written into the RAM. This completes one conversion cycle.

After every 256 clock pulses from N₁, N₃ supplies a positive pulse transition to the clock input of bistable FF₁, which in response toggles to produce the trigger pulse for the oscilloscope, thus marking the start of the display cycle. The toggling of FF₁ (Q=1; Q=0) causes a number of things to happen simultaneously. Output Q is used to enable the output drivers in IC₁ to pass the binary RAM contents to the DAC input lines. As OE of IC₁ is driven high by Q, no contention problems can arise. Also, the low level of Q is used to disable IC₁ by means of controlling its STROBE input, pin 8. Bistable FF₁ is set to prepare for the next toggle action during a conversion cycle. Output Q of FF₁ enables N₃-N₃ to pass the 50 kHz clock signal to the CLK input of address counter IC₂, causing IC₂ to output all data contained in its 256 memory locations. It is important to realize that the first location addressed is determined by the start state of IC₂; as this counter is not reset, the state of its Q₃...Q₀D outputs is simply frozen after Q of FF₁ goes low again. In order to be able to write to all 256 locations in IC₁, an additional clock pulse is needed to enable IC₁ to address the next higher RAM location where data will be stored during the CONVERT cycle. This pulse is obtained from two cascaded counters in IC₁. After the RAM contents are written into the oscilloscope—i.e., after 256 clock pulses from N₁, FF₁ toggles again to start a CONVERT cycle. The falling edge of Q advances counter IC₁ one state. Depending on the setting of the time/screen switch, S₁, a predetermined number of Q transitions must occur before N₃ can produce the previously mentioned additional clock pulse to have IC₁ point to the next higher location in the RAM—see Fig. 3, curve IV. After a short delay caused by C₁-R₁, C₂-R₂, FF₁ is reset.

The above timing arrangement effectively makes the oscilloscope screen being written from the right to the left, creating the impression of a fixed display window through which the signal can be observed to pass smoothly. The positive edge triggering of the scope ensures that only the DISPLAY phase of the DAC output waveform is shown on the oscilloscope screen—see curve IV.

Fig. 4 further illustrates the basic principle of the scrolling oscilloscope image. Although the writing of the data into the RAM is a relatively slow process—the write rate being the time/screen setting divided by 256—the RAM contents are displayed at such a speed as to ensure a stable image on the scope. The display window can
move thanks to the start state of the RAM address counter being increased by one, after counter IC has received a predetermined number of pulse transitions from the Q output of FF. Although the display window is seen to move to the right in Fig. 4, the actual situation is, of course, that the sampled curve moves to the left. The writing of sampled data can be observed as an additional bright dot appearing to the right of the screen, shifting the previously written image to the left. The instantaneous input voltage for the storage unit is visible as a spot to the left of the screen; at the moment it is written into RAM, the curve shifts one dot to the left, as shown in Fig. 4. Pressing the FREEZE button inhibits the additional clock pulse from advancing IC, so that the displayed image comes to a standstill, while the instantaneous value of the input voltage remains visible as a bright dot at the utmost left of the screen. Pressing RESET causes the RAM to be filled with zeroes, and hence clears the display for a new measuring period.

Returning to the circuit diagram, Fig. 2, delaying R-C networks have been fitted at several gate inputs. It would have been possible to arrange for a correct circuit timing with the use of say, a multi-phase clock section, but the low frequencies involved fully justify the use of simple R-C combinations in the relevant positions. It should be noted, however, that the indicated R and C values are specifically dimensioned for HCMOS gates, making it impossible to use LSTTL.

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**Parts List**

- Resistor 1: 5 kΩ
- R1: 1 kΩ
- R2: 10 kΩ
- R3: 1 kΩ
- R4: 10 kΩ
- R5: 100 kΩ
- R6: 1 MΩ
- C1: 10 nF
- C2: 0.1 μF
- C3: 100 nF
- C4: 10 μF
- C5: 1 nF
- C6: 100 nF
- C7: 10 nF
- C8: 0.01 μF
- C9: 0.1 μF
- D1: 1N4148
- D2: 1N4149
- D3: 1N4148
- I1: 74HC393
- I2: 74HC374
- I3: 74HC244
- I4: 74HC245
- I5: 74HC132
- I6: 74HC350
- I7: 74HC350

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Do not use a LSTTL type

<table>
<thead>
<tr>
<th>Miscellaneous</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1: push to break button</td>
</tr>
<tr>
<td>S2: miniature SPST switch</td>
</tr>
<tr>
<td>S3: 2 pole 6 way rotary switch plus knob</td>
</tr>
<tr>
<td>PCB Type 8035 Beer Readers Services</td>
</tr>
<tr>
<td>A66 enclosure, e.g. Varkoka Type 75-2007C</td>
</tr>
<tr>
<td>160 x 120 x 40 mm</td>
</tr>
<tr>
<td>3 off BNC sockets</td>
</tr>
<tr>
<td>Suitable socket for external supply connection</td>
</tr>
</tbody>
</table>

*It is regretted that the front panel for this project is not available through the Readers Services.*
types without upsetting the circuit timing. The add-on unit does not comprise an internal supply, but this should not be too difficult to make, considering the modest current drain of 100 mA or so from a regulated 5 V supply.

**Construction, alignment and extensions**

The VLF add-on unit is constructed on a ready-made PC board Type 86135—see Fig 5. While completing the board, do not forget to fix any of the wire links, and mount pull-down resistors R1, R2, incl. vertically, joining their common ground connection with a horizontally running length of bare wire.

The introductory photograph of this article, and the one shown in Fig 6, should offer sufficient details to be able to complete the unit successfully. The input and output connections of the storage unit are preferably made with BNC sockets, while the 5 V supply can enter the enclosure through a small DC supply socket as used in pocket calculators and portable cassette recorders. Plenty of space remains in the stated Verobox to incorporate a simple mains supply—Fig. 7a shows the circuit diagram of a suggested version.

Aligning the circuit is as easy as constructing it. Set the scope timebase to 500 μs/div, and select negative-going, external triggering. Set the vertical sensitivity to 200 mV/div, or 20 mV/dw when using a 10:1 probe. Select DC input coupling. These settings enable the scope to show the conversion cycle, rather than the display cycle as used normally. Do not apply an input voltage to the add-on unit. The scope should show one period of the ramp output from DAC IC2. Use the X and Y position controls of the scope to move the start of the slanting line to the lower left hand corner of the display graticule, then adjust P1 and P2 to make the upper end of the curve coincide with the top right hand corner of the graticule. This sets the DAC output for a peak-to-peak excursion of 2 V, at a ramp duration of 5 ms. For normal operation of the storage unit, the scope must be set as during the alignment, but with positive external triggering selected.

Finally, the sample time of the proposed storage unit may be extended as required by adding a divider in series with the connection between the pole of S1 and C3. Fig 7b shows a suggested extension circuit to lengthen each of the time/stroke settings by a factor 10 or 100. With this one-chip extension, the maximum attainable sampling period is no less than 250 x 100 = 25,000 seconds, or about 7 hours.
ROM/RAM CARD FOR ELECTRON PLUS ONE

Here is a 32 Kbyte ROM and/or RAM extension module which plugs straight into the Plus One cartridge slot. In other words, extra memory for the baby brother of the BBC-B micro!

Many programs available for the Acorn Electron microcomputer come in the form of ROMs (read only memory chips) to guard the problem of having to load the program in the limited RAM space available. These ROMs either start up immediately after power-on, or they can be accessed by means of a particular user command. ROMs are generally classified as Service (S) ROMs, Language (L) ROMs, or a combination of these S/L ROMs. Although it would be beyond the scope of this article to expand the intricacies of ROM filing, priority assignment, and identification strings, it is none the less useful to consider the memory organization of the Electron micro fitted with a Plus One extension. Fig. 1 shows that the address range from 0000 to BFFF can be used by four banks of 16 Kbytes, which are switched on and off as required by a suitable command from the ROM resident Machine Operating System (MOS, top 16K), which effectively controls the bankswitching procedure during a programming session. Except when L-ROMs are fitted in either one 16 K block in the cartridge, the Electron will run its BASIC interpreter after powering on, or, more precisely, after MOS has examined all add-on ROMs or RAMs for the presence of a language identification string. If this is encountered and found valid, the computer starts executing object code from the highest priority L-ROM, disabling the BASIC interpreter, but leaving the Plus One Utilities accessible through special commands. As to the amount of RAM (random access memory) in the Electron, there is no denying that the number of bytes available to hold a user program depends on the selected video mode, and the size of the system workspace. Obviously, when running programs in any of the high-resolution graphics modes of the Electron, the user space gets rather tight, as up to 20 Kbytes of RAM are reserved for the video processor. To create more memory space for the user, the proposed extension card can hold a maximum of two banks of 16 Kbytes of RAM. It is also possible to install one 16 Kbyte EPROM and two 8 Kbyte RAMs to make for an even more versatile set-up. For instance, copying ROMs to RAM, or moving large buffer areas to sideways RAM (video applications) is no longer problematic.

A good deal more information on the internal organization, and ins and outs of using the full capability of the Electron, can be found in the Advanced User Guide, by Mark Holmes and Adrian Dickens. This book is recommended as an indispensable supplement to the Acorn Electron User Guide, which typically falls short of information on those technical aspects of the micro that are necessary to get the most out of it.

Circuit description

The circuit diagram of the ROM/RAM card is shown in Fig. 2. The Plus One bus signals (see Fig. 3) are fed to the extension circuitry via the slot connector shown to the left of the diagram. Two wire jumpers are used to select between 16 K ROMs and 8 K RAMs in the IC1 and IC2 positions. Gates N5-N7 provide for a correctly timed WR (write) pulse for the RAMs, while N1-N4 are used to divide the memory space within the cartridge into four blocks of 8 Kbytes, which can either be assigned to two ROMs (2 x 16 K), or to four RAMs (4 x 8 K), or to one ROM and two RAMs (16 K + 8 x 8 K). Thanks to the internal AND function of CS1 and CS2 inputs of the Type 2224 RAM and the Type 27128 EPROM, the chip select circuitry on the card could be realized with only a few gates. Table 1 shows the address assignment and the various chip combinations of the memory extension card. When using L-ROMs, observe that ICs have a higher boot-up priority than ICs.

Construction

The ROM/RAM extension is extremely simple to build on through-plated, double sided board Type 86099. Fig. 4 shows the component overlay. While soldering the IC socket pins, do not apply too much solder on the attachment studying a troublesome hardware bug. Also, make sure that decoupling capacitors do not cause a short-circuit anywhere at least one of the three tracks running underneath it. Pins 1 of the memory chips have been inter-
connected. With some types of (EPROM, it may be necessary to connect the pin 1 line to the positive supply rail running right next to it (pin 1 of a 27128 is the programming voltage input), while it is not connected with a 6264 RAM).

Fit the wire links or the jumpers as required for your specific memory configuration, and finish the construction with plugging in the ICs.

Testing and using the extension

The Plus One extension assigns ROM block numbers 0 and 1 to the rear slot, and block numbers 2 and 3 to the front slot, as viewed from the keyboard. Each block is a 16 Kbyte memory area. The test program listed in Table 2 will check for the presence of correctly operating RAM in the far and/or near extension slot on the Plus One extension.

The essential operation of this "assembler-in-BASIC" routine is as follows. In line 60, the ULA inside the Electron is fed with a dummy byte 14h to pass the bank switching control to the program. Location FE05h is a R/W register internal to the ULA, and great care must be taken in accessing it, as it also comprises interrupt control bits. The 16 Kbyte blocks are each examined as to their ability to be read from and written to without modifying the original memory contents. This is done in a number of nested loops, wherein sideways RAM bytes are copied into a 6502 zero-page location, inverted, stored and loaded again, and checked against the original byte. In this way, correct R/W accessibility of the entire 16 K RAM area is checked on a byte-by-byte basis. After initialization lines 30 to 70 the program fetches the first byte, inverts it by means of an EOR FFh instruction, and stores the obtained result back into the RAM, as well as in...
RAM is restored by once more inverting the active ones and writing it to the location in the extension. This loop-and-test function is executed in line 93. Location $0872$ holds a vector address pointing to the RAM location, which is automatically incremented with the end of the Y (index) register available in the 6800 processor. Location $0871$ holds the block number ($88-8F$), while location $087F$ is used to hold an error flag byte F1.

Returning to the loop in line 70, it is seen that RAM errors cause the program to jump to line 114 where the error flag is set, and the faulty address is written into location $0870$. In line 128 bank switching control is returned to the ULA, and BASIC is restarted. Each page -256 bytes in the extension memory that is successfully tested is identified with a + sign written onto the screen. In this way, defective or non-present RAM pages can be singled out at a glance.

The test run below the listing in Table 2 was performed with the ROM/RAM card fitted with RAMs in the ICs 1, 2, and 3 positions. The card was inserted in the front slot (blocks 2 and 3). At power-on, the computer ran its BASIC interpreter as normally, since no LROMs were detected during the system boot.

Running the RAM test program immediately showed that the upper half of block 3 was found faulty, which is not surprising in the absence of ICs (consult Table 1) once more. (EPROMs, of course, also produce a "no RAM at block number" message.

It must be remembered that the extension memory is only accessible through machine language subroutines; thus is because the BASIC interpreter uses the same 16 Kbyte memory area. You may want to study the previously discussed test program a little closer to be able to write your own subroutines for the creation of background memory or for access to subroutines in proprietary ROMs. With the proposed ROM/RAM card, you will have no difficulty in running commercially available L-ROMs such as LISP, FORTH, LOGO etc., while utilities such as VIEW, editor/assembly packages, and games ROMs can be plugged in to considerably add to the versatility of the Elektron plus One computer.

This memory extension board has been designed and developed with the permission of Acorn Computers Ltd. Ed
SOFTWARE FOR THE BBC COMPUTER — 3: PCB DESIGN

Third in the series, this article looks at designing printed circuit boards with the aid of an artwork production package.

Pineapple Software of Ilford, Essex, are the suppliers of PCB, a software package intended to make high-quality artwork for the direct production of printed circuit boards (PCBs). The program comes as a sideways ROM, a disk, and a reference manual. In essence, PCB is a high-resolution draughting program, capable of outputting layouts to a draft quality printer. The maximum size of a circuit board that can be designed is 10 cm x 16 cm, being the standard Eurocard format. PCB fully supports the making of double-sided boards, and uses different colours for the tracks on each side of the board. PCB is not an auto-routing program, which means that it can not automatically decide on the most efficient track route between roundels. The user of PCB draws the track layout on screen, with the aid of the cursor positioning keys, placing roundels at the required locations. Before being able to do this, however, the component mounting plan must be designed.

Making a component mounting plan

After specifying the overall size of the board required, the screen displays its outline and a number of standard component shapes, which may be expanded as required to provide an easy way of handling, for instance, various sizes of DIL enclosure. Component are "picked up" and located in the desired position on the PCB. They can be interchanged, moved about, and identified with part numbers until the component placement is thought satisfactory. Roundels are automatically placed on a 0.1-inch invisible grid, and the cursor moves with a corresponding precision, except during the line drawing mode when it moves in 0.025-inch steps.

Unfortunately, PCB does not enable users to create their own library of frequently used component shapes. On completion of the component mounting plan, this can be stored onto disk.

Making the track layout

After loading the component mounting plan from disk, PCB removes the component outline shapes from the screen, leaving only the roundels present. A new selection of options is presented to the user. At first glance the track layout on screen looks rather coarse. Especially when tracks are run in between IC pins, it often looks as if a short-circuit exists. Three track widths are available: 0.035 inch, 0.05 inch, and 0.075 inch, but wider tracks are easily made with the flood fill facility, which also allows large copper surfaces to be designed with a single user command. As during the component placing phase, the cursor positioning keys are used to move across the screen, while the part numbers may be "called up" for reference and the display of either side of the board may be removed temporarily to make track routing clearer on complex boards. Further routines available during the track layout design phase include circle drawing, partial and complete deletion of tracks, irrespective of the complexity of the route, component identification in four possible orientations, roundel placing at both PCB sides to prepare for through-plating, and returning to the component mounting plan to move groups of roundels.

Artwork printing

The previously mentioned fear of PCB being too inaccurate to cope with very close running tracks is quite unfounded considering the astounding precision of the final artwork produced by the printer. To test the performance of PCB, we set out to design a circuit board for a 6809 CPU card. Fig 1 shows some intermediate results while working with PCB. The print outs were obtained with an Epson FX80 printer. The precision of the true scale track layout on draft quality paper is sufficient to be able to use it for the production of a transparent film. The print routine in PCB is run from the supplied ROM. A good quality printer must be used for optimum precision. Pineapple mentions that it must be Epson FX compatible, which means that it should switch to quadruple density graphics printing when receiving a ESCAPE2 code from the computer.

Conclusions

PCB is a fine tool to design one's own circuit boards. With some experience in making PCB artwork, the program is well suited to producing high quality layouts at reasonable speed. The final accuracy of the
Pineapple Software are in the good habit of supplying free update service for their packages, thus ensuring that the registered user is always in possession of the best working version of the program. Each ROM supplied by Pineapple holds a user-specific, hidden registration code to be able to trace down the original owner of a ROM when discovering "rogue" copies.

A final note concerns the previously mentioned automatic routing facility. It is our understanding that Pineapple will shortly announce an enhanced version of PCB allowing the computer to do the drawing of the tracks automatically once the component locations on the circuit board have been established. Meanwhile, the standard version of PCB is available at £85.00 + VAT, from
Pineapple Software
39 Brownlea Gardens
Seven Kings
Ilford
Essex IG3 9NL.
Telephone: (01 599) 1476.

The next installment in this series will deal with two programs for analogue circuit analysis. St

microsqueaker

This circuit is by way of being an electronic joke. The complete circuit comprises only one transistor, one capacitor, a miniature transformer and a headphone. The transistor can be any germanium type; the transformer can be any miniature type with a turns ratio between 3:1 and 10:1. At supply voltages as low as 0.2 V the headphone produces a distinct sound. Current consumption is then of the order of 10 μA, power consumption is less than 2 μW. The joke of this microsqueaker is that it is not fed from a 'normal' current source, but that the gifts of nature are called upon. The positive connection is a piece of bare copper wire, the negative connection is a bare piece of steel or silver wire. If both ends are stuck into an apple, a lemon or a potato, at some distance from each other, the apparatus produces a tone. A solar cell could also serve as the voltage source. The squeaker may also be used as an indicator for D.C. voltages in the range of 0.2 V...10 V.
FIELD-EFFECT OPTOCOUPLER

by W. Teder

In this article we will examine a number of possible applications of a recently introduced optocoupler incorporating an infrared light-emitting diode and a phototransistor made in field effect technology.

In spite of its many interesting applications in the field of audio engineering, the Type H11F3 FET optocoupler from General Electric (GE) has so far passed unnoticed to many hobbyists and professional designers eager to experiment with new semiconductors.

Apart from its use as a fast, electrically isolated switch (solid-state relay), the H11F3 is eminently suitable for quite a number of applications having to do with AF signal processing. Table 1 shows the maximum ratings of the FET optocoupler, while Fig. 1 shows its pin assignment and its equivalent circuit diagram. The field-effect element in the H11F3 is a non-polarized, photo-sensitive semiconductor layer, comparable to a drain-source junction. This semiconductor essentially behaves like a light-controlled resistor, whose resistance is a function of the current passed through the IR LED in the package. The H11F3 offers a remarkable resistance range of 100 ohms to 500 mega-ohms.

<table>
<thead>
<tr>
<th>Table 1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>H11F3 Maximum ratings</strong></td>
</tr>
<tr>
<td><strong>IR diode</strong></td>
</tr>
<tr>
<td>Is max. continuous</td>
</tr>
<tr>
<td>Is max. (peak)</td>
</tr>
<tr>
<td>Dissipation</td>
</tr>
<tr>
<td><strong>FET</strong></td>
</tr>
<tr>
<td>Uce</td>
</tr>
<tr>
<td>Is max. continuous</td>
</tr>
<tr>
<td>Dissipation</td>
</tr>
</tbody>
</table>

Many applications

In this section we will offer a necessarily brief discussion of a number of application circuits based on the new optocoupler. These applications come under two headings: the use of the H11F3 as a controllable resistive element, and its use as a fast, isolated switch.

Before introducing a number of applications in the first mentioned category, it must be pointed out that the FE element in the H11F3 behaves largely similar to a normal drain-source junction. Therefore, the voltage across Rf must not exceed some 50 mV to avoid distortion. Fig. 2 shows the basic concept of a controlled voltage divider, whose main feature is an unusually low charge injection cross-talk figure. Fig. 3 is a more practical application of the use of the FET optocoupler in a design for a compressor, whose attack, decay, and rate of compression are individually adjustable. The circuit shown in Fig. 4 is based on the use of a comparator circuit which drives the IR LED in the optocoupler whenever the AF input voltage exceeds a preset value. As with the compressor, the attack and decay times can be defined over a wide range.

When designing circuits incorporating a number of optocouplers driven from a common control line, due account should be taken of the fact that the values of Rf of the individual resistive elements need not be identical, even if the same amount of current is passed through the associated infrared-emitting diodes—see Fig. 5. It is, therefore, not recommended to use H11F3s in tracked VCA's, or synchronously tuned active filters. Fig. 6 shows how adjustable current sources can be used to match Rf of two optocouplers. The circuit shown in Fig. 7 can significantly reduce distortion in a compressor, while Fig. 8 demonstrates the basic concept of the new optocoupler as the regulating element in a compressor circuit.

![Fig. 1: Equivalent circuit and pin assignment of the H11F3 field-effect optocoupler](image1)

![Fig. 2: Rudimentary circuit from of an AF attenuator](image2)

![Fig. 3: The new optocoupler as the regulating element in a compressor circuit](image3)
cut is inadequate, however, to compensate for large differences in production tolerance of individual optocouplers. Also, in its basic layout, it cannot rule out the effects of differently shaped Rf characteristics and device-specific minimum and maximum values of Rf.

The use of the new H11F3 as a semiconductor switching element poses less problems than the previously mentioned applications. The typical junction resistance of Rf is 100 to 300 ohms at a LED current of 30 mA (60 mA max). With no current passing through the LED, the FE element reaches an off-resistance of no less than 300 mega-ohms at a stray capacitance of about 15 pF. Figures 7a and 7b show the use of Rf as a short-circuiting and a

Fig. 4 A variable-threshold AF limiter

Fig. 5 The IR diodes connected in series for multi-channel regulation purposes.

Fig. 6 Adjustable current sources are used to match the LED Rf characteristics of two optocouplers.

Fig. 7 Basic AF switch configurations.

Fig. 8 Improving the U1/U0 ratio by using a combined series and parallel switch.
Fig. 11 High pass filter with a switchable cut-off frequency

Fig. 12 An electrically safe input amplifier.

With many electronic games, such as heads-or-tails, roulette, or any of the versions of electronic dice, a considerable saving in battery life can be obtained by ensuring that the circuit, or at least the current-guzzling displays, are switched off after each throw or turn. Naturally enough, it would be somewhat tiresome to have to do this by hand, so the following circuit is intended to take care of this chore automatically.

Battery Saver

W. Jitschin

For instance, the circuit is a simple timer Pushbutton switch S1 is the start button for the die, roulette wheel, etc. When depressed, it causes capacitor C1 to charge up rapidly via C1. Transistor T1 is turned on, so that, via T2, the relay is pulled in, thereby providing the circuit of the game with supply voltage. When the switch is released, initially nothing will happen. C1 discharges via R1, R2 and the base-emitter of T1, however, it takes several seconds until it has discharged sufficiently to turn off T1. When it does so, however, the relay drops out, cutting the power supply to the die, etc.

With the component values shown in the circuit diagram, a delay of roughly 3 seconds is provided in which to read off the display. If that interval is too short (or too long), it can be modified as desired by choosing different values for C1 and/or R1/R2.
I/O and timer cartridge

Fourth in our series on simple to make extension boards for the MSX series of computers is a versatile, cartridge-size, input/output plus timer module, primarily intended to drive the computerscope featured in our September and October 1986 issues.

This article presents those many owners of an MSX computer with an interface extension board featuring:
- 32 (4 times 8) I/O lines;
- 4 programmable timers;
- user-definable address decoding;
- daisy-chained interrupt configuration.

All of these functions have been realized on a single, cartridge-size board which can be housed in a common music cassette box. Although the first aim of this design is to provide an interface between an MSX computer and the computerscope, the I/O and timer cartridge can fulfil a variety of tasks. For instance, there is the field of robotics where stepper motors are to be driven via a computer interface (see Universal control for stepper motors, elsewhere in this issue). The present extension board is also tailored to drive an MSX EPROM programmer, which will be detailed in a forthcoming issue of Elektor Electronics. However the present article will mainly focus on how to use the I/O and timer cartridge in conjunction with the computerscope.

The previous instalments of this series were published in the January, February and March 1986 issues of Elektor Electronics.

Block diagram

Figure 1 shows the various functional blocks comprised in the I/O and timer cartridge. The cartridge address decoder defines the I/O channels through which the card is accessed by the Z80 microprocessor. It will be recalled that MSX computers use I/O mapping

Fig. 1 Block diagram of the MSX I/O and timer cartridge.
based on 255 ($2^{11}$) channels, rather than reserving a specific address area in the system RAM to transfer I/O data and I/O status/control words. After the processor has selected the cartridge by means of an appropriate I/O instruction, the expansion address decoder is enabled to select either one of two parallel I/O blocks, or the timer block. The expansion control bus provides the peripheral blocks with information as to the nature of the word then present on the databus, since this is used to bidirectionally transfer both data and status/control words. Each I/O block comprises two sets of 8 I/O lines plus associated peripheral handshaking lines; the cartridge, therefore, has 32 I/O lines in all, i.e. enough and to spare for all sorts of applications.

**The cartridge hardware**

With the use of three LSI chips from the Z80 peripheral support family, the circuit diagram of the I/O and timer cartridge, shown in Fig. 2, closely resembles that of the block diagram. Cartridge address decoder ICs compares a preset 4-bit address with CPU address bus A-A, and activates its A-B output whenever the two configurations match, i.e. when the computer accesses the cartridge. The previously mentioned 255 I/O channels can be addressed via the least significant byte on the CPU address bus (A-A), while IORQ indicates a CPU I/O cycle rather than a memory access cycle. In MSX BASIC input and output instructions are simply INP (xxx) and OUT xxx, respectively, where xxx is the I/O channel and n is the byte to be output.

Since I/O channels 64 through 255 are reserved for standard MSX software and hardware, A and A in the preset address nibble are hard-wired to ground (logic low) so as to avoid I/O contention problems between the cartridge and resident I/O mapped hardware. Table 1 shows the jumper configurations to define the 16-channel I/O block through which the cartridge is to be accessed.

Address comparator ICs need not be strobed with IORQ as all peripheral LSI chips ICs, ICs, and ICs each have their own IORQ input to this effect. ICs is a dual 2-to-4 line decoder, which provides the PIOs (Parallel Input/Output) and the CTC (Counter/Timer Controller) with CE (chip enable) pulses. These three peripheral functions are selected by an appropriate bit-configuration of address lines A and A, provided, of course, the A-B output of ICs is logic high. Note that the output 3 of decoder 1 in ICs (pin denotation IO3) is used to drive the active low E (strobe) input of decoder 2, decoder 1 therefore, merely functions to invert the A-B output from ICs. If selected with CE, the PIOs and the CTC have access to the CPU data bus as IORQ goes low. The direction of the data

---

**Table 1. The cartridge address block assignment.**

<table>
<thead>
<tr>
<th>cartridge</th>
<th>I/O block (decimal)</th>
<th>jumpers</th>
</tr>
</thead>
<tbody>
<tr>
<td>9-15</td>
<td>a b</td>
<td></td>
</tr>
<tr>
<td>16-31</td>
<td>a d</td>
<td></td>
</tr>
<tr>
<td>32-47</td>
<td>e d</td>
<td></td>
</tr>
<tr>
<td>48-63</td>
<td>c d</td>
<td></td>
</tr>
</tbody>
</table>
flow—i.e., CPU to peripheral, or vice versa—is determined by the logic state of the RD line. Provision has been made to process PIO or CTC-generated interrupts by connecting the INT output of ICs IC and IC to a wired-OR structure. The daisy chain connection of the MI and IEO (interrupt enable input and output, respectively) signals is essentially a method of interrupt priority assignment. In the cartridge, IC has the highest interrupt priority, IC the lowest. Once IC activates its INT output, IC and IC are disabled from outputting interrupt requests to the processor. In this system, high-priority peripherals automatically override INT requests from devices “further down” the daisy chain. Upon receiving an INT pulse, the CPU polls the peripherals to determine the origin of the INT request. This is done by means of an INTACK (interrupt acknowledge; MI AND IORQ) pulse, which causes the relevant peripheral to respond by putting a vector byte onto the databus. This vector is used as the LS address byte for the interrupt service routine. In the 280-based system, pulses MI and IORQ are used to form the INTACK pulse, while the interrupt vector is loaded into the devices during the initialization routine. PIO IC has been assigned the highest priority on the cartridge since PIO IC, and CTC IC are not used in the driving of thecomputerscope. The chips on the cartridge board are either fed from the computer +5 V supply, or from an external supply connected to pins 21 (GND) and 22 (+5 V) of 80-way output connector E (remove link E). If all chips in the cartridge are of the CMOS type, the supply capacity of the computer should be adequate, and link E can, therefore, be left in place. In theory the application of standard NMOS chips in the IC, IC, and IC positions requires the cartridge to be fed from an external supply, as the total (worst case) current demand of the board is then about 320 mA, exceeding the available 300 mA supply capacity of the computer slot. In practice, however, we measured a current demand of about 100 mA with NMOS chips fitted in the circuit, which could, therefore, be fed from the computer without overloading the internal +5 V supply.

From these observations it can be seen that it is good practice to measure the actual current consumption of the cartridge before deciding on computer or external supply.

Programming the PIOs

The 280A PIO from Zilog features two 8-bit ports which can be set to one of four possible operating modes by writing an appropriate byte to the command register in the chip. The logic state at the B/A SEL input determines which of the two ports is to be read from or written to (port A or B), while the bit at C/D SEL indicates transfer of a control/status word (C) or a data word (D) via the 8-bit databus. Address lines A8 and A0 drive B/A SEL and C/D SEL, respectively, enabling the user to configure each PIO for any one of its four possible modes. MODE 0 selects the port A & B byte output mode, MODE 1 the byte input mode, MODE 2 the byte input/output mode, and MODE 3 the bit programmable input/output mode.

Program the CTC

The Type 280 CTC comprises four individually configurable counter/timer circuits. The function of each bit in the CTC control byte is shown in Table 2. The state time constant (bit D1) determines the number of pulses before the T/C output goes high. Each timer/counter will continue to operate until a software (D) or a hardware reset (pin 17) is received by the CTC.

Table 2. Bit functions in the 280 CTC control register

<table>
<thead>
<tr>
<th>Bit</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>vector control byte</td>
</tr>
<tr>
<td>1</td>
<td>software reset</td>
</tr>
<tr>
<td>2</td>
<td>no time constant follows</td>
</tr>
<tr>
<td>3</td>
<td>time constant follows</td>
</tr>
<tr>
<td>4</td>
<td>trigger upon loading time constant</td>
</tr>
<tr>
<td>5</td>
<td>clock/trigger pulse start times</td>
</tr>
<tr>
<td>6</td>
<td>timer mode only</td>
</tr>
<tr>
<td>7</td>
<td>timer mode only</td>
</tr>
</tbody>
</table>

Construction

Since the proposed I/O and timer module is to function as a plug-in cartridge for MSX computers, there is no doubt about the need for a ready-made, double-sided, and through-plated PCB. See Fig. 3. As there are relatively few components on this board, no major problems should be experienced in soldering, as all the parts can be soldered on a home-made PCB. The cassette case must be properly closed so that no dust can enter, and the circuit board must be properly closed. The real problem is to ensure electrical isolation. The design of this board has been tested thoroughly, and all the components and soldered joints are adequately insulated. A list of components is shown in Table 2. All the components are placed on a rectangular slot and are easily accessible for soldering. The end result is a printed circuit board which is entirely enclosed within the cassette case.

MSX software for the computerscope

The general programming
methods for operating the computerscope (see Elektor Electronics, September and October 1986) in conjunction with an Electron, C84, or BBC computer, also apply to the MSX software supplied with PC board Type 86125. However the limited screen resolution of MSX computers necessitates a slightly different position for the oscilloscope controls texts—see Fig. 5. The various scope “controls” can be selected as required by means of the function keys on the MSX keyboard, while the cursor positioning keys permit setting the requisite parameter value.

In view of the previously mentioned limitation imposed on the attainable resolution of the MSX screen (192x256 dots), it was found impossible to retain the quantifying figures alongside the vertical and horizontal axes.

The function keys F1 through F9 on the MSX computer are programmed to do the following: F1 sets the required amplitude and merits no further comment. F2 and F3 serve to set the vertical offset and the trigger level, respectively. This involves the displaying of an absolute voltage level, and, since the trigger level is comprised in the sample byte, changing the vertical offset causes the trigger level to be changed accordingly. The computer displays the trigger threshold thus obtained by a small, blinking, bar. The screen division (graticule) can be defined either in 1-pixel

Fig. 3. Component mounting plan for the I-O timer cartridge.
Fig. 4. Dimensions of the rectangular clearance cut into the music cassette box.
Fig. 5. Two examples of the use of the screendump option offered by the computerscope software.
increments (cursor up/down), or in 8-pixel increments (cursor left/right). This arrangement is also valid for function 7.

F4 selects the trigger mode: automatic, manual, or external. The automatic trigger mode causes the computer to establish the trigger level after a specified period of time. This method is useful for establishing the trigger level while ensuring that the MSX screen output (VDP) remains constant. In all of the display types of a subroutine satisfying the conditions for new MSX users interested in further details on machine language programming will find invaluable information in the book "The MSX red book" by Avalon Software, and in "Behind the Screens of MSX" by Mike Shaw.

Table 3 shows a straightforward test program to check the performance of the cartridge and the computerscope board, in a similar manner as already detailed for the BBC and Electron computers. The cartridge is connected to the computerscope as shown in Fig. 6. It is seemed that the PIO handshake signals ARDY (port A ready) and ASTB (port A strobe) are not used in the basic setup. However, to improve upon the overall speed of the communication between computer and computerscope board, one of the unused inverts N = N1 on the latter may be connected as shown in Fig. 6 to effect inversion of the READY output of the computerscope board. It must be noted, however, that the MSX software supplied is based on PIO MODE 3, as already detailed, and therefore does not support the use of the handshake signals.


table 3. MSX-test computerscope.

<table>
<thead>
<tr>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>19</th>
<th>20</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>SCREEN 2</td>
<td>20</td>
<td>A = 3*16</td>
<td>30</td>
<td>DA = A+4</td>
<td>DB = A+5</td>
<td>CA = A+6</td>
<td>CB = A+7</td>
<td>40</td>
<td>DUT CA, 255: DUT CA, 0, DUT CA, 7: DUT DA, 6H10</td>
</tr>
<tr>
<td>50</td>
<td>DF = 0, IN = 1, OCT. = 0, TB = 8, AM = 8, TR = 0</td>
<td>60</td>
<td>DUT CB, 256: DUT CB, 0, DUT CB, 7</td>
<td>70</td>
<td>DUT DB, (F + B + 12) * TH; DUT DA, 6H14</td>
<td>80</td>
<td>DUT DB, (N + 4 + 12) * TH; DUT DA, 6H12</td>
<td>90</td>
<td>DUT DB, (TB + 16) * AM; DUT DA, 6H11</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>DUT CB, 256: DUT CB, 256: DUT CB, 7: DUT DA, 0, DUT DA, 6H40; DUT DA, 6H10</td>
<td>110</td>
<td>HO = TIME + TB + T*50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>120</td>
<td>IF H &gt; TIME THEN 120</td>
<td>130</td>
<td>IF TR = 0 THEN DUT DA, 6H30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>140</td>
<td>IF TR = 0 THEN DUT DA, 6H38</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>150</td>
<td>IF TR &lt;= 2 THEN 160 ELSE IF INKEY = &quot; &quot; THEN DUT DA, 6H40 ELSE 140</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>160</td>
<td>HD = TIME + 3*TB</td>
<td>170</td>
<td>DUT DA, 0: OUT DA, 6H20, DUT DA, 0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>180</td>
<td>CLS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>190</td>
<td>PSET (0.85)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>200</td>
<td>FDR = 1: TD 256 STEP 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>210</td>
<td>LINE - /2, 150 INPDB(1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>220</td>
<td>DUT DA, 6H40: DUT DA, 0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>230</td>
<td>DUT DA, 6H40: DUT DA, 0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>240</td>
<td>NEXT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>250</td>
<td>DUT DA, 6H20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>260</td>
<td>DUT FDR = 1 TD 512 STEP 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>270</td>
<td>LINE - /2, 150 INPDB(1)</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>280</td>
<td>DUT DA, 6H40: DUT DA, 6H20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>290</td>
<td>DUT DA, 6H40: DUT DA, 6H20</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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Fig. 6. Overview of connections between the cartridge and the computerscope.
Hot ICs - no need for fear
It is perfectly normal for ICs, particularly bipolar digital ICs such as TTL, to become very warm in operation. These ICs draw considerable power which is finally dissipated as heat. An example is the common TTL IC 74145, Typical dissipation for this device is 215 mW and approximately 360 mW maximum, this is in the quiescent state with unloaded outputs. When these are loaded the dissipation is even higher. Since the area of the IC package is relatively small, the IC becomes very warm indeed. This is no problem, however, it is rated appropriately and operates perfectly even at ambient temperatures of up to 70°C. When the computer is installed in a housing, care should be taken to provide ventilation slots for the heat to dissipate. In the event of doubt regarding the temperature rise of ICs, the data sheet should be consulted. If an IC with a maximum dissipation of 10 mW for instance, should not exhibit noticeable temperature rise.

The Microcomputer as a source of interference
Every microcomputer system operates with relatively low logic ICs, such as Schottky TTLs. This means that the digital signals have rapid rise slopes which produce harmonics extending far into the VHF/UHF region. These cause interference, and not only to FM stereo reception. The problem is not restricted to home made microcomputers, some commercially built microcomputers, particularly teaching and experimental systems, can unfortunately be classed as sources of electromagnetic radiation. The only solution is to install the microcomputer in a (metal) screened housing with an earth connection. It may also be necessary to fit a mains RF suppression filter. Screwed (coaxial) cable should be used for connections between the computer and peripheral equipment. These precautions apply to all digital equipment using logic ICs.

G. Sullivan

Microprocessor systems are often regarded as mathematical wizards, so the Junior Computer's aptitude as a frequency counter will come as no surprise...

As the name suggests a 'frequency counter' records a recurrent series of events. This does not necessarily have to be anything to do with electronics. The merry month of May, for instance, (and any other month, for that matter) has a frequency of one sunset every 24 hours (although it isn't often seen in the British Isles). To take an electronic example, if an AC voltage changes its polarity one hundred times per second, this is referred to as a frequency of 50 Hz.

The point is, by what criteria is frequency measured? In the second example the number of polarity changes (from positive to negative, or vice versa) that occur during one second are simply counted. When a microprocessor is "hired" to do the calculation work, a program consecutively displays the contents of three display buffers, in other words the last frequency to be measured. The program is interrupted either once the one second measuring time has passed, or the AC voltage has gone low. A new program is now run to check the cause of the interrupt. If a zero-crossing was involved, the period counter is incremented by one. But if the measuring time (1 second) has passed, the contents of the counter memory locations are copied into the display buffers. At the same time, a new measuring period begins. At the end of the process, a return is made to the main routine, after which the whole procedure starts all over again.

Figure 1. A series of interrupts (IRQ) are required for frequency measurement.
The events are depicted in the flowchart in Figure 1. A certain amount of hardware is also needed and this is shown in Figure 2. This circuit is connected to the port connector of the Junior Computer to allow the frequency data to be entered into the computer. A significant negative zero-crossing in the input signal will pull the port line PA7 low. The program makes sure this is accompanied by an IRQ.

The software is provided in the table. The start address of the program is $1A80. When data is written into location EDET C, PA7 is pulled low thereby enabling an IRQ. Preparations include defining the IRQ jump vector at the start address of the IRQSRV interrupt routine, starting the interval timer (CNTH, in other words, an IRQ is enabled after every 1024 clock pulses) and storing the contents of location COUNT. Then the program LOOP is run until an IRQ takes place.

As soon as any type of IRQ is detected, the IRQSRV program is run. After having the A, X and Y contents (used during SCANDS) on the stack, the computer examines the N flag. If N, or rather the timer flag, is zero, the IRQ cannot have been enabled by a time out. This means that it must have been caused by a change in logic level on PA7. A new AC voltage period has passed and so the computer proceeds to label ADD. The 24-bit BCD number (ACCUM, ACCUM, ACCUM – the periodic counter in Figure 1) is incremented by one. After restoring A, X and Y (EXIT) and executing an RTI, the computer returns to LOOP.

Supposing the IRQ was caused by a time out in the interval timer. The timer is started afresh and the contents of COUNT are decremented by one. Provided COUNT has not yet reached zero, a jump will be made to EXIT. If, however, COUNT is in fact zero, the STORE section is run. The measuring period has now passed and the display buffers, POINTH, POINTL and INH, are assigned values equal to those of ACCUM, ACCUM and ACCUL, respectively.

So much for the program, let’s put everything into practice. Connect the circuit in Figure 2 to the port connector, enter the program on the keyboard (or even battery, read it in from cassette) and start it via the main JC keyboard. (The main JC keyboard must be used, so as to provide the I/O definition for SCANDS.) The highest frequency that can be measured is about 10 kHz. At low frequencies greater accuracy may be obtained by extending the measuring time to 10 seconds (load A0 instead of 10 into TIMEH; address $1A16). The result on display will of course have to be divided by ten to give the correct frequency.

**Literature:**

*Chapter 6 of the Junior Computer Book II.*

*For Junior Computer Book & Kit 528, page 3.64*
A theory which has been with us for some time and which is rapidly gaining credence relates to the quantity of negative ions in the air. A high concentration of such ions is both physically and mentally healthy. One element of scientific thought actually states that the quantity of negative ions contained in the air around areas such as St. Moritz is high, which is one reason for the invigorating effect these resorts have on tourists. There certainly seems some truth in these suggestions as negative ion generators are gaining in popularity. Even institutions traditionally known for their ultra-conservative attitude towards new ideas are now using them.

We published a circuit for a domestic ioniser a couple of years ago operated by the mains supply and the idea came to adapt this circuit for use in the car. The circuit design for a suitable power supply is shown in figure 1. It could be loosely termed as a d.c. to a.c. converter. The 555 timer (IC1) produces a square-wave signal with a frequency around 65 to 100 Hz. The values of R1 and the combination of P1 and R2 have been chosen so that the square wave produced is symmetrical. This is then fed to transistors T1, T2 and transformer TR1. The result is an a.c. voltage across the two secondary windings of the transformer of approximately 400 V (square wave).

Figure 2 shows the circuit diagram of the ioniser which consists of a 27 stage voltage multiplier, in order to step up the voltage from 400 V to around 7.5 kV. The output is then connected to a sewing needle or something similar.

As most readers already know the electric field strength around a charged body is greatest where the curvature is also greatest, hence a sharp point. An intense field is therefore present at the tip of the needle with electrons being ‘sprayed’ onto the air molecules negatively charging them. Each batch of negative ions is repelled by the negative charge of the needle tip allowing new air molecules to be processed. The result is a constant flow of ions away from the needle which feels very much like a light draught. This in itself will have a refreshing effect upon the driver and passengers without giving consideration to the metabolic benefits of an increased concentration of negative ions.

Keep in mind that apart from generating negative ions the needle will also pro-

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Bombay 400 007
Ph 36249, 363478
Telex (011) 76661 ELEK IN

in-car ioniser

fresh air on wheels

The circuit is one way of increasing the concentration of negative ions in the surrounding air, resulting in improved mental concentration, and reaction speed making roads just that little bit safer. At the very least it will refresh the environment.

due ozone (O3). This can on the one hand have certain advantages as it oxidises organic gases. Carbon monoxide for instance, can be reconstituted into carbon dioxide which is far less harmful. However, ozone if breathed in large quantities can cause irritation of the respiratory system, because of its corrosive and therefore poisonous nature. We therefore do not recommend using the ioniser near to asthma sufferers and please remember that for normal use the ventilation system of the car should be reasonably effective.
Construction
The printed circuit board for the power supply is shown in figure 3. There is nothing critical in the assembly and the only calibration needed is to set P1 to its mid position. No provision was made for mounting the transformer onto the board as the size and type will depend on what is easily available.

Although it is possible by changing C1 for a 330 n capacitor to get a 50 Hz a.c. output, we do not advise it. Basically the peak voltage level produced by the circuit using the specified transformer will be far in excess of 240 V, so that 'blowing up' your razor becomes a distinct possibility. The transistors will need small heat sinks. The transformer should have a 220 V primary and two 6 V secondary windings. Its normal function is reversed in this case. The printed circuit board and component layout for the ioniser are given in figure 4. Great care is needed to mount the components. Make sure all soldered joints are smooth and neat as any protruding wires or spikes of solder could result in unwanted discharges. This is especially important towards the 'high-voltage' end. Resistors R1 to R10 limit the current flow in the event of the needle being touched. Lowering the values of these or omitting them is unadvisable as it could result in a fatal shock.

Any sharp needle will do as long as its connection to the printed circuit board is short and rigid. Obviously the needle should point outwards and to prevent accidents a short piece of 30 mm plastic pipe should be mounted coaxially with it. After some use the point will become dirty and possibly eroded, so making the needle removable for cleaning is also a good idea. Safety first is a good motto to follow when mounting the circuit in the car. Use an insulated box to contain the electronics and position the unit within the car so that it is not a hazard to unsuspecting passengers.

Parts list for the power supply

Resistors:
R1 = 1 k
R2 = 47 k
R3 = 470 k/½ W
P1 = 47 k preset

Capacitors:
C1 = 150 n
C2 = 10 n
C3, C4 = 560 p

Semiconductors:
T1, T2 = BD 139
D1, D2 = 1N4004
D3, D4 = 27 V/400 mW zener
IC1 = 556

Miscellaneous:
Tr1 = 2x 6 V/0.8 A transformer
2 heat sinks for the BD 139
S1 = on/off switch

Figure 1. With this circuit the ioniser can be used in the car. With a 12 V d.c. input approximately 400 V a.c. is produced.

Figure 2. The circuit diagram of the ioniser, consisting of 27 diodes and 27 capacitors. The unit is a voltage multiplier delivering 7.5 kV to the probe or needle.

Figure 3. The printed circuit board of the power supply. There is nothing critical in its construction. The transformer uses the 220 V winding as the secondary.
Figure 4. The ioniser board. All the soldered joints and connections have to be smooth and neat in order to eliminate the chances of unwanted discharges.

Parts list for the ioniser:

<table>
<thead>
<tr>
<th>Resistors</th>
<th>Capacitors</th>
<th>Semiconductors</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1 ... R10 = 3MΩ</td>
<td>C1 ... C27 = 33 n ... 47 n/630 V</td>
<td>D1 ... D27 = 1N4007 (1000 V)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>F = 75 mA fuses</td>
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</tbody>
</table>
The capacitor is a device that can hold electrical charge, and when fully charged, the voltage across it is same as the charging battery voltage. Naturally, when the capacitor is fully discharged, the voltage across it is zero volts. Figure 1 shows the connection of a capacitor directly across a battery. When the capacitor is first connected across the battery, it behaves like a short circuit and any large current rushes from the battery to the capacitor. As the charge accumulates on the capacitor, the voltage across it rises quickly to the battery voltage and the current flow stops. All this happens very fast because there is no resistance in the circuit. If we introduce a resistance in the charging path, the initial high current will be limited by the value of resistance. This will slow down the charging process.

We can observe this process experimentally using the circuit shown in figures 2 and 3. The following components will be required for the experiment:

1. Battery of 4.5 V
2. Resistance of 330 Ω
3. Electrolytic Capacitor of 1000 μF/10V
4. Multimeter
5. Red LEDs

A small change over switch can also be used to make the experiment a bit easier but it is not essential.

Connect the circuit as shown in figure 2 except for the connection between the LEDs and the plus pole of the battery. Observe the capacitor polarity correctly. The LEDs are connected in parallel with their polarities in reverse directions. Each of the LEDs will thus indicate current in one direction.

The voltage across the capacitor is initially at OV as it is discharged. Now make the connection between the LEDs and the plus pole of the battery. Observe the multimeter and the LEDs. The voltage on the capacitor starts rising and LED1 glows. At first the voltage rises very fast and LED1 glows brightly, but soon the voltage rise slows down and glow of the LED starts decaying. This indicates the nature of charging process. The multimeter shows the capacitor voltage and the brightness of LED shows the intensity of current flowing to the capacitor. The capacitor voltage finally reaches about 3 V and not 4.5 as expected. This is due to the voltage drop across the LED.

After the charging process is complete, the connection to the plus pole can be removed and connected to the minus pole, thus connecting the LEDs to the minus pole of the charged capacitor. This time the voltage across the capacitor starts falling and LED2 glows. The voltage drops to about 1V. This, once again, is due to the LED. The discharging current can't
flow through the circuit any more below this voltage. The charging and discharging cycles can be repeated as often as wanted, to observe the nature of voltage across the capacitor and current through the LEDs. The current behaves exactly in reverse order compared to the voltage, during the charging cycle. The trend is same even during the discharging cycle – except for the fact that the direction of current is reversed.

This behaviour can be easily explained using the Ohm’s law. The voltage across the resistance is always proportional to the current flowing through it. Also the fact that the resistance and capacitor are connected in series (ignoring the LED for convenience) across the battery means that the sum of voltages across the capacitor and resistance must remain constant. Initially during the charging cycle, the capacitor voltage is 0V and the full battery voltage appears across the resistance and thus the current flowing through the circuit is equal to the battery voltage divided by the resistance value. As the capacitor gets charged, the voltage across it builds up and voltage across the resistance falls by the same value. With reduced voltage on resistance, the current also falls. When the capacitor is fully charged, the current drops to zero and the voltage across the resistance also becomes zero.

During the discharging cycle, the capacitor supplies the current through the resistance. So the discharging current is equal to the capacitor voltage divided by the resistance value. As the charge on the capacitor is depleted, voltage falls and the current through resistance also falls. However, this time the direction of current through the resistance is opposite to that during charging and we can say that a negative current flows during discharging and becomes zero again after the capacitor is fully discharged.

Let us summarise the observations again:

- When the battery is connected across the RC circuit, the capacitor voltage rises continuously. The voltage across the resistance and current through it are initially high and fall continuously.
- If the RC circuit is disconnected from the battery and short circuited, the current through the resistance flows in reverse direction. It is high initially and then falls continuously to zero. The capacitor voltage also drops continuously and reaches zero in the end.

Figure 4 shows the schematic circuit diagrams and the curves of capacitor and resistor voltages. These waveforms show an interesting feature of the RC circuit. The capacitor voltage is a pulsating DC voltage whereas the resistance voltage is an AC voltage. This type of RC configuration can be used to obtain an AC voltage from a pulsating DC voltage as shown in figure 5.
PHASE SHIFT

The RC-Circuit is one of the most used basic circuit in electronics. In the previous article 'Charging/Discharging we have already seen the effect of giving a pulsating DC voltage at the input of an RC circuit as shown in figure 5 of their article. A similar circuit is also shown in figure 1 here however, this time the circuit is also shown connected to an AC square wave as well as the DC pulsating voltage. A close look at the output waveforms will show that the Resistance voltage is same in both cases, whereas the capacitor voltage in the second part of the figure is an AC waveform.

The AC squarewave voltage can be practically generated by using an astable multivibrator circuit. The AMV circuit is shown in figure 2. The two transistors become alternately conductive. This can be seen from the LEDs in the collector circuits of each transistor. The LED in the collector circuit of a conductive transistor glows brightly. Both the LEDs (LED1 and LED2) glow alternately, showing that transistors T1 and T2 are conductive alternately. Consequently, terminal A is more positive than terminal B for some time and then terminal B becomes more positive than A for some time. This effectively gives an AC squarewave between terminals A and B.

The component requirement for this circuit is non-critical, and if no error is done during assembly, it will function at the first attempt. The frequency of the square wave is about 1 Hz. Thus the LEDs will alternately glow once every second. The component layout is shown in figure 3. The RC circuit can be connected to the AMV by connecting the links A and B.

However, LED3 becomes bright somewhat later than LED1, because the capacitor takes some time to charge to the full voltage. When terminal B becomes more positive than A, LED2 and LED4 illuminate. In this case LED4 becomes bright later than LED2, because of the time taken by the capacitor for charging in the reverse direction. At this stage the capacitor polarity is incorrect, but the capacitor can withstand the voltage reversal as the voltage is small.

If we make a chart of AC Voltages from our observation of the LEDs as shown in figure 4, we can see that the AC voltage on the capacitor is delayed in comparison with that at the input of the circuit. This is called PHASE SHIFT. In actual practice, LED1 and LED2 are never extinguished completely because of the capacitor charging current.

Figure 5 shows the phase shift in case of a sinusoidal AC voltage applied to the RC circuit. The larger waveform is the original input voltage. The smaller waveform is the capacitor voltage. It is not only delayed but has reduced amplitude, because a portion of the input voltage must appear across the resistance also. Here the phase shift is about 60°.

Figure 1:
A pulsating DC voltage applied to an RC circuit produces a DC voltage on the capacitor whereas an AC voltage at the input produces an AC voltage on the capacitor.

Figure 2:
The Astable Multi-Vibrator circuit produces an AC square wave at terminals A and B.
The amplitude of output voltage is frequency dependent.

- The capacitor behaves like a frequency dependent resistor.
- The current and voltage on a capacitor always have a phase shift of 90°.

**Summary**

- The RC circuit causes a phase shift between input and output voltages.
- The phase shift is stated with reference to the wavelength, considering the wavelength to be equal to 360°.
- The phase shift of output voltage of an RC circuit with respect to input voltage is frequency dependent.

---

**Figure 3**
Component layout for the construction of the Astable Multi-Vibrator circuit and the experimental RC circuit on a small SELEX PCB.

**Figure 4**
Schematic chart of the illumination of the four LEDs in our experimental circuit. LED 3 and LED 4 glow with a delay compared to LED 1 and LED 2.

**Figure 5**
A sinusoidal AC voltage applied to an RC circuit.

**Figure 6**
A sinusoidal AC voltage applied to an RC circuit.
As we have already seen in our Jan issue, a dimmer is quite a simple device and works on the principle of phase control. One can buy a dimmer from the market and fit it easily on the switch board.

You can also construct a dimmer at home, but don't expect to get the components at a lower cost compared to a bought out dimmer. The cost of your home made dimmer will be almost same – if not more! The size of our home made dimmer will also be larger compared to the dimmers available in the market.

There is no reason to get depressed. Our dimmer can do more than the standard dimmer. It can also be used as a drill speed controller.

The noise filter used in our circuit is also better. You may not always find a ripple filter choke in commercial dimmers.

**The Circuit**

The circuit of the dimmer is shown in figure 1. It has two most important components - a Triac and a Diac. The RC combination is a bit complex and the theory will not be discussed in detail at this stage. The RC combination shown in the circuit consists of R1, R3, P1, P2 and C1. R1 prevents the rapid charging of the capacitor. This eliminates the possibility of the Triac getting triggered too early. A short pause between the blocking and triggering in the next half wave for the Triac is essential. Besides this, P1 is protected against large currents. Function of P1 is to decide how rapidly capacitor C1 is charged.

It is possible that due to the large tolerances generally expected on the commercial quality of components, the circuit may not produce proper triggering just by using the combination of R1 and P1. This is the reason for connecting R3 and P2 in parallel with R1 and P1. The adjustment is achieved by this complex combination for proper functioning of the circuit, the procedure is later described in paragraph entitled "Adjustments."

The series RC combination of R2 and C2 fulfills many functions. The first of all is the protective function. The Thyristors and Triacs are sensitive to excess voltages and voltage spikes. Such type of situations may arise inside the circuit itself or may come from outside on the mains line. Special care must be taken in case of inductive loads like motors, being operated through the dimmer circuit. The series combination of R2 and C2 suppresses these disturbances and protects the Triac from any damage.

Another function of the R2 C2 combination is in connection with the ripple filter choke L1. The phase control action and the triggering during every half cycle produces a high frequency disturbance on the power line and can produce noise in audio.
equipment. The filter choke L1 in connection with R2 and C2 tends to suppress such type of noise from being passed on to the power line. R2 & C2 must be properly selected for this purpose.

The circuit of figure 1 has been designed to function as a dimmer circuit. If a drilling machine is to be connected, R2 must be reduced and C2 increased, depending upon the individual characteristics of the drill machine being used. To conduct the trials, C radio set can be switched in the same room. A station should be tuned, which is a weak station and requires volume control to be kept in a high position.

Now, connect the drilling machine to the circuit and switch it on. Modify the RPM over the entire control range if a disturbance is heard on the radio, try a combination of 100Ω and 220Ω for R2 and C2. Try the following combinations also - 68Ω, 150Ω F and 150Ω with 330Ω F. Remember to switch off the mains supply when changing the components. The Triac rating will also depend on the rated power of the drill machine, and the Triac should be properly selected with adequate safety factor.

**Construction**

The entire circuit can be constructed on a standard lug strip. A schematic construction layout is shown in figure 2. A standard SELEX PCB can not be used for this, because of its tracks being very close to each other.

P1 should be a potentiometer with plastic spindle.

If the dimmer circuit is to be used with a lamp (upto about 200W) then it can be encased in a plastic box as shown in the photograph. Internal details are shown in figure 3. A three pin plug and a three core flexible wire should be used for safety reasons. If higher wattage applications are expected, the Triac should be suitably selected and the enclosure for the circuit must have ventilation holes or slits. Heatsink should be used for cooling of Triac.

As the mains voltage is directly involved in this case, proper insulation must be provided.

**Adjustments**

Please always remember to switch off the mains supply before doing any work directly on the circuit.

For correct adjustment of the potentiometers P1 and P2, follow the procedure outlined below.

---

**Part List**

- R1 = 22kΩ
- R2 = 220Ω
- R3 = 1 MΩ or 2 MΩ
- P1 = 470kΩ Linear Potentiometer with plastic spindle
- P2 = 1 MΩ Trimmer
- C1 = 100 nF/100V
- C2 = 100 nF/100V
- Di = 900 or BR 100 or equivalent
- Tri = T1C 220Ω or equivalent
- L1 = 60 µH/5A Filter Choke

**Other Parts**

- Lug Strip
- Suitable sockets
- 3 Pin Plug
- 3 Pin Socket/adapter
- Mains cable with 3 cores

---

**Figure 1.**

The circuit of the Dimmer

**Figure 2.**

Prototype layout of lug strip construction.

**Figure 3.**

Internal details for a practical arrangement.
HALF WATTAGE DIMMER

A low cost dimmer can be easily constructed using just one diode if reducing the power to half in one step is acceptable. Compared to the commercially available dimmers with continuously variable output, this dimmer costs almost nothing and can be constructed in a few minutes.

Figure 1 shows the effect of our diode dimmer. The mains voltage is rectified by the diode and the output is just a series of half waves in the positive direction, the negative half being blocked by the diode. Effective voltage is thus reduced to half. Another effect of the diode dimmer is that if a light bulb is connected to it, it shows slight flickering due to the negative half waves being blocked by the diode. The lamp does not receive any current during this period and due to this the light output reduces. This effect becomes less visible when the filament becomes sufficiently hot.

Figure 2 shows the connection of a lamp through the diode. Such a connection also increases the life of the lamp, and is suitable for lamp used in staircases and passages. In addition to saving in cost of replacement of such lamps, it saves us the trouble of replacing these lamps which are generally at some inaccessible positions.

Using two switches as shown in figure 3, one can have a choice between half and full power. The diode can be easily accommodated in the switch housing.

Figure 4 shows a typical connection, which can vary with actual types of switches available.

Before making any changes in the electrical wiring, you must switch off the mains and confirm that no live terminal can give you a shock, using a mains voltage tester.

While selecting the diodes it should be always remembered that the incandescent lamps draw high current at the time of switching on. Diode types 1N4004 to 1N4007 are suitable for lamps up to 100W.

Such type of a diode dimmer is also useful for preventing overheating of soldering irons. Most low priced soldering irons get overheated when they are left unused for some time during soldering work. This causes the flux to completely vaporise and then gives rise to defective solder joints. A simple arrangement using a diode and a microswitch can prevent this. One such possible arrangement is shown in figure 5.

Whenever the soldering iron is kept on the hook, the lever is pulled down, releasing the micro switch and brings the diode into circuit. When the soldering iron is lifted off the hook, the micro switch closes and the diode is bypassed, thus providing full power to the iron when in use.

Two important things must be kept in mind while trying out the diode dimmer described here:

First and most important is that mains voltage must be completely switched off from the Electrical Mains Switch or the Mains Fuse must be taken out before doing any rewiring of switches to include the diode in the circuit. Not doing so may result in a fatal accident. You must ensure that all the lines are free from mains voltage, before doing anything with the electrical switches and wiring.

Second thing to remember is that the diode dimmer will work only with resistive loads like incandescent lamps, soldering irons, heaters etc. and not with inductive loads like fans.
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