P.i.d. alarm design

Phase and amplitude response

Mobile radio update

Pioneers—the Siemens brothers

Multi-processor systems
Give it a screen test

The Gould 1604 digital storage oscilloscope has the memory and performance to tackle any role in low frequency electronics, mechanical or physiological R&D and test environments.

With massive 10K word memories on each of its 4 channels the 1604 can examine detail with expansion factors up to 200 times, and resolution down to 50ns.

And it can do so much more.

The 1604 has a built-in colour plotter for instant print-outs of displayed traces, and the ability to archive up to 50 traces in the non-volatile memory pods. For even more capability, interface the fully programmable 1604 to a computer; or plug in the waveform processor.

The 1604 DSO has a wide range of automatic functions at an unbeatable price, and it’s so easy to drive!

Why not let it audition for you?

For further details of the 1604 or the 2-channel 1602, contact: 01-500 1000.

Gould Electronics Limited
Test & Measurement Sales Division
Roebuck Road, Hainault,
Ilford, Essex IG6 3UE
Tel: 01 500-1000 Telex: 263785

Available for rental from Livingston Hire

Gould Electronics

The Gould 1604
Digital Storage Oscilloscope
## CONTENTS

JUNE 1988  VOLUME 94  NUMBER 1528

---

### FEATURES

**COVER**
- This study of an integrated circuit, with its radiating beams, was photographed by Don Carroll. It signals our series of articles discussing multiprocessor systems starting this month on page 534.

**MULTIPROCESSOR SYSTEMS**
- 534
  - Two important characteristics of multiprocessor systems are the way in which the processors are arranged in relation to each other and how they are actually coupled. Alan's first article discusses coupling structures.
  - Alan Clements

**PHASE FROM AMPLITUDE**
- 547
  - A numerical method for determining the phase response of a network from its amplitude response.
  - D.V. Mercy

**A NEW TECHNIQUE IN OTDR**
- 557
  - A new complementary-correlation technique, described last month, speeds up optical-fibre measurement by 64 times. In this second article, experimental results are given with a description of the first commercial o.t.d.r. to use this technique.
  - Steven Newton

**USING PROGRAMMABLE LOGIC**
- 563
  - To get the best out of programmable logic, the p.l.d. should be considered as an integral part of the design rather than as an afterthought. Neil illustrates his discussion of p.l.d. design by describing hardware and software for an alarm system.
  - Neil Kellett

**REVERSING A “CONSTANT” CURRENT IN AN INDUCTOR**
- 571
  - Abruptly reversing the direction of a constant current flowing in an inductor can be a snare for the unwary. D. Griffiths provides an escape route.
  - D. Griffiths

**COMPETITION**
- 573
  - Write about your views on the way forward in engineering research and development and you could win a week in Japan.

**PIONEERS**
- 574
  - Founders of an electrical empire – the Siemens brothers.
  - W.A. Atherton

**INDUSTRY INSIGHT**
- 585
  - Application-specific integrated circuits for the first time user are the subject of the main feature in the third of our new Insight series.

---

### REGULARS

**BBC PORTABLE RADIO PROJECT**
- 610
  - Manufacturers wanted for an r.d.s. radio to carry the BBC logo.

**STRETCHING THE SPECTRUM**
- 613
  - Richard Lambley reports from the mobile radio users' conference on a wrist-watch radiopager for $100, ping-pong cordless telephones, maintenance problems and candour at the DTI.

**MINIATURE BROADCAST RECEIVER**
- 615
  - Synthesized multi-band radio which makes full use of the possibilities of surface-mount devices.

**COMMENT 531**

**FEEDBACK 539**

**APPLICATIONS SUMMARY 543**

**BOOKS 550**

**CIRCUIT IDEAS 553**

**TELECOMMS TOPICS 569**

**NEW PRODUCTS 577**

**SATELLITE SYSTEMS 583**

**TELEVISION BROADCAST 618**

**RADIO BROADCAST 620**

**RESEARCH NOTES 622**

**UPDATE 626**

---

### IMAGES

- Molecular model produced on a Distributed-array Processor – see Multiprocessor parallel computing in Update, page 626.
Setting the standards in test and measurement

The UK's largest second user test and measurement company now incorporates the UK's No. 1 new products distributor. Instrumex, together with Electronic Brokers, now provides the most comprehensive service to the test and measurement marketplace.

New Instruments for Industry

Instrumex has developed the most comprehensive new products distribution service in Europe, selecting a wide range of top quality products from the World's foremost manufacturers. Instrumex will satisfy all your test equipment needs from DMMs to spectrum analysers for general purpose use or for specific industries such as telecommunications or broadcasting.

Instumex sales engineers offer expert and friendly advice on your requirements and then provide fast delivery from stock. For details of the full Instrumex range of new products phone for your free copy of the Blue Book.

The UK's largest second user test and measurement company now incorporates the UK's No. 1 new products distributor. Instrumex, together with Electronic Brokers, now provides the most comprehensive service to the test and measurement marketplace.

Second User Division

The Instrumex reputation for supplying the highest standard of second user equipment, electronically and cosmetically, is unchallenged. Drawing on a world-wide inventory worth over £110 million, almost every need can be met at substantial savings off list prices. All equipment has been regularly maintained and calibrated, and is thoroughly checked prior to dispatch in our own service laboratories. We back this up with our own 12 months warranty (3 months on computers). For our latest comprehensive product catalogue contact us now.

Instrumex has developed the most comprehensive new products distribution service in Europe, selecting a wide range of top quality products from the World's foremost manufacturers. Instrumex will satisfy all your test equipment needs from DMMs to spectrum analysers for general purpose use or for specific industries such as telecommunications or broadcasting.

Instumex sales engineers offer expert and friendly advice on your requirements and then provide fast delivery from stock. For details of the full Instrumex range of new products phone for your free copy of the Blue Book.

Dorcan House, Meadfield Rd., Langley, Berks SL3 8AL
Fax: 0753 682843. Telex: 935371. Tel: 0753 44878

SECOND USER TEST EQUIPMENT

THE SOURCE OF QUALITY SECOND USER TEST EQUIPMENT

The Instrumex reputation for supplying the highest standard of second user equipment, electronically and cosmetically, is unchallenged. Drawing on a world-wide inventory worth over £110 million, almost every need can be met at substantial savings off list prices. All equipment has been regularly maintained and calibrated, and is thoroughly checked prior to dispatch in our own service laboratories. We back this up with our own 12 months warranty (3 months on computers). For our latest comprehensive product catalogue contact us now.

Instrumex has developed the most comprehensive new products distribution service in Europe, selecting a wide range of top quality products from the World's foremost manufacturers. Instrumex will satisfy all your test equipment needs from DMMs to spectrum analysers for general purpose use or for specific industries such as telecommunications or broadcasting.

Instumex sales engineers offer expert and friendly advice on your requirements and then provide fast delivery from stock. For details of the full Instrumex range of new products phone for your free copy of the Blue Book.
DEFENCE MECHANISMS

There must be many engineers, in many countries East and West, working in the weapon business whose attitude to their daily occupation lies uneasily between two extremes. At one end there is complete acceptance. This may result from a variety of sentiments and conditions ranging from sincere patriotism through economic necessity to moral indifference. At the other extreme is complete rejection, possibly stemming from religious, ethical or other such convictions. Here the engineer either leaves the military electronics business if he is employed in it or refuses any job he may be offered in this field.

Those in the middle are probably intelligent people who are well aware of the purpose of the electronic equipment they are helping to make.Intellectually, they know it is part of the armoury designed to threaten, on the principle of defence by deterrence, or in the final instance to destroy, other human beings. But because of the many persons employed in the work and the highly specialized nature of individual contributions, these engineers do not feel that they are directly engaged in a hostile activity. If pressed on the moral implications, an engineer in this situation might well argue, apparently reasonably: "If I did not do this work, somebody else certainly would. So it really doesn’t make any difference whether I, personally, am involved: the work would get done in any case."

But just how reasonable is this utilitarian argument? As a pragmatic analysis purely in terms of man-hours it is perfectly sound. In terms of actual human behaviour and its social consequences, however, the rationalization is not conclusive. If, for example, an engineer prompted by conscience leaves a weapons job specifically to do socially beneficial work, say in the medical field, the person who performs this work is thereby helping to make it respectable among those colleagues and friends who know and value him as a decent person. Thus his decision is not confined to himself: it can influence others. If he does the reverse, either refusing or leaving military work on ethical/social grounds, his decision has two human consequences. First, his action has a small but real effect on the moral climate in electronics engineering employment. Second, he is free to campaign from outside against other engineers going into such work.

Finally, looking at the personal rather than social consequences, if the engineer with this particular uneasiness of conscience stays in work which he finds in some degree morally repugnant, he will probably—being that sort of person—damage his own psychological integrity and self-esteem. In addition, his willingness to live such a lie, or be at war with himself, could infect his relationship with other people, particularly his family or personal friends. So this individual remaining in a weapons job could cause distress, whereas a less concerned person probably would not. Again, a difference is possible.

Thus the rationalization: "It doesn’t make any difference whether I, personally, do the work" is not universally true, and one cannot hide behind it with complete safety. The action taken by the individual engineer can certainly make a difference in its human consequences. In the end, if we can’t rely on the utilitarian argument we may have to make an absolute moral choice.
DIAGRAM II - now also available for ARCHIMedes

Diagram II is a completely new version of Pineapple's popular diagram drawing software. The new version has a whole host of additional features which make it the most powerful and yet quick to use drawing program available for the BBC. One of the new features mean that Diagram II can now be used for all types of drawings, not just circuit diagrams. Scale drawings are allowed and the facilities for producing circuits and rubber banded lines together with the pixel drawing routines make any type of graphic possible. This advent has been produced completely using Diagram II.

Summary of Diagram II features:

1. Works on all model BBC computers and makes use of Shadow memory if noss.
2. Basic line drawing routines with automatic zoom for circuit diagrams.
3. Rubber band line and circle drawing modes.
4. Moves of the Eprom GHP rom to produce ellipses, arcs, sectors, chords and flood filling.
5. Pixel drawing mode allows very fine detail to be added.
6. Defined areas of screen may be moved, copied, deleted or saved to disc.
7. On-screen cursor position indication allows scale drawings to be made.
8. Keyboard keys may be defined to print user defined characters allowing new character sets to be added.
9. Underendoscopic files may be loaded and formatted into defined areas.
10. Up to 800 UDC's if shadow memory available, 381 without shadow.
11. Compatible with Marconi Trackerball and most makes of 'mouse'.
12. 0 to 880 UDC's if shadow memory available, 381 without shadow.
13. Completely 'scaleable print routines allow any area of the diagram to be printed either horizontally or through 90deg.
14. Smooth scrolling over the whole area of the diagram.
15. 'B+', Master and Master Compact with disc drive.

Diagram II consists of a set of disk files and a 16k (prom. complete with any saturation characteristics. Transducers and signal conditioners can also be modelled using polynomial functions. Most representations allow switches, diodes (including zeners), JFETs, MOSFETs, BJTs, SCRs, discharge lamps, motors and etc to be modelled statistically.

We are not decrying today's excellent test instruments but we think you ought to know:

1. No longer must you wait until a circuit is built before you can test it and 2. No longer must you wait until it is in production before you can sample its behaviour.

All the scope you may ever need on paper!

Those Engineers have always offered the highest performance in analogue circuit simulation. The latest version of ECA-2 is stacked even higher with useful features (fully programmable signal generator, Monte Carlo and Worst Case tolerance analysis, Fourier analysis of transients) and is up to four times faster than before. Circuits of over 500 nodes and 2500 components can be modelled. Its non-linear representations allow switches, diodes (including zeners), JFETs, MOSFETs, BJTs, SCRs, discharge lamps, motors and etc to be modelled. Equation and signal conditioners can also be modelled using polynomial functions. Most importantly, despite its capabilities, ECA-2 is easy to use and user-friendly. Interfaces are now available to schematic and PCB design software.

If you would like to see how easy it is to debug your designs on paper for less than the cost of many a 'scope, phone us for a free IBM PC compatible demonstration disk.

STOP PRESS! Logic Analyser L.C.A.-1 Software just released. This logic circuit design aid produces logic analyser style graphics – please send for details.

---

PINEAPPLE SOFTWARE

Programs for the BBC model 'B', 'B+', Master and Master Compact with disc drive

PCB

Pineapple's new PCB drafting aid produces complex double sided PCB's very rapidly using any model BBC micro and any PC compatible dot-matrix printer.

The program is supplied on disk and uses a mode 0 screen to display the two sides of the board in red and blue either separately or superimposed. Component layout screens are also produced for a silk screen mask.

The print routines allow a separate printout of each side of the board in an expanded definition high contrast 1:1 or 1:2 scale. The print time is typically about 5 mins for a 1:1 print of an 8" x 12" board. This program has too many superb features to adequately describe here, so please write or phone for more details and sample printouts.

£ 55.00 + vat

PCB Auto - Routing

This brand new addition to the PCB program greatly increases the power of the software and streamlines the design of PCB's ever more.

A list of up to 100 connections may be entered in the form of a 'rats nest' and then the computer does the rest! You may specify which side of the board you wish a track to be on or you may leave the choice to the computer, and you may also say whether tracks should be allowed to pass between I.C. pins.

The program is in the form of a second Eprom and full features are available on a standard model 'B'.

COMPLETE AUTOROUTE PACKAGE £ 185.00 + VAT

PINEAPPLE SOFTWARE

506 Fortune Green Road • West Hampstead • London NW6 1DS

Tel: 01-435 7771 • E-Mail: One to One Box 23332001 • Tlx: 8950611 (ansbk ONEONE G) Quoting box 23332001

All orders sent by return

39 Brounlea Gardens, Seven Kings, Ilford, Essex IG3 9NL

Tel 01-599 1476

MICROLINK - MAG 12085

ENTER 73 ON REPLY CARD

£ 85.00 + vat

DRIVER TO SUIT

£ 65.00 + VAT

For Model 'B' and B+ (with Icon Artmaster)

£ 65.00 + vat

For Master 128 (with Pointer Rom)

£ 65.00 + vat

£ 55.00 + vat

MARCONI TRACKBALL

£ 55.00 + vat

P & P free

£ 60.00 + vat

£ 60.00 + vat

£ 60.00 + vat

£ 60.00 + vat

£ 60.00 + vat

£ 60.00 + vat

£ 60.00 + vat

£ 60.00 + vat

£ 60.00 + vat

£ 60.00 + vat
## Second User Equipment

### DEVELOPMENT SYSTEMS

<table>
<thead>
<tr>
<th>Product</th>
<th>Price £</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z80</td>
<td>2000</td>
</tr>
<tr>
<td>Z80A</td>
<td>200</td>
</tr>
<tr>
<td>Z80B</td>
<td>1300</td>
</tr>
<tr>
<td>Zilog Z80 Personality Board</td>
<td>1000</td>
</tr>
<tr>
<td>Zilog Z80A Personality Board</td>
<td>975</td>
</tr>
<tr>
<td>Zilog Z80B Personality Board</td>
<td>1300</td>
</tr>
<tr>
<td>Motorola 68000 Personality Board</td>
<td>995</td>
</tr>
<tr>
<td>Motorola 68008 Personality Board</td>
<td>1350</td>
</tr>
<tr>
<td>RCA 6502 Personality Board</td>
<td>995</td>
</tr>
<tr>
<td>32K Memory Board</td>
<td>275</td>
</tr>
<tr>
<td>64K Memory Board</td>
<td>495</td>
</tr>
<tr>
<td>128K Memory Board</td>
<td>450</td>
</tr>
<tr>
<td>Real Time Trace</td>
<td>275</td>
</tr>
<tr>
<td>Break Point Processor Card</td>
<td>395</td>
</tr>
<tr>
<td>P.S.U.</td>
<td>95</td>
</tr>
<tr>
<td>Power Supply</td>
<td>95</td>
</tr>
<tr>
<td>Mythe 68TA</td>
<td>690</td>
</tr>
<tr>
<td>Mythe 68TB</td>
<td>690</td>
</tr>
<tr>
<td>Mythe 68TC</td>
<td>630</td>
</tr>
<tr>
<td>Mythe 68TH</td>
<td>630</td>
</tr>
<tr>
<td>Mhe 8086</td>
<td>68SB</td>
</tr>
<tr>
<td>868A</td>
<td>68PA</td>
</tr>
<tr>
<td>688B/68PA</td>
<td>68BA</td>
</tr>
<tr>
<td>Support Board</td>
<td>125</td>
</tr>
<tr>
<td>Base Unit inc. Base Card</td>
<td>1750</td>
</tr>
<tr>
<td>Eprom</td>
<td>1750</td>
</tr>
<tr>
<td>CHASSIS</td>
<td>1750</td>
</tr>
<tr>
<td>Trace Card</td>
<td>275</td>
</tr>
<tr>
<td>MISE</td>
<td>5MM</td>
</tr>
<tr>
<td>MISE</td>
<td>5MM</td>
</tr>
<tr>
<td>Speech Synthesis Box</td>
<td>500</td>
</tr>
<tr>
<td>Logic Analyser</td>
<td>495</td>
</tr>
<tr>
<td>PPSZ3/9M100</td>
<td>525</td>
</tr>
<tr>
<td>PPSZ16A</td>
<td>350</td>
</tr>
<tr>
<td>PROG</td>
<td>150</td>
</tr>
<tr>
<td>TDKRONIX</td>
<td>1500</td>
</tr>
<tr>
<td>Logic Analyser Mainframe</td>
<td>1200</td>
</tr>
<tr>
<td>9 Channel 100 MHz Card</td>
<td>700</td>
</tr>
<tr>
<td>10 Channel 50 MHz Card</td>
<td>1200</td>
</tr>
<tr>
<td>P6460</td>
<td>300</td>
</tr>
<tr>
<td>P8065 Rom Pack</td>
<td>50</td>
</tr>
<tr>
<td>12RM02</td>
<td>50</td>
</tr>
<tr>
<td>12RM02-01</td>
<td>50</td>
</tr>
<tr>
<td>12RM41</td>
<td>50</td>
</tr>
<tr>
<td>12RM41-01</td>
<td>50</td>
</tr>
<tr>
<td>12RM34</td>
<td>50</td>
</tr>
<tr>
<td>12RM34-01</td>
<td>50</td>
</tr>
<tr>
<td>12RS01</td>
<td>50</td>
</tr>
<tr>
<td>8KB Ram Pack</td>
<td>95</td>
</tr>
<tr>
<td>IEEE 488 System Controller with 1110</td>
<td>4500</td>
</tr>
<tr>
<td>8002A</td>
<td>4500</td>
</tr>
<tr>
<td>8002A Development System</td>
<td>200</td>
</tr>
<tr>
<td>Integration Unit</td>
<td>4500</td>
</tr>
<tr>
<td>Intel 8065 Emulator</td>
<td>1500</td>
</tr>
<tr>
<td>Intel 8085 Emulator</td>
<td>1100</td>
</tr>
<tr>
<td>Intel Z80/2 Emulator</td>
<td>1600</td>
</tr>
<tr>
<td>Motorola 68000 Emulator</td>
<td>1000</td>
</tr>
<tr>
<td>Intel 8085A Emulator</td>
<td>475</td>
</tr>
<tr>
<td>Intel 8086 Emulator</td>
<td>675</td>
</tr>
<tr>
<td>Intel 8086/67</td>
<td>475</td>
</tr>
<tr>
<td>Z8001 Emulator Probe</td>
<td>1100</td>
</tr>
<tr>
<td>Z8002 Emulator Probe</td>
<td>950</td>
</tr>
<tr>
<td>68000A Emulator Probe</td>
<td>1100</td>
</tr>
<tr>
<td>Zilog Z8002 Emulator</td>
<td>1750</td>
</tr>
<tr>
<td>Comms Interface</td>
<td>1950</td>
</tr>
<tr>
<td>Trigger Trace Analyser</td>
<td>1950</td>
</tr>
<tr>
<td>64K Ram Board</td>
<td>1500</td>
</tr>
<tr>
<td>Memory Allocation Controller</td>
<td>1350</td>
</tr>
</tbody>
</table>

### MICE

- **CEP 8048**: Intel 8048/840/850 Personality Board & 1320
- **CEP 8051**: Intel 8051/8751/8031 Personality Board & 1650
- **CEP 8085**: Intel 8085 Personality Board & 1195
- **CEP 8086/88 Max**: Intel 8086/8088 Personality Board & 1195
- **CEP 8086N**: Intel 8086 Min Personality Board & 1200
- **CEP 8086X**: Intel 8086 Max Personality Board & 995

### Price for up to date list and prices contact:

**0344 41 1011**

**ATS TechniRent SECONDHAND SALES**

Park House, The Pavilions, Downmill Road, Bracknell, Berks RG12 1QS.
In this, the first of three articles, Alan Clements looks at various multiprocessor architectures and discusses their advantages and disadvantages.

ALEN CLEMENTS

The local-area network is designed to enable users to share resources such as discs and printers that are geographically distributed.

OVERVIEW

Multiprocessor systems exist only because a given task can be carried out by means of several low-cost processors operating in parallel, rather than by a single high-cost high-performance processor operating alone. For example, suppose an application requires a throughput equivalent to a single 68000 operating at a clock rate of 60MHz. Clearly, such a device does not exist and the cost of constructing a system from off-the-shelf logic or buying a super minicomputer may be prohibitive. It may be possible to partition the task into subtasks in such a way that, say, ten 68000s operate on the subtasks simultaneously to give an effective throughput equal to that of a single high-performance processor.

Even when a multiprocessor system is not mandatory in a particular arrangement, multiprocessing can provide an economic advantage by increasing the power of a computer for very little additional cost. The economic benefits of multiprocessing arise because the cost of computer hardware lies almost entirely in its memory and peripherals. Often the microprocessor itself represents no more than one to less than 0.01% of the retail price of the system. Therefore, adding extra processors has little effect on the overall cost of the hardware. Unfortunately, an extra processor cannot just be plugged into an existing system. The global implications for the system hardware and its software are not trivial, because the individual processors have to share the available resources (i.e. memory and input/output). As with people, a one-person job is dispute-free, while a two-person job introduces the possibility of conflict. An effective multiprocessor system must be able to allocate resources to contending processors without seriously degrading the performance of the system.

Another reason for the interest in multiprocessor systems springs from their potential reliability. It can be argued that, if the probability of failure over a given time of a processor is p, then the probability of the simultaneous failure of two processors is p^2. Thus, if p is 1% per 10^8 hours for a given microprocessor, reliability of a dual-processor system is 0.01% per 10^8 hours. Similarly, the reliability of a triple-processor system is 0.0001% per 10^8 hours.

Alas, life is not as simple as the above figures would suggest. The processor represents only a tiny fraction of a computer's total hardware and there is little point in replicating this relatively reliable component alone. A realistic implementation of a highly reliable system replicates memory, control and peripheral elements. To make matters worse, the extra logic needed to detect, report and deal with the failure of a processor reduces the reliability of the system. Consequently, multiprocessor systems can be designed to be highly reliable, but are not necessarily cheap. Such systems are said to offer a 'high level of availability' and display 'graceful degradation'. The latter term implies that the failure of part of the system results in a reduced level of performance, but not necessarily its total shut-down.

Some multiprocessor systems are termed reconfigurable, which means that the structure of the hardware itself can be modified by the operating system. For example, the way in which memory is distributed between the individual processors can be changed dynamically under software control. Similarly, interrupt handling can be dynamically partitioned between the various processors to maximize efficiency. We do not discuss reconfigurable architectures further here.

While the architecture of a stored-program computer (i.e. a Von Neumann machine) can be defined quite precisely, there is no similar definition of a multiprocessor system. Multiprocessor systems come in many different forms and a configuration suitable for one particular application is almost useless for another. The only really universal characteristic common to all multiprocessor systems is that they have more than one processor! We shall soon examine the various classes of multiprocessor system.

Along with the advantages of multiprocessor systems come the disadvantages. To be more precise, the disadvantages are really the problems that the systems designer must consider. These are: the distribution of tasks between processors, the interconnection of the processors (i.e. the topology of the multiprocessor system), the management of the memory resources, the avoidance of deadlock and the control of input/output resources.

The distribution of tasks between processors is of crucial importance in selecting the architecture of the processor system itself. In turn, the distribution of tasks is strongly determined by the nature of the problem to be solved by the computer. In other words, the architecture of a multiprocessor system can be optimized for a certain type of
A classic problem that often involves multiprocessing belongs to the world of air traffic control. A radar system receives a periodic echo from the targets (i.e., aircraft) being tracked. Each echo is a function of the bearing and distance of the target. Due to imperfections in the system, there is an uncertainty associated with the echo. Moreover, a new echo is received every few milliseconds. From this constantly changing input, the computer connected to the radar receiver has to calculate the current positions of the targets and then to estimate the future track of each target and report any possible conflicts. Such a system requires very large amounts of computer processing power with relatively little I/O activity or disk access. Obviously it is not unreasonable to try to solve the problem by means of multiprocessing. For example, as one processor is updating a target's current position, another processor can be calculating its future position.

The preceding problem is described as classic, because it is so well suited to multiprocessing. There are several ways of allocating the mathematics involved in the radar calculations to the various processors. It is, unfortunately, much less easy to decompose a general task into a number of subtasks that can be run in parallel. Often it is necessary for the programmer to write programs in such a way that they involve the greatest amount of parallel activity.

TOPICS IN MULTIPROCESSOR SYSTEM DESIGN

The most important characteristic of a multiprocessor system is its topology, which defines how the processors are arranged with respect to each other and how they communicate. Another important characteristic is the degree of coupling between the various processors. I will discuss processor coupling first and then look at multiprocessing topologies.

Processor with facilities for exchanging large quantities of data very rapidly, are said to be tightly-coupled. Such computers share resources like buses or memory blocks. The advantage of tightly-coupled systems is their potential speed, because one processor does not have to wait long periods of time while data is transferred from another. Their disadvantage stems from the complexity of the hardware and software necessary to coordinate the processors. If they share a bus or memory, some arbitrator is needed to determine which processor is permitted to access the resource at any time. Arbitration may require both complex software and hardware elements.

Loosely-coupled processors transfer data via an I/O channel, i.e., a parallel or even a serial port, which offers a much slower data interchange but which simplifies the hardware design. Although a problem associated entirely with multiprocessors, the avoidance of deadlock must be in the design of some classes of multiprocessor. Deadlock is a term that is most frequently used in the world of multiprocessing and describes the situation in which two tasks are unable to proceed because each task holds something needed by the other. In a real-time system, the sequential tasks (i.e., the software) require resources (memory, disc drives, I/O devices, etc.) while in a multiprocessor system these resources are required by the individual processors.

Suppose a multiprocessor system has two processors X and Y. To complete its task, processor X needs resources P and Q, and processor Y also needs resources P and Q. If X seizes resources P and Q before Y, there is no problem because X continues and Y must wait for the resources to become available. Conversely, if X seizes P and at the same time Y seizes Q, we have a deadlock. X is waiting for Y to release Q but Y will not release Q until it has used P. Similarly, Y is waiting for X to release P. Therefore, the system halts and goes into an infinite waiting loop, a situation also called the 'deadly embrace'.

When designing multiprocessor systems, the problem of deadlock cannot be overlooked and ways of avoiding the situation in which no processor has all the resources it needs must be considered. One way of avoiding deadlock falls within the scope of the operating systems designer and is not considered further here.

Every multiprocessor system, like every single processor system, has facilities for input or output transactions. We therefore have the problem of how I/O transactions are to be treated in a multiprocessor system. It is not hard to argue that each processor has its own I/O arrangements. Is the I/O pooled between the processors, with each processor asking for I/O facilities as they are needed? Finally, is it possible to dedicate one or more processors solely to the task of I/O processing?

In a similar vein, the designer of a multiprocessor may need to construct an appropriate interrupt-handling system. When a single processor system, there is not a lot to decide. Either the processor services the interrupt or it is deferred. In a multiprocessor system you have to decide which processor services the interrupt, which in turns begs the question, "Do we pool interrupts or do we allocate certain types of interrupt to specific processors?" If interrupts are pooled, the interrupt-handling software must also be pooled, as processor A must deal with an interrupt from device X in exactly the same way that processor B would deal with the same interrupt. In addition to interrupts generated by I/O devices, it is possible for one processor to interrupt another processor.

Like any other computer, the multiprocessor requires an operating system. There are two basic approaches to the design of operating systems for multiprocessors. One of the simplest arrangements is the master/slave operating system in which a single operating system runs on the master processor and all other processors receive tasks that are handed down from the master. The master/slave operating system is little more than the type of operating system found in conventional single-processor systems.

Distributed operating systems provide each processor with its own copy of the operating system, or at least a processor can access the common operating system via shared memory. Distributed operating systems are more reliable than their master/slave counterparts because the failure of a single processor does not necessarily bring about a complete system collapse.

The problems I have just highlighted serve to emphasize that a multiprocessor system cannot easily be designed in isolation. Whenever you are faced with the design of a multiprocessor system, it is necessary to ask, 'Why do I need the multiprocessor system and what are its objectives?', and then to configure it accordingly. In other words, almost all design aspects of a multiprocessor system are very much problem dependent.

MULTIPROCESSOR ORGANIZATION

Although there is an endless variety of multiprocessor architectures, you can identify broad groups whose members have certain features in common. One possible approach to the classification of multiprocessor systems, attributed to Flynn, is to consider the type of the parallelism (i.e., architecture or topology) and the nature of the interprocessor communication. Flynn's classification of multiprocessor systems is based on the number of processors, the way the processors communicate, and the way resources are shared. It is referred to by the abbreviations: s.i.s.d., i.m.s.d., m.i.s.d., and m.i.m.d. and are described later. However, before continuing, I must point out that Flynn's topological classification of multiprocessor systems is not the only one possible, as multiprocessors may be categorized by a number of different parameters. One way of multiprocessors depends on the processor's relationship to memory and to other processing elements. Multiprocessors can be classified as processor-to-memory structures or as processing-element-to-processing-element structures. Figure 1 describes these two structures. A processor-to-memory architecture has N processors, an interconnection network and N memory elements. The interconnection network allocates processor X to memory Y. The more general processing-element-to-processing-element architecture uses N processors, each with its own memory, and permits processing element X to communicate with processing element Y via an interconnection network. The multiprocessors described in this series best fit the processing element to processing element model.

SINGLE-INSTRUCTION/ SINGLE-DATA STREAM

The s.i.s.d. computer is nothing more than the conventional single processor system. It is called single instruction because only one instruction is executed at a time, and single data-stream because there is only one task being executed at any instant.

SINGLE-INSTRUCTION/ MULTIPLE-DATA STREAM

The s.i.m.d. architecture is designed to execute instructions sequentially, but on data in parallel. The idea of a single instruction operating on parallel data is not as strange as it may sound. Consider vector...
general-purpose microprocessors. arithmetic and logic units, really number crunchers or high-speed vector, i.e. the multiple data-stream processing elements acting on the components of instruction-stream and an array of processors steps through the program, i.e. the single generally consists of a single controller that requires n processors, one for each component of the vector. Such an arrangement generally consists of a single controller that steps through the program, i.e. the single instruction-stream and an array of processing elements acting on the components of vector, i.e. the multiple data-stream in parallel. Often, such processing elements are really number crunchers or high-speed arithmetic and logic units, rather than general-purpose microprocessors.

The inner product is expressed as single operation, i.e. \( s = AB \), but involves multiple data elements \( a_i, b_i \). One way of speeding up the calculation of an inner-product is to assign a processor to the generation of each of the individual elements \( a_i, b_i \). The simultaneous calculation of \( a_i, b_i \) for \( i = 0 \) to \( n-1 \) requires n processors, one for each component of the vector. Such an arrangement generally consists of a single controller that steps through the program, i.e. the single instruction-stream and an array of processing elements acting on the components of vector, i.e. the multiple data-stream in parallel. Often, such processing elements are really number crunchers or high-speed arithmetic and logic units, rather than general-purpose microprocessors.

The inner product is expressed as single operation, i.e. \( s = AB \), but involves multiple data elements \( a_i, b_i \). One way of speeding up the calculation of an inner-product is to assign a processor to the generation of each of the individual elements \( a_i, b_i \). The simultaneous calculation of \( a_i, b_i \) for \( i = 0 \) to \( n-1 \) requires n processors, one for each component of the vector. Such an arrangement generally consists of a single controller that steps through the program, i.e. the single instruction-stream and an array of processing elements acting on the components of vector, i.e. the multiple data-stream in parallel. Often, such processing elements are really number crunchers or high-speed arithmetic and logic units, rather than general-purpose microprocessors.

The s.i.m.d. architecture, or array processor as it is frequently known, has a very high performance/cost ratio, together with a great degree of efficiency, as long as the task running on it can be decomposed largely into vector operations. Consequently, the array processor is best suited to the air-traffic control problem discussed earlier, to the processing of weather information (this involves partial differential equations) and to tomography where the output of a body-scanner is processed almost entirely by vector arithmetic. As s.i.m.d. architecture is generally built around a central processor controlling an array of special-purpose processors, the s.i.m.d. architecture is not discussed in any further detail here.

Fig. 1. Two main multiprocessing structures are the processor-to-memory configuration and the processing-element-to-processing-element configuration.

**MULTIPLE- INSTRUCTION/ SINGLE-DATA STREAM**

The m.i.s.d. architecture performs multiple operations concurrently on a single stream of data and is associated with the pipeline processor. A pipeline processor is best described in terms of an analogy with an automobile assembly line, where a single stream of components is operated on by a number of sequential processes to produce the finished automobile.

For example, four cars may be in the pipeline at any instant with a different operation being applied to each car. A complete car is produced after a car has passed through each of the stages in the pipeline and has been operated on at each stage.

In multiprocessor terms, the various processors are arranged in-line and are synchronized so that each processor accepts a new input every t seconds. If there are n processors, the total execution time of a task is nt seconds. At each epoch, a processor takes a partially completed task from a down-stream processor and hands on its own task to the next up-stream processor. As a pipeline processor has n processors operating concurrently and each task may be in one of the n stages, it requires a total of nt + (K-1)t time slots to process K tasks.

Reduced instruction-set (risc) microprocessors use pipelining to achieve a high throughput. At each clock cycle, one stage of the pipeline of the processor is fetching an instruction, one stage is decoding an instruction, one stage is executing an instruction and one stage is storing the operand from the previous execution stage. Multiple-instruction/single-data-stream systems are highly specialized, requiring special-purpose architectures, and are not discussed further here. In fact, m.i.s.d. architectures have never been developed to the same extent as s.i.m.d. and m.i.m.d. architectures.

**MULTIPLE- INSTRUCTION/ MULTIPLE-DATA STREAM**

The m.i.m.d. architecture is the most general-purpose form of multiprocessor system and is represented by systems in which each processor has its own set of instructions operating on its own data structures. In other words, the processors are acting in a largely autonomous mode. Each individual processor may be working on a subsection of the main task and does not necessarily need to get in touch with its neighbours until it has finished its subtask, Fig. 1.

Because of the generality of the m.i.m.d. architecture, it can be said to encompass the relatively tightly-coupled arrangements discussed in my next article, and the very loosely-coupled geographically distributed local-area networks. Figure 2 provides a graphical illustration of the classification of multi-processor systems according to Fathi and Krieger (IEEE Computers, March 1983, Multiple Microprocessor Systems: What, Why and When).

Alan...Clements, BSc., PhD., is...a reader in the School of Information Engineering at Teesside Polytechnic.
IF YOU NEED...

R.F. Interference/Field Strength Meters

- 9 kHz to 1.7 GHz
- CISPR/FCC specified
- GP-1B Interface standard
- Synthesized L.O.
- Complete range of aerials available
- Weight 4 KG

Radio Monitoring Systems

- System tailored to your needs
- GP-1B computer controlled
- Wide variety of spectrum

THEN YOU NEED TO CALL...

ANRITSU EUROPE LIMITED
Thistle Road, Windmill Trading Estate,
Luton, Beds, LU1 3XJ
Telephone: 0582 418853
Telex: 826750 Fax: 0582 31303

ANRITSU EUROPE LIMITED
Kansas Avenue, Langworthy Park,
Salford, Manchester M5 2GL
Telephone: 061-873-8041
Telex: A69719 Fax: 061-872-8040

ANRITSU EUROPE LIMITED
1230 Aztec West, Almondsbury,
Bristol BS12 4SG
Telephone: 0454 615252
Telex: 445677 Fax: 0454 618017

ENTER 35 ON REPLY CARD
Let the OGGITRONICS LTD CDG512/7 take all of the headache out of the front end design of your colour image acquisition system.

The board accepts a standard 1 volt composite signal and provides all of the following:
- Linear red, green, blue outputs through a high performance colour decoder.
- Digital 7-bit resolution red, green, blue outputs at 10MHz sample rate.
- Line locked 10MHz output clock.
- Horizontal and vertical (field and frame) signals. 75ohm buffered CCIR sync and blanking signals.
- Automatic internal/external sync switch for sync pulse generator.
- Colour and In-lock LED indicators.
- DC control of saturation and contrast.

Requires +5V and an unregulated 14V supply. Complete with all documentation and leads ready to go.

Substantial quantity discounts available.

Further information contact:
Dan Ogilvie at Oggitronics Ltd., Poole House, 37 High Street, Maldon, Essex CM9 7PF.
Telephone: (0621) 50378.

£795 + VAT

MASTERCLASS OSCILLOSCOPES

Highlights of the new HM 806 are the 3-Channel measurement amplifier and the true 2nd Timebase, allowing expansion and detailed analysis of extremely small waveform sections. In the alternating time base mode, the normal signal is displayed together with the expanded signal section, resulting in a 6-trace display when all three input channels are utilized.

For stable and jitter-free representation of asynchronous signal components, the HM 806 features a separate 2nd trigger facility with independent slope and level selection. Reliable trigger is ensured to above 100MHz. An active TV-Sync-Separator enhances triggering of noisy or distorted video signals.

The x 10 Mag. feature extends the maximum sweep range to 5ms/div, allowing for example, a 100 MHz signal to be viewed with one period over every 2 screen divisions. The HM 806 like all other HAMEG scopes with higher bandwidth! has a built-in switchable 1kHz/1MHz Calibrator with approx. 3 ns risetime.

The variety of essential trigger, amplifier, and time base features greatly simplify complex measurements in advanced laboratory and service applications. Operational comfort and solid reliability are strong testimony for the HM 806’s high technology standard.

2 years warranty on machines.

£698* exclusive of VAT

80 MHz Multi-Function Oscilloscope Triggering DC to 120MHz:
- 3 Channels, max. sensitivity 1 mV/div, Delay Line.
- Timebase A: 2.5s – 5ms/div, incl. x 10.
- Timebase B: 0.2s – 5ms/div.
- “After-Delay” Trigger, TV Separator.

70-78 Collingdon Street, Luton, Bedfordshire LUI 1RX
Telephone: (0582) 413174 Telex 825484

ENTER 26 ON REPLY CARD

538 ELECTRONICS & WIRELESS WORLD
Confessions of a frustrated inventor

Who ever thought that an article "Concerns of a frustrated inventor" by Heinz Lipschutz in your March issue. To be honest, my emotions were mainly the product of self pity, because a lot that Mr Lipschutz wrote about was recognized by me from personal experience. The way he described his case was impressive and piteous as well, starting with a cool account of the facts, and ending with a hardly hidden outburst of rage. The subject of technology may seem to be down-to-earth and emotionless to most people, but when a man devotes the best hours of his day, and the best years of his life to a technical subject, then it becomes a real part of his reason for living. If it then appears that "the world" denies his brain-child or his product of self pity, because a lot of people in industry are not interested in earning money for the things you have put your heart in. The reason was a 'Catch-22' situation in that nobody wanted to know, having never before even heard of me, and that most of the media did not want to publish anything by me for the same reason, so that as a consequence nobody heard of me.

I have all the credibility he feels he needs. The British Government has spent £100,000 on my invention (WW, July, 1981). I have received hundreds of thousands of pounds for my patents. Millions have been spent on my ideas. However, I am absolutely sure that I would not receive a fair hearing, or any hearing at all, for my new invention. This is in spite of the fact that everyone seems to have heard of me. No one, including myself, will ever gain credibility in Britain as an inventor.

References.


Ivor Call
St Albans
Hertfordshire

Instrumentation amplifiers

In the April edition of EWW you published two letters criticising some aspects of my February article on instrumentation amplifiers and I would like the opportunity to reply.

It is quite clear in the analysis that I presented that both the differential gain and common mode gains refer to the output voltage of each amplifier in relation to the input terminal voltages, and in so doing there is a tacit assumption that the source impedances of the signals applied to the inputs are negligible with respect to the input impedances. When processing any voltage information from a signal source, it is clearly important to ensure that the input impedance is very much greater than the driving source impedance. The input buffering action in the three-op-amp circuit does indeed give the instrumentation amplifier some advantages in this respect and I touched on this aspect in the final paragraph of my article.

To evaluate the effects of non-zero and imbalanced driving source impedances on the single op-amp differential amplifier, the values of $R_2$ and $R_3$ need to be modified to $R_1$ and $R_3$ given by

$$R_1 = R_1 + R_{si}$$
$$R_3 = R_3 + R_{ss}$$

where $R_{si}$ and $R_{ss}$ are the Thevenin equivalent source impedances driving the inverting and non-inverting inputs respectively. With this substitution the rest of the analysis remains the same and the effects of $R_2$ and $R_3$ only degrade the single op-amp differential amplifier.

The purpose of my article was to focus on the less obvious aspects of enhanced c.m.r.r. offered by the three-op-amp instrumentation amplifier that accrue significance only when the gain-bandwidth product of the complete differential amplifier cannot be achieved with a single op-amp circuit, such as the standard differential amplifier.

Both critics misquote my concluding remarks. I do not claim without qualification that the three-op-amp instrumentation amplifier offers no significant advantages over the single op-amp differential amplifier; the qualification being, as stated above, when the specified gain-bandwidth product of the complete amplifier can be achieved with a single op-amp circuit.

John Lidgey
Oxford Polytechnic
Oxford

Convolution

Howard Hutchings points out the difficulty of visualizing the process of analogue convolution in his excellent article in the February issue. The following explanation should be more helpful than the standard method based on sliding two graphs across each other.

Consider a system with a response hit) to a unit impulse where $1$ is the time after the impulse is presented to the input. A unit impulse or delta function has an area of $1$; therefore an impulse with an area $A$ will produce a response of $Aht$).

If a series of pulses is applied to...
the input, then each one will contribute its own $A h(t)$ to the response.

Now, a continuous function applied to the system can be considered as a series of narrow pulses. Note that $t$ is real time. A pulse occurring after a time $t$ with width $\Delta t$ will have an area $f(t)\Delta t$ and for this pulse $h(t-t)$.

So the contribution of this pulse is

$$A h(t') = f(t)\Delta t \times h(t-t')$$

The contribution for all pulses will then be

$$+ \sum_{-\infty}^{+\infty} f(r)h(t-\tau)\Delta \tau$$

or, in the limit, the response $r(t)$ is then

$$r(t) = \int_{-\infty}^{+\infty} f(r)h(t-\tau)d\tau$$

This is the convolution integral. It should be remembered that the unit impulse contains all frequencies, so that when transformed to the frequency domain, the impulse response $h(t)$ gives the system frequency response $H(f)$. Thus, if the input signal is $F(\omega)$, then the output response $R(\omega)$ will be

$$R(\omega) = F(\omega)H(\omega)$$

This is the immediate result if the convolution integral is transformed to the frequency domain.

I hope this will be helpful to readers.

T. Green
Bicester
Oxfordshire

**Feedback**

**Seven per cent**

I am afraid Mr Catt (April) has not made any new discovery, but has merely rewritten in a different form the well known Zipf's Law of word occurrence. This was originally published in 1949 in the book Human Behaviour and the Principle of Least Effort.

This law states that the number of occurrences of a word in a long length of text is the reciprocal of the order of frequency of occurrence. For example, the tenth most frequent word occurs about 1/10 as many times as the most frequent word.

Applying this law to Catt's text of 16384 different words gives the following:

<table>
<thead>
<tr>
<th>N</th>
<th>Rank</th>
<th>Reciprocals</th>
<th>Sum of reciprocals</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>8</td>
<td>1/5-1/8</td>
<td>0.6345</td>
</tr>
<tr>
<td>9</td>
<td>16</td>
<td>1/9-1/16</td>
<td>0.6629</td>
</tr>
<tr>
<td>17</td>
<td>32</td>
<td>1/17-1/32</td>
<td>0.6777</td>
</tr>
<tr>
<td>33</td>
<td>64</td>
<td>1/33-1/64</td>
<td>0.6954</td>
</tr>
<tr>
<td>65</td>
<td>128</td>
<td>1/65-1/128</td>
<td>0.6892</td>
</tr>
<tr>
<td>129</td>
<td>256</td>
<td>1/129-1/256</td>
<td>0.6911</td>
</tr>
<tr>
<td>513</td>
<td>1024</td>
<td>1/513-1/1024</td>
<td>0.6926</td>
</tr>
<tr>
<td>1025</td>
<td>2048</td>
<td>1/1025-1/2048</td>
<td>0.6916</td>
</tr>
<tr>
<td>2049</td>
<td>4096</td>
<td>1/2049-1/4096</td>
<td>0.6930</td>
</tr>
<tr>
<td>4097</td>
<td>8192</td>
<td>1/4097-1/8192</td>
<td>0.6931</td>
</tr>
<tr>
<td>8193</td>
<td>16384</td>
<td>1/16384-1/16384</td>
<td>0.6931</td>
</tr>
</tbody>
</table>

Thus it will be seen that each binary doubling of ranking increases the percentage frequency by approximately 7%, as Catt suggests.

It can easily be shown, by adding together the reciprocals in the Zipf series, that each binary doubling will give an equal increase in frequency.

It will thus be seen that Catt's 7% rule can be derived from Zipf's Law.

Benoit B. Mandelbrot, who was later to achieve fame through his work on fractals, suggested a theoretical basis for the law.

Zipf found the law applied in many other areas besides word frequencies, such as the populations of cities within a given country.

G.R. Turner Sloughbridge West Midlands

**The observer in Science**

Tom Iva'lls article 'The observer in science' (April) leaves the impression that many philosophers, once they have formulated a model of scientific and technological activity, don't question too closely whether scientists actually behave according to the model. The empiricists at least could not have been expected to appreciate that the brain's forte lies in imposing patterns on arrays of objects, in detecting systematic changes in these patterns, especially periodic changes, and above all in detecting moving objects.

These facilities, which are essential for any animal that wishes to find its way around, to find things to eat, and to avoid being eaten, represent a big advance on Locke's 'white paper'.

With them an alert shepherd, watching over his flock at nights for months or years in the same area, can discover for himself the regular rotation of the pattern of stars, the cycle of the moon, the seasonal changes in the position of sunrise and sunset, and even the erratic motion of some 'stars' ('planet' is derived from a Greek word meaning wanderer). This knowledge of astronomy he acquires in the way foreseen by the empiricists. The experiences of shepherds may be unfamiliar to modern city dwellers, but they form the backcloth to biblical times. However the complex pattern of planetary movements is unlikely to be unravelled except by someone who first assumes that such a pattern exists, and then deliberately looks for it.

Anyone attempting to codify planetary movements may well produce some sort of 'model' to act as a mnemonic. For this purpose even a tale of the goings-on of gods and goddesses may serve. In fact our notions of 'red', of 'animal', etc. are no more than models, to be adjusted as we gain increasing experience of the outside world. If anything they are less absolute than the models of the physicist, otherwise why so many arguments about the colours and patterns of carpets, clothes and curtains?

Philosophers may have persuaded themselves that an observer and the system he observes are interdependent, but it is far from obvious to those actually engaged in physics experiments.

Nowadays the details of the experimental configuration and the way in which the experiment is to be run will as likely as not be entered into a computer, and subsequently set up automatically. If the experimenter were to be killed in a road accident before the experiment began, that would hardly affect its outcome. In fact the interaction between the observer and the system observed is immaterial; what really matters is the interaction between the equipment used for the measurements and the system observed.

It is even possible to make a random choice of the measurements to be performed. Aspect's experiments demonstrating violations of Bell's inequality (deduced from Special Relativity) come very close to this, and provide some of the clearest experimental evidence for the quantum mechanical predictions that in certain cases the system used to make measurements must inevitably affect the state of the system measured.

C.F. Coleman Grove
Oxfordshire.
wise excellent article in the April issue of EWW is that the capabilities of human senses are restricted in just the same way that there is a limit of detection for all experimental procedures and the instruments used in them. At very low intensities of stimulus, a human observer is unable to tell with certainty whether an event external to the body has happened or not. Psychologists call this the lumen of perception and assign a probability of 0.5 to all sensory experiences at this level. This constraint will, therefore, also apply to all human knowledge that has been acquired by accumulation of sensory experience within an evolutionary context.

Since, in addition, nervous activity depends on electrical pulses ('action potentials') and an 'all-or-nothing' mechanism, it follows that all events in the Universe will be perceived as being quantized, whether or not they are in terms of 'objective reality'. The implications of this are far-reaching and, unless they are recognized by physicists and others, will continue to provide stumbling blocks to the rational solution of problems. The ultimate truth is that all procedures in logic end in paradox, resolvable only by arbitrary toss of a coin. Curiously, this makes fitting conceptual models to experimental data much easier.

Frequency changes

We are very pleased to hear that your correspondent Mr West (May Letters) is generally able to enjoy Radio 4 long wave in Vilteral, and that the sound quality is good.

Radio 4 long wave moved to 198 kHz at 0100 on 1 February, 1988. It is now in line with the International Frequency Plan referred to by Mr West. This change follows from an agreement at the 1979 World Administrative Radio Conference which assigned frequencies in the long-wave band to a 9 kHz spacing. This agreement will also extend the band, eventually, to 283.5 kHz.

The change has been coordinated internationally in three stages. Whilst most broadcasters concerned changed frequency on 1 February as required under stage 2 of this process, the 1 MW Algerian transmitter is still on 200 kHz. Depending on the propagation conditions, this can cause a 2 kHz heterodyne when listening to any service on 198 kHz. This is the most probable source of Mr West's problem.

We have asked the Algerians to come into line and adopt 198 kHz too, and hope they will soon change.

Mick Gleave
Asta Head, Engineering Information Department
BBC London

Flow charts

Mr Medes (April Letters) shows that thinking which will do for hardware design may well be too sloppy to work when programming. His Fig.1 shows something inherently impossible and which cannot exist. If both inputs R and S are low, then both outputs are high and cannot be Q and not Q. Also, if R and S change simultaneously from low to high, the outputs are indeterminate. Of course, in the world of hardware there are unwritten conventions for dealing with these awkward situations, but in programming everything relevant must be stated explicitly. It is silly to compare the diagram of the RS flip-flop with code that does more than the diagram. If you remove the absurdity and call the outputs X and Y, and if you ignore the awkward case of indeterminate outputs, you then get

IF NOT (R AND S) THEN
   X := NOT R;
   Y := NOT S
END;

That should make it perfectly clear what the flip-flop does, even to someone who doesn't already know! I can't think why Mr Medes should take such evident pride in having produced the bad code in his Fig.2. No, Mr Medes: hardware and software are such different things that you can't get away with mixing them as you have tried to do.

Mr Sweeney rightly disapproves of his little piece of code on the grounds that its straight left margin made it unclear. Now Mr Medes tells us that wavy lines are the bane of the computer industry. I must learn to program in Arabic (so as to get a wavy right hand margin) in the hope that that is less offensive than waves on the left.

Mr Medes makes me chuckle at his attempt to merge into one person R0s and praTT; ROTT! I hope Mr Ross doesn't mind!

J.G.D. Pratt
Leatherhead, Surrey.

It's not often that I need to reply to a magazine article, but A. Medes of Australia's letter, in your "Feedback" column in the April issue, contained many statements about computer science which are not accurate, especially concerning flow charts. His comparison of them with circuit diagrams is very misleading and as someone reading a joint degree in both fields I feel I must correct him.

Circuit diagrams, as you must realise, show all the physical information about a circuit, with the exception of the actual p.c.b. layout and are generally the best representation of a circuit. Whereas flow charts in no way show all the program details. For example such important issues as data structure and scope are shown on any flow chart which I've seen, but even worse the programme structure itself may be changed in representing it in a flow chart: for instance consider the recursive program segment:

fac(x) = \( \begin{cases} 1 & \text{IF } x = 0 \\ x \times \text{fac}(x-1) & \text{ELSE} \end{cases} \)

This is closer to the circuit diagram than a flow chart in that it completely describes all the information about the function, it could even be used to define the factorial function. It is also like a circuit diagram, in that it does not contain the actual implementation details.

I would like to see a flow chart which comes as near to representing the program as well as the above line, without converting it to a iterative version first. Flow charts were used, when the languages about were flat and all the under-laying workings of the computer were apparent to the programmer. In the above segment the cogs of the program are hidden, like in most modern languages but unlike in older "Fortran"-like languages.

Finally, flow charts like pseudo-code are only programming aids: in the future, languages will become more natural to write and the workings of the computer will be hidden from the programmer, as in the case of the new massively parallel computers being made, where we will not have any choice but to hide the implementation details and whether we use diagrams or text to represent the new highly structured languages being written for them, is only "syntactic sugar", but the charts as the stand, come way near to being expressive enough.

D. Celano
Swindon
Wiltshire

Moving-coil head amplifier

I would like to thank Mr Nalty (April) for his generous praise of my moving-coil preamp design. However, I winced to read his next sentence "Every competent engineer knows that the inclusion of electrolytic capacitors in the signal path will seriously distort its sound quality" This is quite untrue.

Mr Nalty blames "dialectical absorption" (sic). Perhaps he means "dialectic absorption", which my dictionary defines as testing the truth by logical disputation. Nothing would please me better, so long as we can keep both sides of the disputation logical.

The use of electrolytics in audio paths sets two major traps for the unwary, neither of which Mr Nalty addresses. The first is a slight tendency to microphony, which is unlikely to be detectable at the signal levels found in pre and power-amps. The second, and more important, is the possibility of a sharp rise in non-linear distortion and measurable changes if a signal voltage across the capacitor is allowed to develop. This point was thoroughly explored, if not actually beaten to death, in EWW two years ago. Neither of these tediously practical consid-
Relativity and engineering

J.C.G. Field quotes an accuracy for Nuvarst (GPS) of 18 metres. Perhaps engineer Field could put reliability aside for a moment and consider the 18-metre error.

The earth turns on its axis once every 24 hours. Hence the signal from the satellite to the ground observer suffers a phase shift resulting from the Sagnac effect (principle of the laser gyro). Since the satellite is in a 12-hour orbit, the distance between the satellite and the ground observer is continuously changing; that is, there is a time rate of change of the Sagnac phase shift, which is a frequency. That frequency should be added to the Doppler in the algorithm but is not.

For a numerical example, consider an observer on the equator in the plane of a polar satellite. His ground position error, as a function of the satellite elevation angle is, then:

<table>
<thead>
<tr>
<th>elevation angle (degrees)</th>
<th>error (meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>14.15</td>
</tr>
<tr>
<td>10</td>
<td>14.4</td>
</tr>
<tr>
<td>20</td>
<td>15.25</td>
</tr>
<tr>
<td>30</td>
<td>16.7</td>
</tr>
<tr>
<td>40</td>
<td>19.0</td>
</tr>
<tr>
<td>50</td>
<td>22.7</td>
</tr>
<tr>
<td>60</td>
<td>29.9</td>
</tr>
<tr>
<td>70</td>
<td>56.7</td>
</tr>
<tr>
<td>78.182 (horizon)</td>
<td>infinite</td>
</tr>
</tbody>
</table>

The beauty of this observation is that the noted phase shift is compatible, according to the establishment, with both the Special and General Theories of Relativity. Is there an Establishment "cover-up" of this error? You bet!

References

3. E.W. Silvertooth
4. Olga
5. USA

In EWW for March, 1988 J.C.G. Field comments on Einstein's theory of relativity on the basis of physical effects of moving bodies and clocks. Referring to such effects is a common method when defending this theory instead of answering the criticism.

The mass-increase phenomenon was initially discovered by Kaufmann in 1901 in cathode-ray experiments, and not predicted by Einstein's theory. It is known that H.A. Lorentz and Abraham Pais had suggested a theoretical formula for it, the formula which the particle physicist uses today.

The relation E = m.c^2 was also known and suggested by Poincare, Haseoholfo and Langevin independently of Einstein and before him. It is even known that the time-dilation effect was suggested by Larmor in 1900 and the hypothetical length-contraction effect by Lorentz and Fitzgerald some years before. Poincare was the inventor of "the principle of relativity" as reported from an international congress of Physics at St. Louis, USA, in 1904. The mathematics of space and time was developed by Lorentz.

Obviously, the adduced effects as referred to in the theory of relativity can be deduced from other starting points having nothing to do with relativity and not necessarily erroneous. Hence, we may ask: "What have these physical effects to do with relativity?" The theory of relativity has been criticized mainly on the basis of its invariant light hypothesis, the hypothesis constituting the base of the theory. Einstein himself said: "If the speed of light is in the least bit affected by the speed of the light source, then my whole theory of relativity and theory of gravity is false". Dedicated relativists try to muddy the water by talking about other things when this criticism appears, neglecting what the critics are trying to say: if the base hypotheses of a theory are not correct, the predicted imaginary physical effects of the theory cannot be correct. Dedicated relativists seem to have real difficulties in accepting this simple and obvious fact. Ove Tedenstig

References

1 Letters, E&WW Feb. 86, pp43,44.

Atomic fission

There is a certain sardonic smugness to the assertions professed by Hankey and Coleman (Letters, March): we are told that "experiments have failed to determine a size for the electron", but that "the two particles do, in fact, have drastically different sizes"; and I did not deny an internal structure for them, as a more careful rereading will show. I warned that the article was "simplistic" in order to dissuade any reader from assuming that the diagrams were scaled, thereby to infer that gamma frequencies need be involved, but some are so fond of the taste of shoe leather that they must perforce open their mouths.

Should any biologist offer an analysis of a cell nucleus which completely ignored its environment, he would be roundly condemned; yet physicists model the atomic nucleus with no reference whatever to the intense, complex, and dynamic electromagnetic field surrounding it, and demand absolute authority for their deductions. Since no one to my knowledge has ever seen a sub-atomic particle (the above gentlemen possibly excepted) our understanding of them must rely on many steps of inference and reasoning, any of which may at some future date be proved faulty or incomplete. As a more cautious commentator observes, "How a particle sits in equilibrium with the aether in a quiet background can be very different from how it appears in our mammoh machines in reacting to high-energy collisions". By investigating the relationship that exists between the e.m. field and the nucleus, there is every chance that we may be able to influence the nucleus indirectly by manipulating the field, and this involves readily obtainable energies, such as from ordinary lasers. My reason for not quoting any numerical values was not that they might be "too complex for EWW readers", but simply because the research needed to establish them has not been done.

Carl Adams
Terran Research
Eastwood
Australia
Digital opto-coupling for analogue signals

Direct transfer of analogue signals through opto-couplers, shown in the left-hand illustration, is adequate for many applications but higher linearity and stability can be achieved by passing the analogue information through the opto-coupler in digital form.

With analogue techniques, the smallest achievable linearity error is typically between 0.5 and 1%.

Isocom’s Application note No.1 details methods of connecting digital inputs and outputs to opto-couplers to improve linearity and stability. It does not discuss digital encoding techniques but it does give a good description of switching considerations for opto-couplers.

Included in the three-sheet note is a brief outline of the computer interface shown on the right. The graph shows that, for analogue coupling, linearity improves as input current rises.

Cordless telephone receiver

Audio amplification, second conversion and second i.f. demodulation sections form the ULN3883A dual-conversion receiver i.c. This low-power device, designed for narrow-band f.m. i.f., is used here as part of a cordless telephone.

Conversion of the 10.7MHz first i.f. to 455kHz is done by the 10.245MHz crystal. A tuned transformer matched to a ceramic filter with 15kHz bandwidth forms the 455kHz filter.

Output of the ceramic filter is matched with a 1.8kΩ resistor at the i.f. amplifier input. Loading the detector coil with 68kΩ gives a Q of about 25 to produce an audio output of around 170mV r.m.s. for a 3kHz peak deviation. Since this is more than enough to drive the audio amplifier, an RC network can be inserted between the detector output and volume control to provide de-emphasis.

Muting is accomplished by amplifying noise present at the detector output in the absence of a signal, rectifying it and applying the rectified signal to the mute input. When voltage at pin 8 exceeds 0.6V, the audio amplifier turns off.

The internal op-amp between the detector output and rectifier circuit forms an active bandpass filter with 7kHz centre frequency. This filter should be designed to respond to the guard-tone signal being transmitted.

Also in the Sprague ULN 3883 data/applications sheet are test circuits and a circuit similar to this one but taking advantage of the good signal-handling capability of the i.c’s mixer.

Addresses

Philips
Mullard House
Torrington Place
London WC1E 7HD
01-580 6633

Sprague Electric
Airtech 2
Flemming
Crawley
West Sussex RH10 2YQ
0293 517878

Isocom Ltd
Prospect Way
Park View Ind. Est.
Brenda Road
Hartlepool
Cleveland TS25 1UD
0429 221431

Jack 17
Spaceheights Ltd
6 Prospect Place
Chapelhay, Weymouth
Dorset DT1 1BY
0305 771974
Finding linear-network instability

The "Practical guide to the analysis of linear electronic circuits using a personal computer" is specifically written with the Jack 17 analysis program in mind, but much of its information could be helpful to users of other analysis programs.

One example from the Spaceheights guide, case study 13, is concerned with tracking down instability. In Jack 17, amplifying devices can be specified in terms of mutual conductance. To track down instability, the guide suggests that after finding the offending loop, you break it immediately before the mutual conductance in the amplifying device. Next, the conductance is driven with a signal and the resulting voltage between the nodes that normally drive the conductance is measured. If the measured voltage ratio is greater than or equal to one at every frequency where the phase is zero degrees then the network is unstable. If the ratio is less than one at zero degrees, the network is stable regardless of how large the ratio may be at other phase angles.

In the two uppermost diagrams, gain of the amplifying device is expressed in terms of $g_m$, so the device input resistance forms the load over the output. In the second example, current gain is specified. Output of the loop is taken across current-measuring resistor $R_n$, through input resistor $R_i$.

Other case studies in the guide are concerned with procedures for creating circuits and devices.

A and $\mu$-law companding with digital signal processors

Pulse-code modulation is used to transmit voice signals over digital communications networks since it allows analogue signals such as speech to be reliably transmitted with a relatively low signal-to-noise ratio. Transforming continuous hand-limited signals into p.c.m. requires sampling, quantization and binary encoding. Quantization errors occurring during analogue-to-digital conversion appear as distortion, and the effect of this distortion depends on two factors: quantization step size (resolution) and characteristics of the analogue signal.

Simply decreasing quantization step size reduces distortion but increases the transmission rate. Non-linear characteristics of the analogue signal however can be compensated for by companding, with relatively few disadvantages. Companding provides a constant signal-to-noise ratio over a large dynamic range.

Digital companding is the subject of an application note from Philips called "A and $A$-law companding with the PC15010 and PCB5011". The PCB devices are signal processors so the note obviously contains specific information on how to produce companding software for these chips. But it also contains good descriptions of $A$-law companding, which is essentially logarithmic, and $\mu$-law companding, which gives better s-to-n ratio at lower levels.
CONQUERING NEW HEIGHTS

*$ Component Comparator  
$ Variable Hold Off  
$ Triple DC Source  
$ DC – 25 MHz  
$ 40ns/div  
$ 2mV/div  
$ Low Cost  
£319*

To scale the heights, just call us for your FREE copy of our catalogue

*(Ex VAT & Delivery)

Crotech Instruments Limited
2 Stephenson Road, St. Ives, Huntingdon, Cambs. PE17 4WJ
Telephone: (0480) 301818

PRoTErL
The Circuit Designer’s Dream . . .

The dream becomes reality with Protel in action

Engineering Solutions Limited
King’s House, 16 Kings Street, Maidenhead, Berks. SL6 1EF
Tel: (0628) 733444 Telex 89445 Fax: (0628) 7462

ENTER 46 ON REPLY CARD

ENTER 34 ON REPLY CARD
Farnell Instruments manufactures instruments for the production, test, or repair and recalibration, of mobile radios, pocket pagers and other communications equipment.

The instruments include field portable units, bench or rack mounting models, and complete systems for manual or automatic use under computer control.

The equipment designs are state-of-the-art and competitively priced and available world-wide through a network of Agents.

Please ask for full details.
Phase from amplitude

A numerical method for determining phase response of a network when the amplitude is known.

D.V. MERCY

It is possible to derive the phase response of a network from details of its amplitude response, and vice versa, provided that the network in question is a minimum phase-shift type. Two similar conditions relate the real and imaginary components of a network function. Consequently, no one parameter can be specified independently of the others and this was shown by Bode to be very relevant to feedback amplifier design. The relationships are also useful when determining other properties of minimum phase-shift networks, such as their transient behaviour, if data on only one parameter, say the amplitude response, is initially available.

The equations which relate amplitude and phase can be expressed in several ways. However, the derivation of these equations is not discussed in detail, since this work is well covered elsewhere. (For example, the results have been obtained directly by means of contour integration in the complex plane, and as special cases of Hilbert transform relationships).

A common problem with these results is that they contain integrals which cannot be evaluated analytically except for a few special cases. Even then, the calculations are not trivial and are time consuming if great accuracy is required.

Bode demonstrated how to find the phase response from the amplitude response by a graphical method, making use of an amplitude characteristic which he called the "semi-infinite characteristic of attenuation". This is shown in Fig.1(a), which indicates zero loss up to frequency \( \omega_0 \), and an attenuation above this frequency which increases at 6dB per octave or 20dB per decade or, using a unit favoured by Bode, at 1 neper per e (=2.718) times increase in frequency. The phase curve corresponding to this attenuation characteristic has been calculated and is shown in Fig.1(b).

If \( f(s) \) is the input impedance, input admittance, transfer impedance or transfer admittance of a network, then the general expression for the response function to be considered in this paper is:

\[
f(s) = \frac{(s+a_1)(s+a_2)\ldots(s+a_p)}{(s+b_1)(s+b_2)\ldots(s+b_q)}
\]

The following constraints are to apply to the expression:

(i) There are \( Z \) zeros in total, with \( L \) zeros at the origin and \( M \) in the left half plane. No zeros exist in the right half plane.
(ii) There are \( P \) poles, all in the left half plane and \( P \geq Z \).
(iii) All the a's and b's occur as real numbers, or if complex, in complex conjugate pairs.

Phase from amplitude

If \( f(s) \) is the input impedance, input admittance, transfer impedance or transfer admittance of a network, then the general expression for the response function to be considered in this paper is:

\[
f(s) = \frac{(s+a_1)(s+a_2)\ldots(s+a_p)}{(s+b_1)(s+b_2)\ldots(s+b_q)}
\]

The following constraints are to apply to the expression:

(i) There are \( Z \) zeros in total, with \( L \) zeros at the origin and \( M \) in the left half plane. No zeros exist in the right half plane.
(ii) There are \( P \) poles, all in the left half plane and \( P \geq Z \).
(iii) All the a's and b's occur as real numbers, or if complex, in complex conjugate pairs.

Figure 3 gives a general schematic of \( f(s) \), showing an typical group of poles and zeros in the \( s \) plane.

The function \( f(\omega) \), the value of \( f(s) \) along the \( j\omega \) axis, can be expressed as:

\[
f(\omega) = \Re(f(s)) + j\Im(f(s))
\]
where \( f(u) \) and \( jv(u) \) are the real and imaginary parts of the function \( f \), defined along the jo axis. It is the relationship between \( u \) and \( v \), among others, that are of interest here. Bode and others (see reference 4 for an extensive list) have derived the relationships between the real and imaginary parts of \( \Phi(j\omega) \). Equations (3) to (5) are those to be evaluated below, although other versions of the relationships exist.

\[
v_i = \frac{2}{\pi} \int_0^{\infty} \frac{u - u_i}{\omega^2 - \omega_i^2} \, d\omega \tag{3}
\]

\[
u_i - u_i = -\frac{2}{\pi} \int_0^{\infty} \frac{v_i - v_i}{\omega^2 - \omega_i^2} \, d\omega \tag{4}
\]

\[
u_i - u_i = -\frac{2}{\pi} \int_0^{\infty} \frac{v_i - v_i}{\omega^2 - \omega_i^2} \, d\omega \tag{5}
\]

where \( u_i \) and \( v_i \) are shorthand methods of writing \( u(\omega) \) and \( v(\omega) \), and so on. An alternative expression for \( \Phi(j\omega) \), given in terms of amplitude and phase rather than real and imaginary parts is,

\[
\Phi(j\omega) = A(\omega) e^{j\omega(t)} \tag{6}
\]

where \( A \) is the amplitude (magnitude) response and \( \omega \) the phase response of the function \( f \), defined along the jo axis. By taking logarithms of both sides of equation (6), it becomes

\[
\ln(\Phi(j\omega)) = \ln(A(\omega) + j\omega(\omega)) \tag{7}
\]

and expressions which relate the real and imaginary parts in this equation are similar to equations (3), (4) and (5) given above: i.e.

\[
\phi = \frac{2}{\pi} \int_0^{\infty} \ln A - \ln A_i \omega^2 - \omega_i^2 \, d\omega \tag{8}
\]

\[
\ln A_i - \ln A = -\frac{2}{\pi} \int_0^{\infty} \frac{\phi - \phi_i}{\omega^2 - \omega_i^2} \, d\omega \tag{9}
\]

\[
\ln A_i - A = -\frac{2}{\pi} \int_0^{\infty} \frac{\phi - \phi_i}{\omega^2 - \omega_i^2} \, d\omega \tag{10}
\]

For the two sets of equations above, i.e (3) to (5) and (8) to (10), the same numeric solutions can be used, provided that the correct units are chosen. In particular, the amplitude should be expressed in nepers and the frequency in radians/sec in the equations. The nepers are a unit used frequently by Bode and his contemporaries. It is applied to a result when the natural logarithm of a voltage or current ratio is taken. It is easy changed to the more familiar decibel by means of the conversion 1 nepers = 8.686 dB.

**PHASE RESPONSE FROM AMPLITUDE RESPONSE**

Equation (8) is relevant here but, before proceeding, some general comments can be made about the behaviour of the magnitude of the expression given in (11).

If \( \Phi(j\omega) \) is plotted against log \( \omega \) then the resulting curve can be considered to have three regions. Firstly, there is a high-frequency region where the response falls linearly at 6\( \log(\omega) \) dB per octave, where \( (P - Z) \) is the difference between the total number of poles and zeros in \( f(\omega) \). Secondly, there is a low-frequency region where the response falls linearly at 6\( \log(\omega) \) dB per octave as \( \omega \) approaches zero, where \( L \) is the number of zeros at the origin. Thirdly, there is the important mid-frequency region, where the particular characteristics of the response are dependent to the specific pattern of all the poles and zeros of the function. (The precise arrangement is actually unknown, of course, only the resultant amplitude response is known).

The solution of equation (8) can now be broken down into three parts, one for each of the regions just mentioned.

**High-frequency contribution.** If a frequency \( \omega_0 \) is chosen in the high-frequency attenuation region of the response, then the integral \( A_h \), for the frequency range \( \omega_0 \) to \( \infty \), can be written

\[
A_h = \frac{2}{\pi} \int_{\omega_0}^{\infty} \ln A - \ln A_i \frac{1}{\omega^2 - \omega_i^2} \, d\omega \tag{11}
\]

Now at high frequencies,

\[
A(\omega) \approx \frac{K}{\omega^{P-Z}} \tag{12}
\]

where \( P \) is the total number of poles and \( Z \) is the total number of zeros.

Therefore

\[
A_h = \frac{2}{\pi} \int_{\omega_0}^{\infty} \ln (K/\omega^{P-Z}) - \ln A_i \frac{1}{\omega^2 - \omega_i^2} \, d\omega \tag{13}
\]

Expanding the right hand side,

\[
A_h = \frac{2}{\pi} \int_{\omega_0}^{\infty} \ln K - (P - Z) \ln \omega - \ln A_i \frac{1}{\omega^2 - \omega_i^2} \, d\omega
\]

so finally

\[
A_h = \frac{2}{\pi} \int_{\omega_0}^{\infty} \ln K - \ln A_i - (P - Z) (1 + \ln \omega) \, d\omega \tag{13}
\]

Before equation (13) can be evaluated it is necessary to obtain values for \( \ln K \) and \( (P - Z) \). To do this, two frequencies \( \omega_{01} \) and \( \omega_{02} \) are chosen in the high frequency region of the response, with \( \omega_{02} > \omega_{01} \) and with attenuation values \( A_{h1} \) and \( A_{h2} \), respectively.

Since, at high frequencies, from equation (12)

\[
\ln A_h = \ln K - (P - Z) \ln \omega, \tag{14}
\]

and

\[
\ln A_{h1} = \ln K - (P - Z) \ln \omega_{01}, \tag{15}
\]

Solving equations (14) and (15) gives

\[
(P - Z) = \ln A_{h1} - \ln A_{h2} \tag{16}
\]

and

\[
\ln K = \ln A_{h1} - \ln A_{h2} - \ln \omega_{01} - \ln \omega_{02} \tag{17}
\]

Equations (16), (17) and (13) are sufficient to allow the evaluation of \( A_h \) for the frequency \( \omega_0 \). However, the computational work can be simplified if, first of all, equation (13) is written as

\[
A_h = C_{h1} \omega_{01}^2 (D_{h1} - \ln A_i) \tag{18}
\]

where

\[
C_{h1} = \frac{2}{\pi} \frac{1}{\omega_{01}^2} \tag{19}
\]

and

\[
D_{h1} = \ln K - (P - Z) (1 + \ln \omega_{01}) \tag{20}
\]

and where \( \omega_{01} \) is replaced by \( \omega_{02} \), a frequency already chosen.

Following the determination of \( P - Z \), \( K \), \( C_h \) and \( D_h \) during preliminary calculations, it is only necessary to work with equation (18) thereafter when evaluating the value of \( A_h \) at each frequency \( \omega_0 \).

**Low-frequency contribution.** For the frequency range 0 to \( \omega_0 \), where \( \omega_0 \) is a frequency in the low-frequency region of the response, the integral expression is

\[
A_h = \frac{2}{\pi} \int_{\omega_0}^{\infty} \ln A - \ln A_i \frac{1}{\omega^2 - \omega_i^2} \, d\omega \tag{19}
\]

Now, from equation (1) the expression for \( \Phi(j\omega) \) as \( \omega \to 0 \) becomes

\[
|\Phi(j\omega)| \approx |\frac{K}{\omega^{P-Z}}| \tag{19}
\]

and

\[
|\Phi(j\omega)| \approx |\frac{K}{\omega^{P-Z}}| \tag{19}
\]
so the logarithm of the magnitude can be written

\[ \ln |A(\omega)| = \ln K + L \ln \omega \]

where

\[ \ln K = \ln K_0 + \sum_{i=1}^{n} \ln a_i + \sum_{i=1}^{n} \ln b_i \]  

(20)

and so, provided that \( \omega_0 = \omega_1 \),

\[ \ln_{0} = \frac{2\omega_0}{\pi} \int_{0}^{\omega_0} \ln \omega + \ln A_0 - \ln A_0 \omega_0, \]  

(21)

and finally

\[ \ln_{0} = -\frac{2\omega_0}{\pi} \left( \ln K_0 - \ln A_0 + L \ln \omega_0 - 1 \right) \]

To determine the values of \( K_0 \) and \( L \), which are required for the evaluation of equation (21), consider two frequencies \( \omega_0 \) and \( \omega_2 \) in the low-frequency region of the response, with \( \omega_0 \geq \omega_1 \).

Then

\[ \ln A_{02} = \ln K_0 + L \ln \omega_0 \]

(22)

and

\[ \ln A_{01} = \ln K_0 + L \ln \omega_1 \]  

(23)

Solving equations (22) and (23) gives

\[ \ln A_{02} - \ln A_{01} = L (\ln \omega_2 - \ln \omega_1) \]

(24)

Thus, the value of \( L \), for a frequency \( \omega_0 \), can be evaluated by means of equations (21), (24) and (25).

For convenience of computation, equation (21) can be rewritten

\[ \ln_{0} = \frac{2\omega_0}{\pi} \left( D_0 - \ln A_0 \right) \]

(26)

where

\[ D_0 = \frac{2\omega_0}{\pi} \left( \ln K_0 + \ln \omega_0 - \ln (\ln \omega_0 - 1) \right) \]

and where it is convenient to put \( \omega_0 = \omega_1 \), since this is a frequency already chosen. Values of \( C_0 \) and \( D_0 \) are obtained as part of the preliminary calculations, so that only (26) needs to be used in subsequent calculations.

Mid-frequency contribution. The expression that requires evaluation is

\[ \ln_{m} = \frac{2\omega_0}{\pi} \int_{\omega_0}^{\omega_1} \ln A - \ln A_0 \omega_0 - \omega_0^2, \]  

(27)

It is necessary to resort to numerical integration to evaluate this expression, since it is not normally possible to find an analytic solution. However, it is an integral between finite limits and, provided proper care is taken when \( \omega_0 = \omega_1 \), a straightforward procedure is possible.

Amplitude values are known at a number of frequencies. These are the points (nodes) chosen originally to define the response. In the first instance, it is convenient to calculate the values of phase at these same frequencies. (The value of phase at any other frequency can be derived, as required, but it is first necessary each time to determine the amplitude value at the chosen frequency. This can be done by interpolation between the appropriate pair of nodes on the amplitude plot.)

It is possible to carry out the numerical integration by means of the trapezium rule, as this is easily implemented; it copes well with the non-linear frequency scale and it gives adequate accuracy. If, first of all, the frequency interval between two adjacent nodes is subdivided into a number of logarithmically equal intervals (eight or more subdivisions give good results), then corresponding amplitude values may be obtained by interpolation. For example, if point 1 has a gain value \( A_1 \) at frequency \( \omega_1 \) and point 2 has values \( A_2 \) and \( \omega_2 \), and if the frequency interval is divided into \( n \) logarithmically equal subsections, then the intermediate frequencies are calculated using

\[ \omega_{1/2} = \omega_1 + \frac{\omega_2 - \omega_1}{2}, \]

(28)

and the corresponding amplitude values are

\[ \ln A_{1/2} = \ln A_1 + \frac{A_2 - A_1}{2} \]

for \( 0 < m < n \)

and

\[ \ln A_m = \ln A_1 + \frac{A_{m+1} - A_1}{m+1} \]

for \( 0 < m < n \)

If the phase value is currently being calculated at frequency \( \omega_m \) (with amplitude value \( A_m \)) then the value of Bode's function at each point is

\[ BD_m = \frac{\ln A_{m+1} - \ln A_m}{\omega_{m+1} - \omega_m} \]

(30)

for \( 0 < m < n \)

and

\[ \Delta \text{Area} = \frac{1}{2} (BD_{m+1} + BD_m) \left( \omega_{m+1} - \omega_m \right) \]

(31)

and the total area between two adjacent nodes is the summation of the sub-areas as \( m \) is stepped through from zero to \( n-1 \). This process is repeated for all the segments in the mid-frequency range.

However, whenever \( \omega_0 = \omega_1 \), equation (30) cannot be used directly, so it is necessary to find separately a value for BD whenever this occurs. It can be found as the limiting value of the right hand side of (30) as \( \omega \to \omega_0 \) and is given by

\[ BD_{\omega_0} = \lim_{\omega \to \omega_0} \frac{\ln A_{m+1} - \ln A_m}{\omega_{m+1} - \omega_m} = \frac{1}{2} \frac{d}{d\omega} (\ln A) \]

(32)

There is an additional complication because the function being considered for integration is not a smooth curve, but consists of a series of straight line segments (i.e. the function is not analytic at the nodes). So each time \( \omega \to \omega_0 \), it is necessary to find two limiting values of BD, one as \( \omega \to \omega_0 \) from the low-frequency side and one as \( \omega \to \omega_0 \) from the high-frequency side.

Therefore, two values of the gradient of the amplitude response are required, each time \( \omega \to \omega_0 \), for the evaluation of equation (32). To obtain them, choose two frequencies very close to \( \omega_0 \), one on the low-frequency side at, say, \( \omega_0 \), and one on the high-frequency side at, say, \( \omega_0 \). Values of the amplitude, \( A_0 \) and \( A_0 \), respectively, can be obtained at these frequencies by interpolation in much the same manner as discussed previously, using an expression similar to equation (29). Then on the low-frequency side

\[ \frac{d}{d\omega} (\ln A) \left|_{\omega_0} \right. = \ln A_0 - \ln A_0 \]

and similarly on the high-frequency side

\[ \frac{d}{d\omega} (\ln A) \left|_{\omega_0} \right. \]

With these results, the two outstanding values of BD can be calculated, using equation (32), and the calculation of areas can be completed through the range \( \omega_1 \) to \( \omega_2 \).

Then

\[ \ln_{m} = -\frac{2\omega_0}{\pi} \int_{\omega_0}^{\omega_1} \ln A - \ln A_0 \omega_0 - \omega_0^2, \]

(27)

Summation of contributions. The final answer, at a given \( \omega_0 \), is the sum of the three contributions calculated as described above, i.e.

\[ \omega_0 = \omega_0 + 1 \to \omega_n \]

This answer is in radians and can, of course, be easily converted to degrees if required.

The calculations are repeated for other values of \( \omega_0 \), as required. The frequencies chosen for the initial calculations are normally the other nodes of the response, as mentioned above, with additional frequencies chosen later, if they are needed.

Examples. Three examples are given below to illustrate the results achievable by the procedure. In these cases it is possible to obtain the answers by analytic means, to allow the accuracy of the method to be checked.

In the examples, the interval between adjacent nodes is subdivided into ten parts, as this is considered to be a good compromise between accuracy and computing time (taking, say, 16 subdivisions certainly increases the accuracy of the results a little, but the program takes 50% longer to run). In any case, the final accuracy is much more dependent on how well the initial data points are chosen, when first characterizing the response.

Results so far obtained agree well with the predictions given by Thomas, i.e. if the straight line segments are chosen to approximate the true response with errors that do not exceed 0.5dB, then the resultant phase plot will not deviate by more than 3 degrees from the correct value.

Although the work in this article concentrated on obtaining phase from amplitude, the same procedure is applicable to the derivation of the imaginary part of a network function from the real part and this is demonstrated in the third example.

Example 1. The amplitude plot is shown at (a) in Fig.4. It is a low-pass filter characteristic and is a third-order Chebyshev with 3dB ripple. The phase response of this filter obtained by analytic means is shown by the full line at (b).

The triangles shown on the amplitude curve are the points chosen to define the
Example 2. In this example the amplitude response, that of a 5th order Butterworth high-pass filter, is shown at (a) in Fig. 5 and the phase response, obtained by analytic means, is shown at (b).

As in example 1, triangles on (a) indicate the points chosen to characterise the amplitude response and the circles and squares on (b) are the results of the numeric procedure.

Example 3. Here a network real part is the input data and is shown at (a) in Fig. 6. This is the real part of the transfer impedance of the network shown in Fig. 7. The imaginary part, obtained by analytic means, is shown at (b).

As in the previous examples, triangles define the input data and circles or squares show the calculated results.

**Books**

**Newnes and audi and hi-fi engineer's pocket book** by Vivian Capel. Heine-mann Professional Publishing, £9.95. Concise reference work with a practical slant, covering acoustic principles, and the theory and use of microphones, the gramophone, Compact Discs, tape recording, radio, amplifiers, loudspeakers and public address systems. The facts and figures are put into perspective by brief but useful explanations. A chapter at the back sets out formulae for resistance and impedance, Q factor, matching circuits, and more. Hard covers, 190 pages 95 x 195mm.

**Newnes radio amateur and listener's pocket book** by Steve Money. Heine-mann Professional Publishing, £8.95. Compendium of reference data for the radio operator. Subject headings include antennas, transmitters and receivers, radio frequencies, digital communication, picture communication, utility stations, space communication, propagation, operating data. Hard covers, 160 pages 95 x 195mm. (Despite the similar outward appearance of volumes in this series, it is notable that there is relatively little overlap in the contents.)
HEWLETT-PACKARD MODEL 8565A
SPECTRUM ANALYSER

- Internal Pre-selection 1.7-220GHz
- Resolution Range 1kHz-3MHz
- Digital Readout of Control Settings
- Simple 3 Knob Operation
- Detailed Specification Available on Request

FREQUENCY 10MHz-2.2GHz
(40GHz EXT. MIXING)

A FIRST QUALITY ‘SECOND-USER’ DEAL £10,750 + v.a.t.

FIBRE OPTIC T.D.R. ANRITSU MODEL MW98A
inc. 1300nm monomode plug-in

Range up to 72km
Resolution down to 1m (at all distances)
Loss measurement
High-speed averaging
Large CRT display with on-screen a-sha-numerics
Fully programmable using HPIB interface

PRICE £9500 + v.a.t.

HEWLETT-PACKARD MODEL 8903A
AUDIO ANALYSER

- Frequency range 20kHz-100kHz
- Measures: A, B, C
- Total Harmonic Distortion
- DC volts
- Frequency
- Built-in low distortion oscillator
- Programmable via HPIB

PRICE £1950 + v.a.t.

Carston Electronics Limited
2-6 Queens Road, Teddington, Middlesex TW11 1LR
Tel: 01-943 4477 Telex: 938120 (CARLEC G)
ALSO IN FRANCE: Contact Contact Telephone Paris (1) 46 86 97 01

ALL ITEMS CARRY OUR COMPLETE PARTS & LABOUR GUARANTEE
PRICES SHOWN, (SUBJECT TO AVAILABILITY). EXCLUDE DELIVERY AND VAT

ENTER 9 ON REPLY CARD

COMMERCIAL QUALITY SCANNING RECEIVER

The IC R7000, advanced technology, continuous coverage communications receiver has 99 programmable memories covering aircraft, marine, FM broadcast, amateur radio, television and weather satellite bands. For simplified operation and quick tuning the IC-R7000 features direct keyboard entry. Precise frequencies can be selected by using big key in sequence of the frequency by using the main tuning knob. FM wide/FM narrow/AM upper and lower FS8 modes with 6 tuning speeds 0.1, 0.5, 1.0, 2.0 and 5.0kHz. A sophisticated scanning system provides instant access to the most used frequencies. By depressing the Auto-M switch the IC-R7000 automatically memorises frequencies that are in use whilst it is in the scan mode, this allows you to recall frequencies that were in use. Readout is clearly shown on a dual-colour fluorescent display. Options include the RC 12 infrared red remote controller, voice synthesizer and HP-1 headphones.

Tel: 0227 163859. Telex: 965179 ICOM G
M & B Authorised Welsh distribution by:
M&BS Communications Ltd. Cardiff Tel: 0222 24167.

Please send information on Icom products & my nearest Icom dealer.
Name/address/postcode:

Enter 5 on reply card

ICOM
Low profile IC sockets: Pins

- 27C512 8.95 8.35 250ns
- 27C256 250ns
- 27256 250ns
- 27128 250ns
- 2764 250ns
- 2732A 250ns
- 2716 450ns 5 volt
- 6264 150ns Low Power
- 6116 150ns
- 4164 12Ons 6.50
- 41256 62256
- 4116 200ns

Part type

- 552
- 551

Please add 50p post & packing to orders under £15 and VAT to total. Access orders by phone or mail welcome.

Non-Military Government & Educational orders welcome. £15 minimum.

HAPPY MEMORIES (WW), FREEPOST, Kington, Herefordshire HR5 3BR. Tel: (054 422) 618

ENTER 47 ON REPLY CARD

EPROM PROGRAMMER

AT LAST! Over 50 Generic Device Types. . .

HAPPY MEMORIES

THE MQP ELECTRONICS MODEL 18 PROM PROGRAMMER

- Automatic Data Page setting 300-19,200 baud.
- Two independent Communications Protocols built in.
- Terminal Mode Protocol.
- Use any host computer with RS232 port and Terminal Emulator.
- Host Computer Protocol!
- Use our PROMDRIVER Advanced Features User Interface Package available for all M-QOS, PC-DOS and CP-M-80 computers.
- No personality modules to install, no switches to set.
- Fast interactive algorithms automatically selected as appropriate.
- Upgradable for future types.
- Designed, manufactured and supported in the UK. "EX-STOCK!"
- Comprehensive 60 page User Manual.
- n.b. Devices other than 24/26 pin require low cost socket adapter.

Write or telephone for further details:

ENTER 14 ON REPLY CARD

ELECTRONICS & WIRELESS WORLD
Digitally-multiplexed telemetry link

These circuits were developed to provide remote monitoring of physical and physiological quantities in ambulant patients. Eight analogue channels are provided at the transmitter and a parallel interface at the receiver allows direct connection to the user port of a BBC microcomputer. A modified radio-microphone system operating at around 147MHz provided an r.f. data link.

Multiplexer IC5, sampling at 100Hz, feeds each of the eight ±5V analogue channels sequentially to a-to-d converter IC2. When conversion is complete, monostable multivibrator IC3, triggers loading of the data into the 6402 uart and increments the multiplexer address counter. Serial output is attenuated to about 0dBm before being fed into the transmitter. When IC3, times out, IC3b is triggered to start conversion of the next sample.

A pulse on the clock input of bistable device IC1a, starts the system. Converter and uart clocking signals, at 9600Hz and 153kHz respectively, are produced by IC9 and a 2.45MHz crystal. These frequencies give a 950ps conversion time and 9600 baud data.

Since a-to-d converter input is not sampled and held, the unit is only suitable for signals with a low slew rate. For one l.s.b. error, the slew rate should be <40V/s.
At the receiver, recovered audio at about 3.5V pk-pk feeds a comparator whose reference is set using a potentiometer to give error-free data. Data is converted from serial to parallel form by a second uart then buffered by IC12 for feeding to the computer. Simple handshaking for the microcomputer interface is provided by uart lines DR and CB2. A machine-code routine is needed to read the data from the uart. An example of assembly language that might be used is,

```plaintext
READY: LDA #&FO
Pulse CB2 low
STA &FE6C
(DRR) to reset
LDA #&DO
flag from
STA &FE6C
uart CB1 (DR)

.TEST: LDA &FE6D
AND #&10
if high 'read
BEQ TEST
(data else
LDA &FE60
CBI (DR)

Handshaking line CB1 goes high on receipt of the first valid character. This provides transmitter/receiver synchronization since channel one is the first transmitted after a start pulse. It is advisable to use ferrite beads on the power supply lines; the transmitter needs ±5V supplies and the receiver 5V.

A.G. Birkett
London

Don't waste ideas

We prefer circuit ideas contributions with neat drawings and widely-spaced typescripts but we would rather have 'scribbles on the back of an envelope' than let good ideas be wasted.

Minimum payment of £35 is made for published circuits.

NEXT MONTH

High-definition television. There is currently a great deal of activity directed towards the establishment of one or more standards for enhanced television systems with higher definition. We present an article explaining the factors which will influence the choice.

Waves. Joules Watt has come to the conclusion that many youngsters reading electronics at university possess only a nodding acquaintance with the subject of wave motion. This month's JW piece should help with the introductions.

Pioneers - Strowger. One of the great names in communications, Almon B. Strowger is the subject of this part of W.A. Atherton's historical series.

Pseudo-science in audio. As a professional audio engineer, Doug. Self has lost patience with the "subjectivist tendency" in audio. He attempts to remove some of the mythology that has permeated the subject in the last few years.

Sequency-division multiplexing. The use of Walsh functions offers an alternative to frequency-division or time-division multiplex, with a reduced sensitivity to noise. C.H. Langton explains.

Risc processors. Approaches to the architecture and design of risc processors are described by authors from two of the companies engaged in this development.
Embedded Computer

TDS 9090

A powerful control computer based on the new Hitachi 6303Y and high level language Forth. 100mm x 72mm. 30K bytes RAM, 16K dictionary RAM/PROM, 256 bytes EEPROM, 16K Forth. You can attach 64 key keyboard, LCD and FC bus peripherals. Built-in interface for character generators, multi-tasking, time of day clock, watchdog timer, full screen editor and symbolic assembler. 32 parallel and two serial ports. Single power supply and low power 3mA operational mode.

1 of £194.95 including manual and non-volatile RAM.

Triangle Digital Services Ltd
100a Wood Street, London E17 3HX
Telephone 01-520-0442 Telex 262894 (quote M0775)
**A new technique in o.t.d.r.**

A new correlation technique for fibre o.t.d.r. measurements, described last month, gives readings 64 times faster than conventional single-pulse methods. This second article discusses practical advantages.

STEVE NEWTON

Performance advantage of a complementary-correlation o.t.d.r. over a conventional single-pulse o.t.d.r. using the same laser, receiver, and other components can be summarized as follows. When coded probe signals consisting of L bits are used to probe a fibre, a big-way dynamic range increase of $VL/4$ is achieved relative to a conventional single-pulse measurement in a given averaging time, while maintaining the response resolution corresponding to the width of a single bit. Alternatively, the same result obtained with a single-pulse measurement can be obtained a factor of $L/4$ times faster using complementary codes. The way in which this improvement is obtained in theory was described last month. This article describes how these performance improvements were demonstrated in practice.

**EXPERIMENT**

A block diagram of the experimental arrangement used to make the complementary-correlation o.t.d.r. measurements is shown in Fig. 1. A code generator was used to drive a commercially available InGaAsP laser diode ($\lambda=1.3\mu$m) with the appropriate Golay-codes and their one's complements. The shot-to-shot repetition rate of the code bursts was approximately 700kHz. A peak power of 6mW was coupled from the laser into its single-mode fibre pigtail. The laser power was coupled into the fibre under test using a fibre directional coupler whose second output was index matched to suppress reflection. Peak power coupled into the fibre under test was approximately 2mW.

Approximately half of the return signal from the fibre under test was coupled to the receiver via the directional coupler. The receiver consisted of a pigtailed InGaAs p-i-n photodiode followed by a transimpedance amplifier. Bandwidth of the receiver was approximately 3.5MHz, and its noise equivalent power was 400pW (−64dBm).

The amplified signal was then digitally sampled, averaged, and processed to reconstruct the fibre backscattering impulse response. In the first experiments, the averaging, correlation, and display were performed using a desk-top computer (HP9836). For later experiments, including many of those described in this article, the functions of the clock, code generation, averaging, and correlation were performed by a single piece of digital circuitry, essentially a specialized 32bit 10 Mips signal processor. This high-speed processing capability allowed the reconstructed data to be displayed on a c.r.t. with updates of the averaged data approximately every 250ms.

**EXPERIMENTAL RESULTS**

A variety of fibre configurations were used to test the performance of the complementary-correlation o.t.d.r. The fibres used in these experiments had attenuation coefficients ranging between 0.34 and 0.4dB/km. Elastomeric splices were used to make most of the connections, although measurements made on side-lobe deviation using connectors yielded similar results. The results presented here represent the main performance advantages of this complementary-correlation technique: strong side-lobe suppression, signal-to-noise improvement without compromising resolution, improved dynamic range, and greatly reduced measurement time.

Figure 2 shows a measurement of an extremely large reflection made using 32bit codes consisting of 4µs bits. This result, plotted on a linear scale, shows autocorrelation side lobes which occupy a fraction of one division to the right of the peak. However, since the height of the peak is 1187 of these divisions, the worst side-lobe deviation (which could also be interpreted as receiver undershoot) is 38dB down, with the rest of the structure more than 40dB below the peak. It should be noted that this is a typical and not a best result; in some cases, side lobe suppression approaching 45dB has been observed. This is the best side-lobe suppression reported to date for a correlation o.t.d.r. and is 20-30dB better than what is possible using Barker or finite pseudo-random codes, even under ideal conditions.

Figure 3 shows two measurements of a 5km span of fibre centred at 25km after five seconds of averaging time. In both cases, the bit duration was 125ns. In Fig.3(a), a 4bit code was used to represent the result that would be obtained using a conventional o.t.d.r. Figure 3(b) shows the result of using 256bit codes in the same five-second measurement time. In this case, the noise is greatly reduced and the backscattered signal is visible. This result is obtained without sacrificing resolution, as evidenced by the fact that in both cases the 3dB width of the reflection peak is only 16m.
Fig. 3. Two five-second measurements using 125ns bits. Left-hand curve represents a conventional measurement, right-hand curve results from using 256bit codes.

Fig. 4. Resolution of 26m at a distance of 35.4km with a measurement time of 20s.

Fig. 5. Two ten-second measurements using 250ns bits. Graph (a) is a single-bit measurement and (b) is a measurement using code length 128.

An example of high resolution at long range is shown in Fig.4. The reflection feature is located at a distance of 35.4km. It contains not one, but two peaks that are separated by only 26m and clearly resolved. These peaks are the result of reflections from two ends of a 26m segment of fibre which is spliced into the cable at that distant point. Whereas a conventional o.t.d.r. might take only 20 seconds to obtain such a result, this measurement, which used 256bit codes, took only 20 seconds.

Fig. 6. Two measurements with equivalent signal-to-noise ratio, both using 500ns bits. The 32bit measurement was made 32 times faster.

Bit duration was 250ns. In the measurement shown in Fig. 5(a), wherein a single-bit code was used, a reflection is visible at about 27km and the backscattering signal drops into the noise. When a code length of 128 was used, Fig. 5(b), however, the backscattering signal is free of noise and the end of the fibre is clearly seen. The noise level was reduced by about 10.5dB in the same measurement time, in good agreement with theory (seven octaves × 1.6dB/octave).

Figure 6 shows two backscattering response measurements made on the same 20km segment of a fibre recirculating delay line. Both measurements exhibit roughly the same signal-to-noise ratio. However, whereas the measurement using 1bit codes required 256 seconds of averaging to obtain this result, the same result was obtained using 32bit codes in only eight seconds, or 32 times faster.

Finally, Fig. 7 shows three measurements of a 20km span of fibre between 20 and 40km from the input. In each case, 500ns bits were used. The measurements shown in Figs 7(a,b) were made using 4bit codes to represent the performance of a conventional single-pulse o.t.d.r. After 15 seconds of averaging, Fig. 7(a), a single reflection is visible at 25km, and the backscattering signal descends into the noise. After 16 minutes of averaging, Fig. 7(b), the backscattering signal is largely free of noise, a second reflection is visible at 313km, and the end of the fibre at 35.5km is clearly seen. However, by using codes of length 256, Fig. 7(c), the same result was obtained after averaging over only 15 seconds. Relative to the 15 second measurement made with 4bit codes, Fig. 7(a), the two-way dynamic range is improved by 9dB.

These experiments verify each of the major performance advantages predicted by the theory of the complementary correlation o.t.d.r. They demonstrate low autocorrelation sidelobes, improved dynamic range in a fixed measurement time, and dramatically reduced measurement time at a given range. Furthermore, these improvements are accomplished without any sacrifice in response resolution.

THE HP 8145 OTDR

The Hewlett-Packard 8145, shown on p.560, is the first commercially available o.t.d.r. to realize the full advantage of a spread-spectrum technique. It employs every aspect of the new technique, but in a more sophisticated way. As a result, it is able to equal (and occasionally exceed) the results of the laboratory experiments described earlier and reported in the scientific literature. In fact, some of those results were obtained using systems that were basically laboratory prototypes of the finished product, operated under controlled test conditions and without any of the automatic or user features of the instrument.

Developing a state-of-the-art experimental measurement system into a rugged, portable instrument without compromising performance is neither an easy nor a frequently accomplished task. In the case of the HP 8145, a number of practical problems had to be solved in order to make full use of the complementary correlation technique without compromising either the quality or the integrity of the measured data. Complementary correlation depends on a linear system in order to operate correctly. Unfortunately, real measurement situations can present the o.t.d.r. receiver with an extremely wide range of optical-power levels. For example, any receiver sensitive
The 8145 is designed to operate at maximum averaging efficiency under all measurement conditions, including when both saturating and non-saturating power levels are present. All of its analogue circuitry is linear over a wide range. When that range is exceeded, the instrument automatically compensates to insure that all of the recorded data is valid.

Several factors contribute to the linear behaviour of the instrument:

- A fast, linear laser driver is used to provide coded probe signals that are extremely uniform over a large range of power levels and environmental conditions.
- A proprietary technique is used to extend the range and linearity of the a-to-d converter.
- The receiver is extremely linear over a wide range of input-power levels, and can saturate only when very strong reflections are present near the input of a fibre under test.

As a result of these and other proprietary features and techniques, the instrument is able to reproduce the backscattering impulse response with excellent fidelity, and to suppress autocorrelation side lobes to the -40dB level, where they do not distort the signal.

The instrument is also able to operate in this linear range when using codes because it can automatically sense and avoid saturation when data is being taken. This is accomplished using a probe signal optimization algorithm of the kind shown in Fig. 8.

Before each new set of data is measured, the fibre is probed to determine the highest probe power level and the longest code length that can be used without causing saturation. This probe signal is used to measure the next set of data, thereby guaranteeing that the data will be valid.

Coupled with this automatic optimization of the probe signal is the ability of the 8145 to make piece-by-piece measurements of the fibre under test. This capability allows the complementary correlation technique along with all of its signal-to-noise advantages to be used even when the backscattering impulse response contains large saturating reflections.

Figure 9 shows how the piece-by-piece measurement capability combined with probe optimization allow the instrument to adapt to the fibre response and produce an efficient measurement. If a saturating reflection is so large that it can only be measured without distortion by using a single pulse, the instrument temporarily resorts to L=1.

However, as soon as the data up to a given range has been averaged enough so that any further signal-to-noise improvement would...
In summary, the performance of an o.t.d.r. can be dramatically improved using a new correlation technique that employs codes having complementary auto-correlation properties. Using this technique, equivalent results were obtained 64 times faster than what is possible with a conventional single-pulse measurement using the same laser, receiver, and coupling optics. Alternatively, a 9dB two-way range improvement was obtained in the same measurement time.

This technique has been successfully employed and improved upon in a reliable, portable instrument, the 8145 o.t.d.r. The performance of this instrument is far superior to that of previously available conventional o.t.d.rs, and has been shown to exceed the best performance reported to date for any practical measurement system of its kind.

### References


Steve Newton received his BS degree in physics, summa cum laude, from the University of Massachusetts, Amherst in 1976. He received MS and Ph.D degrees in applied physics from Stanford University, Palo Alto, California, in 1978 and 1984, respectively.

From 1978 to 1982, he was a part-time member of the technical staff at Hewlett Packard Laboratories, Palo Alto, where he was engaged in research involving optical design, metal-vapour lasers, and optical data storage. Since 1988, when he became a full-time member of the Technical Staff at HP Labs, his research activities have involved photonic measurement systems, optical-fibre components and circuits, and integrated optics. Since 1986, he has been in his present position of Project Manager of the fibre-optics group in the wave-technology department of HP’s Instruments and Photonics Laboratory. He has been project manager of the o.t.d.r. effort at HP Laboratories and is a co-inventor of the technique described in this article.

### Acknowledgements

The author would like to acknowledge the efforts of many of his colleagues, in particular that of co-inventor Moshe Nazarathy.
MAKING ELECTRONICS C.A.D. AFFORDABLE

Z-MATCH
Smith Chart Program
for IBM PC/XT/AT £130, BBC B £65 (ex VAT)
Takes the drudgery out of Matching problems.
Includes many more features than the standard Smith Chart. Full calculation of all parameters.

ANALYSER II
For IBM PC/XT/AT
A.C. CIRCUIT ANALYSIS
Now analyses coaxial and microstrip transmission lines plus R’s, C’s, L’s, T’s, Op-amps and Bipolar & Field Effect transistors

PCB DESIGN
For IBM PC/XT/AT
from £160 (ex VAT)
Low cost PCB draughting packages.
Very easy to learn and use.
Component library facilities.
Write or phone for full details. Ref WW
NUMBER ONE SYSTEMS LIMITED
Harding Way, Somersham Road,
St Ives, Huntingdon,
Cambs. PE17 4WR
Tel: 0480 61778
We offer full offer-sales support with telephone "HELP HOTLINE" service.
Software updates FREE within 6 months of purchase.

Real Time and Cross Support Software
MORE TIME IS SPENT DEBUGGING THAN CODING.
SAVE TIME AND DEBUG INTERACTIVELY WITH FORTH.
Course Forth
Modular Forth
GEM-Forth
STE ROM-Forth
Cross-compile
Prom Programmers

KESTREL ELECTRONIC COMPONENTS LTD.
- All items guaranteed to manufacturers spec.
- Many other items available.
‘Exclusive of V.A.T. and post and package’

MICROPROCESSOR ENGINEERING LIMITED
133 Hill Lane, Southampton SO1 5AF.
Telephone: 0703 631441

ELECTRONICS & WIRELESS WORLD
Teach IBM Microcomputer Troubleshooting and Repair the Hands-on Way DIGIAC 5501

- Complete program for computer repair - Hardware and Courseware.
- Teach your students the specific skills necessary for computer troubleshooting and repair.
- System is based on modified IBM Hardware.
- Utilizes real hard-wired switched faults - enabling troubleshooting down to lowest replaceable modules.

Comprehensive Teachware package based around IBM Diagnostic Software provides a complete self-teach course of study.
- Additional modules available for 'workshop' alignment and repair - including Monochrome Monitor, Floppy Disk Drive and Matrix Printer.

Send for full details today - Tel: (0603) 748001. Telex: 975504.

LJ Technical Systems Ltd., Francis Way, Bowthorpe Industrial Estate, Norwich, NR5 9JA.

TWIN TWIN PPM

Comprising two PPM9 boards, featuring inherent stability with law under microprocessor control, the unit gives simultaneous monitoring of A/B on red/green and M/S on white/yellow pointers. Together these provide complete information about stereo signals, in contrast to the ambiguous readings of phase meters. Manufactured under licence from the BBC.

ALSO: PPM7. highest specification single channel driver on the market: PPM3, unbalanced; PPM5, 20-pin DIL hybrid; PPM8, IEC/DIN -50/±6 dial; Illuminated Twin Boxes and movements.

SURREY ELECTRONICS LTD
The Forge, Lucks Green, Cranleigh, Surrey GU6 7BG.
Tel: 0483 275997

RACKMOUNT CASES

19" Self-Assembly Rack Mounting Case with lift off Covers. Front Panel 10 gauge, Brushed Anodised Aluminium, Case 18 gauge, Plated Steel with Removeable Rear & Side Panels. In 1U & 2U Types, a Subplate Chassis is Mounted to Bottom Cover. In 3U Type the Subplate is located on two Rails Mounted Between The Side Plates.

1U (1¾) height, 230m depth £28.30
2U (3½) height, 308m depth £33.60
3U (5¼) height, 230m depth £41.00

Width Behind Front Panel 437m (All Types).
All prices include Postage & VAT. Cheques, Postal Orders Payable to J. D. R. Sheetmetal, 131 Grenfell Road, Maidenhead, Berks SL6 1EX.
Maidenhead 29450.
Programmable logic devices, p.l.d.s, can provide designers with an efficient, compact means of producing digital circuits. However, this efficiency is impaired by poor design techniques.

Most digital design engineers are familiar with standard logic families and tend to design circuits with these devices in mind. Only when a circuit has been proven is an attempt made to convert the design into programmable logic. Not only is this an inefficient use of programmable logic, but it negates one of the major benefits of these devices - their programmability.

A more efficient way of designing programmable logic is to consider the desired system as a black box with a number of inputs and outputs (complex systems may comprise more than one of these black boxes). The system is then defined as the relationship between the inputs and outputs, either as Boolean or state equations. Once these equations have been derived it is a simple matter to produce the desired system function using one or more programmable logic devices.

This method does not preclude the possibility of direct conversion from standard logic to programmable logic where design time is of the utmost importance and a discrete circuit solution already exists. Software called Amaze, mentioned later, contains a schematic-to-Boolean conversion routine to do just this, but generally this method will lead to a non-optimal p.l.d. solution.

This article shows the design process involved in producing a programmable logic device to provide a reasonably complex system function.

SYSTEM DEFINITION

An alarm-system controller is used here to illustrate the design methodology. The alarm provides three basic functions. Firstly, it should deter intruders. Secondly, should an intrusion take place the system must give an alarm. And thirdly, an alarm should be given as a result of any other alarm condition such as fire, personal attack or injury.

Deterrence is generally achieved by mounting a large box clearly marked as being part of an alarm system in a prominent position. A programmable logic device can be designed to provide the second and third functions and could form the basis of a range of alarm and security systems.

Implementing the alarm controller in user-programmable logic increases the controller's versatility. By altering slightly the program table of the programmable logic devices, it is possible to configure the system to suit any alarm transducer without alter-
then a transition to STO takes place.

Similarly, other arrows on the state diagram represent transitions between other states when specified input conditions occur. Output parameters are shown to the right of the slash line. Where there are no output parameters specified in a transition term, this indicates that no output changes are desired during this transition. That is, an output will hold its present value until told to change.

**PFD IMPLEMENTATION**

Having defined the desired system operation it is now time to select the required device to implement the desired system function from a p.l.d. databook. In this case, the device selected is the PLS168, Fig.3. It allows up to twelve inputs (plus clock and enable) and provides up to eight registered outputs. Additionally, the device contains six embedded registers with feedback which means the device is particularly suited to state-machine applications.

Internally, the 168 consists of fully programmable And and Or arrays. This fully programmable And/Or architecture makes this type of device functionally superior to the programmable-And/fixed-Or architecture of Pal type devices. Fusible NiCr links are used to configure the device to a particular pattern. The programmability means it is possible to configure the alarm controller in several ways while retaining the basic system I/O structure.

**AMAZE SOFTWARE**

Having selected a device, the system function must be programmed into it. This is done very easily using Mullard's Amaze software running on an IBM PC compatible or a VAX computer under the VMS operating system. It allows designers to define a p.l.d. in terms of Boolean or state equations and from these generate a fuse pattern which can then be sent to a p.l.d. programmer. Other features of the software include a fuse table editor to allow direct modification of the fuse pattern, a functional and a.c. timing simulator to test the device, a schematic-to-Boolean converter to develop Boolean equations from a schematic diagram of a desired circuit, a Pal-to-p.l.d. converter to convert Pal designs to p.l.d. designs, and a device programmer interface to allow downloading of the fuse pattern to a programmer through an RS232 link.

**PIN INFORMATION**

Firstly, the Amaze software labels the device using a routine called the pin-list editor. Figure 4 shows the pinning information for the alarm controller. A 10bit counter within the controller produces the entry/exit and sounder turn-off delays since this makes more efficient use of the p.l.d. facilities than implementing the delays as part of the state machine. This counter uses seven internal registers used in either the Boolean equation or state equation entry file are given names in this file, in this case t1 to t6. Equations for the 10bit counter are entered after the title line "LOGIC EQUATION", using registers t1 to t10in. Register SR0 halts and clears the counter while the controller is in certain states. This needs to be considered when defining the state vectors.

**STATE EQUATION ENTRY**

The state equation entry (.SEE) file of Amaze uses a state-transition language, parameters of which are taken directly from the state diagram. Information is entered into this file in a free format. The only points to remember are that square brackets should be used throughout to define the state registers and transitions, semi-colons should be used to mark the end of a vector definition and apostrophes should be used to indicate a registered output.

State vectors for these registers have to be chosen with care to ensure that the beacon output is activated at the correct time. Other inputs and outputs are as already discussed. Note that the PR/OE pin is not used. This pin must be tied to ground in the final circuit.

Three other registers form state registers and are labelled SR0, SR1 and BEACON. State vectors for these registers have to be defined using the Boolean equation entry (.BEE) file of Amaze. List 1 shows the .BEE file for the alarm controller. Any internal registers used in either the Boolean equation or state equation entry file are given names in this file, in this case t1 to t6. Equations for the 10bit counter are entered after the title line "LOGIC EQUATION", using registers t1 to t10in. Register SR0 halts and clears the counter while the controller is in certain states. This needs to be considered when defining the state vectors.

**BOOLEAN EQUATION ENTRY**

Once the pin information has been entered, any Boolean expressions desired can be defined using the Boolean equation entry (.BEE) file of Amaze. List 1 shows the .BEE file for the alarm controller. Any internal registers used in either the Boolean equation or state equation entry file are given names in this file, in this case t1 to t6. Equations for the 10bit counter are entered after the title line "LOGIC EQUATION", using registers t1 to t10in. Register SR0 halts and clears the counter while the controller is in certain states. This needs to be considered when defining the state vectors.
to halt and clear the 10bit counter, particular care must be taken in defining the state vectors in this instance.

From the state diagram, the counter must begin counting during states \( \text{ST}_1 \) and \( \text{ST}_2 \) and it must be cleared during states \( \text{ST}_1 , \text{ST}_2 \) and \( \text{ST}_3 \). State \( \text{ST}_3 \) represents the power-up state of the PLS168 in which all register outputs are at logic one. Thus the inactive state of the counter is defined as being when SR0 is at logic one.

With the system fully defined as such or as \( \text{C Stoke} \) statements as shown, Entry/exit and sounder turn-off delay times are represented as a decoding of the 10bit counter states. Thus to get the desired 16 second entry/exit delay, 17 must be decoded and to achieve the 128 second sounder turn-off delay 1101 must be decoded.

DEVICE PROGRAMMING

With the system fully defined it is now simply a matter of assembling the design information using the Amaze assembler to produce the fuse pattern for the desired device. Should any design changes need to be made to a device, the fuse pattern may be modified directly using the program table editor of Amaze. However, this course of action is not recommended since the Boolean equation and state equation files are not altered correspondingly.

Functioning of the device can be verified with the Amaze simulator, which can also be used to check a.c. timings before downloading the pattern to a device programmer, such as a Stag ZL30A or Data I/O 29B, to program the device. Test vectors are produced either automatically or interactively by the simulator.

PROGRAMMABILITY

The PLS168 device could now be used as the controller of an alarm system. As it stands, the device assumes that all the alarm inputs indicate an alarm condition when in the high state, logic one, and that the alarm outputs are active low, i.e. at logic zero.

Should an alarm input transducer be used which indicates an alarm condition as a low state, this can be catered for by altering the .SEE file. For example, consider a smoke detector which outputs logic zero on detection of an alarm condition and assume that this transducer is driving the ‘fire’ input of the device. By changing all references to ‘fire’ in the .SEE file to ‘fire’ and all instances of ‘fire’ to ‘fire’ then the activation of the alarms will occur when logic zero is applied to this input and not when logic one is applied, as in the original case. Pin-list and .BEE files do not need to be altered.

Polarity of the output signals cannot be altered so easily as the device will always power-up with the outputs at logic one. This should not prove a problem since the outputs simply drive output transistors and these can be used to produce the correct polarity signal for the beacon and sounder.
SYSTEM IMPLEMENTATION

Figure 5 shows a typical alarm system based on this device. The system clock is produced by a relaxation oscillator built from 74HC132 schmitt triggers. Values of R1 and C1 shown result in a frequency of approximately 4Hz which will provide the desired entry/exit and sounder turn-off delays. These delays can be modified either by changing the external oscillator circuit or by decoding a different internal counter state. For example, to increase the entry/exit delay change all references to t7 in the .SEE file to t8.

Both normally-closed and normally-open loop implementations are shown. Due to the distances involved in an alarm system, the open-loop configuration may cause problems, being driven by the positive supply. To avoid this problem, input-detect polarity of the open-loop circuit can be changed by altering the .SEE file.

Status indication can be provided by connecting leds as in Fig.6. When the reset button is pressed, any led being lit will indicate an alarm condition for that input. Note, this will not reset the alarm system unless the arm switch is off.

SYSTEM EXPANSION

The system can be expanded to allow more inputs and different status indication provisions by adding further P.L.Ds. These devices are Mullard PLS153's used as simple decoders to allow a number of input loops or single inputs to be grouped. Timed and untimed circuits should not be mixed on these expansion devices. Figure 7 shows the pin list for such one device.

Figure 8 shows how such a device can be incorporated into the alarm system. Note that the status indication can be provided as previously or by connecting DLED, WLED1, WLED2 and OLED outputs as shown. Pin label names are given as a guide only, to indicate how the device could be used. These devices can be concatenated, allowing an almost infinite variation in I/O structure.

Reference

P1 AL is a trademark of Monolithic Memories Inc.

An assembled fuse pattern for the alarm controller and a Boolean equation file for the additional PLS153 decoder can be obtained by sending an s.a.e. marked 'Alarm' to Electronics & Wireless World Editorial, Room L303, Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS.

List 2. State vectors, shown here, are simply a means of labelling an arrangement of state registers which can be used later to define state transitions.

```
List 2. State vectors, shown here, are simply a means of labelling an arrangement of state registers which can be used later to define state transitions.

```
The TRIO transformation!

What's in a name? For over a decade Trio has been associated with quality and innovation in oscilloscopes and other test instruments. In fact, Trio was a trademark of the Kenwood Corporation who are also market leaders in communications and audio equipment. Now all products carry the Kenwood logo.

The oscilloscope range is extensive and expanding, real-time models from 20MHz to 150MHz plus advanced digital storage in the form of the CS-8010 illustrated below. This features 10MHz sampling, simultaneous real-time and stored display, and cursor measurement, all for £1,195. Beat that!

With its new models, competitive pricing and improved support the Kenwood range is outstanding. To make a full evaluation, send for the data book quickly. You won't be disappointed. Oh, if you need a translation of the Japanese text, please see below*

QUALITY QUARTZ CRYSTALS QUICKLY

Our frequency ranges are:

- M.P.U. Crystals
- M.P.U. Oscillators
- Professional Crystals

10kHz 50kHz 100kHz 500kHz 1MHz 10MHz 25MHz 360MHz

We also supply quartz crystal filters, oscillators of all types and communication antennae.

Webster Electronics
ILMINSTER,
SOMERSET TA19 9QA,
ENGLAND
TEL: (0460) 57166
TELEX: 46571 FRQNCY G
FAX: (0460) 57865

HARRISON ELECTRONICS
Century Way, March,
Cambs PE15 8QW
Tel: (0354) 51289

HIGH QUALITY - LOW PRICES

4+11GHz SATELLITE TV RECEIVING EQUIPMENT

RECEIVERS, LNB's, LNC's, FEED HORNS, ANTENNAS, ANTENNA POSITIONERS, POLOROTORS, LINE AMPLIFIERS, ETC.

For further details contact:
HARRISON ELECTRONICS
Century Way, March,
Cambs PE15 8QW
Tel: (0354) 51289
**INDUCTANCE & RESISTANCE STANDARDS**

**INDUCTANCE STANDARDS**
- 15 Inductance Standards from 1uH-1H.
- Accuracy 0.02% at 1KHz.
- Temperature coefficient 50 PPM per deg. C.
- Inductors are wound on toroidal formers and are fully screened against external electrical and magnetic fields.
- Size 180mm x 180mm x 240mm.

**RESISTANCE STANDARDS**
- High value resistance standards from 10^10-10^14 megohms.
- Accuracy 0.005%.
- Size 120mm x 280mm.
- Temperature coefficient 20 PPM.
- Rated voltage. 100V - 2000V depending on value.

A full range of calibration equipment available which includes:
- MOD STD 05-24, 05-26 NATO AQAP4 APPROVED.

**Time Electronics Limited**
Telephone (0732) 355993  Telex 95481  Fax (0732) 770312

---

**Toroidal & E.I. Transformers**
As manufacturers we are able to offer a range of quality toroidal and laminated transformers at highly competitive prices.

**Toroidal Mail Order Price List**

<table>
<thead>
<tr>
<th>Price</th>
<th>VA</th>
</tr>
</thead>
<tbody>
<tr>
<td>15va</td>
<td>9.12</td>
</tr>
<tr>
<td>30va</td>
<td>9.48</td>
</tr>
<tr>
<td>50va</td>
<td>10.16</td>
</tr>
<tr>
<td>80va</td>
<td>11.02</td>
</tr>
<tr>
<td>120va</td>
<td>12.08</td>
</tr>
<tr>
<td>12.23</td>
<td>14.44</td>
</tr>
<tr>
<td>225va</td>
<td>16.37</td>
</tr>
<tr>
<td>300va</td>
<td>18.05</td>
</tr>
<tr>
<td>500va</td>
<td>20.00</td>
</tr>
<tr>
<td>225va</td>
<td>26.46</td>
</tr>
<tr>
<td>500va</td>
<td>30.66</td>
</tr>
<tr>
<td>500va</td>
<td>34.14</td>
</tr>
<tr>
<td>1000va</td>
<td>49.40</td>
</tr>
</tbody>
</table>

Also available 1k2, 1k5, 2k, 2k5, 3k. Prices on request.


**Quantity prices and delivery on request**

**IEEE 488.2 CONTROLLERS**

**From M A Instruments Limited**

**IBM PC/XT/AT and compatibles including Amstrad PC**
1512/1646 Half length interface card, 1M IEEE cable, operating manual plus a language extension for Turbo Pascal versions 3 and 4, Quick BASIC versions 2, 3 and 4, many versions of C including Microsoft versions 4 and 5, Microsoft MASM or GW BASIC.

£235.00

**Acorn 'B' and Master**
Interface in a separate case, software supplied in PROM, IEEE 488 cable and comprehensive operating manual.

£280.00

For owners of Acorn controllers the IEEE 488.2 language extensions for the Acorn computers is available separately in PROM.

£28.00

All our controllers give a command structure which follows the IEEE 488.2 recommendation. This simplifies the control of existing GPIB devices, reducing the number of commands needed and is compatible with new devices using IEEE 488.2 format instructions.

**IEEE 488.2 Devices**
32 bit TTL input/output or relay driver, relay output, digital multimeter, function generator and dual 16 bit digital to analog converter. All the devices use the IEEE 488.2 command and reporting structures and are available as separate devices or as a measurement system using only one IEEE 488 address.

Designed, manufactured and supported in Great Britain.

For more information contact:
M A Instruments Limited, Axtown Lane, Yelverton, Devon PL20 6BU.
Telephone (0822) 853858.
Co-operative effort at CeBIT

CeBIT 88 at Hanover, the largest event in the world for office automation, information technology and telecommunications, attracted 480,000 visitors to see the products and services of 2,730 exhibitors, of which 980 came from 35 other countries. Because of CeBIT's wide attraction it is frequently used by companies and organizations to stage major launches. For example, Fujitsu Europe, subsidiary of Japan's largest computer manufacturer, used CeBIT as the launch pad for a range of facsimile machines—even though the company is not selling the products under its own name in Germany. They will be sold into the UK with a major push into the office equipment dealer market in what is the company's first venture into fax in Europe under its own name. The three Group 3 fax machines and a Group 4 fax will be supported by activity aimed at establishing a nationwide dealer network in the UK by the end of 1988.

The 17 companies and administrations participating in the current X.400 message handling system initiative at CeBIT presented the actual application of X.400 as a highlight of their stand displays and presentations. They demonstrated the electronic exchange of messages from one stand to another, i.e. among systems made by diverse manufacturers, using the public infrastructure provided by Deutsche Bundespost and AT&T. Users were therefore able to see how electronic messaging works in practice and the benefits of this concept offers in business, trade, industrial and administrative applications.

Companies which joined forces in the X.400 initiative at the Fair were: AT&T, CAP, DEC, Deutsche Bundespost, Hewlett-Packard, IBM, NCR, Nixdorf, Olivetti, Philips, Retix, Siemens, SPAG, Sun Microsystems, Systems Designers, Triumph Adler and Tandem Computers.

Another of the common standards coming to the fore is Office Document Architecture (ODA). This allows the connection of incompatible systems. Bull, Olivetti, ICL, Siemens and OCE had a joint stand to provide information on the current implementation. The latter company, best known for high-volume and high-reliability photocopiers, is mainly concerned with output devices. The objective of this working group is to ensure a true-to-original exchange of all kinds of documents among diverse systems, thus allowing for their further processing.

The project is supported by the EEC Commission as part of its Esprit programme. It now appears likely that ODA will be approved as ISO Standard 8613 before the end of this year.

It was at CeBIT 87 that Bull, ICL, Olivetti and Siemens demonstrated that it was possible to interchange word processed text documents between different systems, and continue processing the documents without the need for partial or total rekeying. Reactions to this first demonstration were encouraging and proved that there is ample demand for the concepts.

A new optical drive technology designed to handle a flexible optical disc was announced at CeBIT by ICI Electronics. It is being developed by Bernoulli Optical Systems (Bosco) of Boulder, Colorado, USA. While Bosco will be marketing its own drive units in the near future, its partner ICI was at CeBIT to promote the technology, which will also be available for licensing to other drive manufacturers.

Operating on the Bernoulli principle of fluid technology (when air above a surface moves faster than the air below, it causes 'lift') as with an aeroplane wing) the disc rotates in close proximity to the read/write head. Because the medium is flexible it is able to take up a highly planar form to a greater degree of precision than is possible with a moulded rigid optical disc. In addition, it can deform to follow the head more closely. This allows a small low-mass head which obviates the need for focussing servos. See also this month's 'Update'.

The presentations at CeBIT 88 extended to cover the interchange of mixed text, graphics and image documents. The interchange preserves the integrity and processibility of the document, meeting the expectations of more and more users, and overcoming the current restrictions of being able to interchange complex documents only in paper or in non-reproducible form.

Digital Communications Inc. (DCA) of the USA used CeBIT to stage the worldwide launch of some networking products: the DCA LAN Gateway and DCA Lan-Server, which link wide area (wan) and local network (lan) users through a DCA Series 300 network processor; and an enhanced version of the company's Protocol Processor II.

A key feature of this new version, Protocol Processor IVST, is its multiplexed slave trunk (ST) link which connects asynchronously terminal users in a DCA Series 300 network to IBM 3270 compatible mainframes or IBM System/3X hosts.

Like the earlier Protocol Processor II, the enhanced ST model allows the use of inexpensive asynchronous terminals in an IBM environment.

DCA's LAN Gateway is claimed to be the first wan processor gateway to use the TCP/IP networking protocol for accessing Ethernet-based lan's. Its software resides on a datacard with a DCA series 300 processor.

TCP/IP enables terminal users on a lan to enter a simple command to get into the wan, through the wan processor, to access other resources outside his or her immediate lan, or another lan in the network. TCP/IP is considered the industry's most widely-used local area network-protocol, and is gaining acceptance in the European marketplace. In practice its throughput is of the order of 100 characters per second on a 10Mb/s bus. However, DCA offers its own proprietary protocol, LanPro, claimed to offer four times the throughput.

X/Open, the international consortium of 13 of the world's major computer system vendors committed to the implementation of open systems had a major presence at CeBIT. All 13 members were exhibiting: AT&T, Bull, Digital Equipment, Ericsson, Hewlett-Packard, ICL, Nixdorf, NCR, Olivetti, Philips, Siemens, Sun and Unisys.

Geoff Morris, president and chief executive officer, said: "We see CeBIT as the most significant and influential event in the IT calendar. It offers a unique forum for X/Open to communicate its strategy and progress to an audience of almost three quarters of a million users and members of the worldwide computer community. The activities that we are undertaking will ensure that the X/Open messages of freedom, flexibility and long term investment that can be achieved through the X/Open computing standard are more widely understood and acted upon."

X/Open, founded in 1984, is an independent non-profit consortium of international computer system vendors. These companies are investing business, technical and marketing resources in the development of an open, multi-vendor Common
Applications Environment based on international and de facto standards. Specification of the Common Application Environment is achieved through close co-operation with users, independent software vendors and standards organisations worldwide. All members of X/Open are committed to supporting the environment defined.

Northern Telecom used CeBIT to make its worldwide announcement that it has significantly extended its range of data switches (DPNs) downwards so as to meet the needs for small to medium switches. This family of packet switches, the DPN-100 networking system, is based on the DPN-100 architecture introduced in 1987, and enables Northern Telecom to serve a wider packet data communications market. Various models offer from 8 to 30 000 access lines and a throughput rate ranging from 64 to 30 000 data packets per second.

NT can now address the needs of a market that ranges from large telephone operating companies to corporations, government, and small businesses. Northern Telecom (and its associated German company, AEG) is one of the two contenders for the second phase of the German public packet switched network. Test systems from NT and Siemens have been installed, used and evaluated by the Deutsche Bundespost. Now both companies are waiting to learn which has been awarded the contract.

Northern Telecom was also demonstrating ISDN, networking between private branch exchanges (p.b.x.s) which conform to the CCITT recommendation for Primary Rate Access, known as Q.931. Primary Rate Access is the ISDN link between p.b.x.s 'in-company' as well as the interface between a p.b.x. and the digital public telecommunications network. NT believes that it is the first company to be able to provide such a demonstration even though other companies have indicated their support.

Northern Telecom used CeBIT to make its worldwide announcement that it has significantly extended its range of data switches (DPNs) downwards so as to meet the needs for small to medium switches. This family of packet switches, the DPN-100 networking system, is based on the DPN-100 architecture introduced in 1987, and enables Northern Telecom to serve a wider packet data communications market. Various models offer from 8 to 30 000 access lines and a throughput rate ranging from 64 to 30 000 data packets per second.

NT can now address the needs of a market that ranges from large telephone operating companies to corporations, government, and small businesses. Northern Telecom (and its associated German company, AEG) is one of the two contenders for the second phase of the German public packet switched network. Test systems from NT and Siemens have been installed, used and evaluated by the Deutsche Bundespost. Now both companies are waiting to learn which has been awarded the contract.

Northern Telecom was also demonstrating ISDN, networking between private branch exchanges (p.b.x.s) which conform to the CCITT recommendation for Primary Rate Access, known as Q.931. Primary Rate Access is the ISDN link between p.b.x.s 'in-company' as well as the interface between a p.b.x. and the digital public telecommunications network. NT believes that it is the first company to be able to provide such a demonstration even though other companies have indicated their support.

The joint venture formed by the merger of the telecommunications activities of GEC and Plessey has been formally launched with the slogan “Linking up to the world”. In size GEC Plessey Telecommunications Ltd (GPT) is within the world’s top ten, with a turnover of £1.2G. With a product range embracing almost the whole field of telecommunications, GPT is established as the leading UK manufacturer. Sales levels will create the necessary funding for continuous research and development of products for world markets. Mr Richard Reynolds, managing director of GPT, said: “Over the past few years the structure of the industry has evolved to a stage where only the largest companies can provide the complex advanced products customers require in a competitive market.”

“Individuals Plessey and GEC have both shown the technical skills and the vision to produce these products. By combining, GPT can harmonize these strengths and give Britain a powerful, coherent voice on a truly world scale.”

### GaAs space switch

Bell Northern Research (BNR) has developed a gallium arsenide 4 x 4 space switch circuit capable of handling signals at 5Ghz.

Paul Jay, manager of GaAs device design at BNR, Ottawa, Canada, said that the 5Ghz bandwidth "means that each channel on the chip can reliably move digital information at rates as high as 2.4Gbit/s. Any one of the four input channels may be connected to any, or all, of the four output channels", explained Dr Jay.

"As well as the ability to handle extremely high volumes of data, a major benefit of the new chip is that it can change the destination of the information in the circuit in one nanosecond, enabling the device rapidly to redirect data to a given destination", said Dr Jay.

The circuit achieves its extremely high speed through the use of a BNR chip design employing GaAs and air bridge technologies.

GaAs is particularly suited to high-speed applications because electrons travel through the material faster than through more conventional silicon based circuits. Air bridges form a complex network of highly conductive metal pathways which direct information that they require for pre-flight planning and in-flight use.

### UK trunked radio agreement

GEC, Motorola and Philips have signed an Intellectual Property Rights co-operation agreement concerning the manufacture of equipment which complies with the UK standards for trunking systems. By 1992, all equipment operated on the new networks will need to have been approved to this specification.

The co-operation agreement relates to the standards defined in specifications MPT 1327, MPT 1343, MPT 1347 and MPT 1352 and to patent rights owned by the three companies which may impact these specifications. The companies have agreed to make available licence rights to users and manufacturers on a defined basis.

Detailed provisions also exist to ensure that any modifications to the standards which become necessary over time are published and available to all participating manufacturers.

Telecomms Topics is compiled by Adrian Morant.
Reversing a ‘constant’ current in an inductor

A need to reverse ‘constant’ d.c. current through a coil can only be a recipe for trouble; David Griffiths offers a guide to some of the ‘funnies’.

D. GRIFFITHS

If capacitors were very much more cumbersome and difficult to make than inductors, then we would use LR networks around our transistors and op-amps without hesitating at an eye-lid—well, maybe. The little inductive monster that caused this reflective mood was virtually air-cooled too, forsooth, so I could not even blame non-ideality of its core for my puzzlement.

For the reader who might be engaged in a similar electronic skirmish, I relate the story using rounded numbers for the parameters. I know many consider it ‘low-brow’ not to accommodate within the ±15V supply lines available. By tickling the coil with a square wave voltage applied through a 100kHz, pretty ringing was observed at 20kHz, which dropped to 10kHz with 10nF across the coil. Because the resonant frequency goes as the square root of the circuit capacitance, this frequency ratio of 20/3.5=6 meant that the 10nF was some 16 times larger than the coil self-capacitance. Thus, this inductor must be used to provide a high output resistance of the ±15V supply lines. In Fig.1, the LM317 and \( R_1 \), provide this function, with \( R_2 \) and \( R_3 \) providing fine adjustment of the voltage regulation value. The output pin of the National LM317 will take up whatever voltage will cause a nominal 1.25V to appear across \( R_2 \). The output current can only decay (and go to 0) if nothing gave way. Clearly, zener clamping across the coil would be needed.

Because of the voltage spike just calculated, it is easy to be trapped into thinking that there will be a correspondingly massive current surge into a voltage clamp across the coil and that a hefty rated zener will be required. Fortunately, this is not the case at all: the 30mA in the inductor can only decay (and go to 0) if nothing gave way. Clearly, zener clamping across the coil would be needed.

From previous experience, I had little doubt that a three-terminal voltage regulator connected as a current generator would be a satisfactory source of the constant 30mA, and provide it without using up too much of the voltage headroom of the ±15V supply lines. In Fig.1, the LM317 and \( R_1 \) provide this function, with \( R_2 \) and \( R_3 \) providing fine adjustment of the sensing resistance value. The output pin of the National LM317 will take up whatever voltage will cause a nominal 1.25V to appear across \( R_2 \), making the output current has some lower voltage to go to. At the current level used here, the data sheets show that a minimum of 2V between ‘in’ and ‘out’ on the LM317 is required, so the device will stay in its linear regime if the bottom end of \( R_2 \) is always at least 4V below +15V, by suitably clamping the coil voltage transient.

The LM317 is a particularly good choice of device to use in this way, for which hint I am indebted to that invaluable compendium of lore ‘The Art of Electronics’ by Horowitz and Hill (Cambridge U.P.) and the ‘adj’ terminal is very small (50µA nominal) and astonishingly independent of load current and input/output voltage and temperature, so that the output loading by the ‘adj’ pin does not greatly impair the servo action, which is now striving to give a high output resistance in this configuration. The ‘third-pin’ current is made so low and constant by steering all the ‘return’ currents in the supply amplifiers in the LM317 to the ‘out’ pin: thus, this regulator must be used to provide a minimum output current of 10mA (worst case), which is no problem in this application.

The output resistance of the LM317 was assessed by un hitching the bottom end of \( R_1 \) from the circuitry and connecting it via a milliammeter successively to the 0V and ±15V lines; the nominal 30mA current increased by some 30µA for this change of compliance voltage of 15V, implying a z.f. output resistance of 15V/30µA = 500kΩ. It is sobering to reflect that, if the various feedback tricks had not yet been thought of, then this current generator performance could only have been attained by feeding 15kV to a 500kΩ resistor.
The circuit is almost completed by hanging a bridge of switches around the coil. The four mosfet switches in the ubiquitous little VQ 1000U from Siliconix handle the prospective coil current very easily. Their typical 5 ohm resistance giving negligible power dissipation or voltage drop. Since their gate-source ratings is ± 40V, they can be controlled directly by the op-amp comparators in the LF353 as shown in Fig.2. For half a cycle S1 and S3 are ‘on’ with S2 and S4 ‘off’, then the switch drive conditions change to reverse the direction of current flow in the coil. Due to slew-rate limitations in the op-amps, there is some time skew in this switching, but it is trivial compared with the time taken for the inductive transient to decay to a negligible level.

To ensure that the VQ1000U switches are definitely ‘off’, their gates must not be significantly positive with respect to the corresponding sources. Since it would be unwise to assume that the LF353 op-amp outputs will swing more than ± 12V about 0V, the bottom of the switch bridge thus needs to be at least 3V above -15V. This voltage drop is provided by R7, which also makes a convenient monitor of the current generator output; if R7 = 1000, of 1% tolerance, then the circuit current can be set up to the specified precision by adjusting R5 until there is 3.00V across R7.

A pair of 15V zeners back-to-back across the coil gives a nominal 16V clamp level, since one or other zener must be forward biased. As will be shown, a quicker reversal of the coil current could be obtained by using higher zener voltages, but a 15V pair does allow the circuit to operate off ±12V supplies, which was a useful option in the present application.

Now, both reader and writer must be brave and try to visualize what goes on while the coil current is reversing. First, in an effort to simplify, let us re-label the constant voltage at the top of R6, ax 0V, as in Fig.3, and mark the coil ends as ‘x’ and ‘y’. This gives us sketch 3(a), showing 30mA flowing through the coil from ‘y’ to ‘x’, with the zeners ‘off’ since there is only 7.5V across them.

Still looking at Fig.3(a), consider which way the voltage will go at point ‘y’ when the current generator supply is interrupted (as it is in effect when the bridge switches reverse). In getting point ‘y’ up to +7.5V, the current must have been changed, thereby involving a particular sense to dI/dt, the rate of change of coil current. Whether or not we label this sense as positive or negative, it is certain that, as the coil current decays, then the sign of dI/dt must change – and cause point ‘y’ to go zooming off in the opposite sense, trying to take ‘y’ negative with respect to ‘x’ by the 700Ω or so calculated earlier.

Taking a deep breath, we see that collapsing then occurs with ‘x’ 16V positive with respect to ‘y’ when the current generator is in effect disconnected.

Taking another deep breath, we tell ourselves that 30mA is still flowing in the same direction from ‘y’ to ‘x’ at this time. I think that this is the sticky bit about inductors – the voltage has whistled off in the other direction, but the current is still flowing in the same sense.

If you agree to the story so far, then you will have to concede that, immediately after the switches reverse the coil connections, the conditions must be as shown in Fig.3(b), improbable as it may seem at first glance. Because the LM317 regulator is clearly not going to accept the unwanted gift of 30mA pushed back towards its output (since there is enough voltage across it to keep it pumping out 30mA), then there must inevitably be no less than 60mA through the zeners at this stage.

These currents can be monitored quite easily if one has a dual channel oscilloscope with the invert-one-channel and add-channel facilities, giving the user a differential amplifier, in effect. Then one puts a low value resistor, say 221, in series with the coil and then in the zener arm and differentially monitors the voltage across it, finding this 30mA ‘upwards’ in the coil and 60mA in the zeners just after switch reversal.

The oscilloscope traces show that the coil current decreases from 30mA ‘upwards’, passes through 0mA and finally taking up the steady value of 30mA ‘downwards’. When the coil current is zero, the zeners take the 30mA from the LM317. When the coil finally accepts the full 30mA from the current generator, there is no current for the zeners and they come out of conduction, the coil voltage taking up its steady value of 7.5V due to its ohmic drop.

Bitter experience over many years has shown that it is remarkably common for a newly developed circuit (or complete instrument) to seem quite satisfactory, but for some aspect of it to be working in an unforeseen and unperceived way – giving rise to premature breakdown or inexplicable failure to pass apparently properly tolerated test schedules in production runs. By definition, of course, there can be no procedures guaranteed to find the as yet ‘unthought of but a powerful counter-measure to estimate as many as practicable of the secondary features of a new circuit or instrument and check the correspondence with bread-board behaviour. If only you could know which were the aspects to check!

With these thoughts in mind, it was prudent to try to estimate the time the coil
voltage should be clamped by the zeners. Of course, a modest home computer could solve the circuit equation easily enough, but I feel that the use of pencil and paper whenever possible is more likely to force one to ponder the details more carefully, which is the object of the exercise.

I think the clipping situation is best viewed thus. First, consider that the coil resistance and zener slope resistances are negligible. In this simplified case, Fig.3(b) shows that the coil back e.m.f. must be a constant 16V during the whole clamping cycle. That is L.dI/dt = 16, which, with L = 0.2H, gives R1 = 80Ω. With a current change of 60mA during reversal, this leads on to expect a clamping time of 0.06/60s = 750μs, which is close to the observed value—praise be.

Thus encouraged, one can now consider the effect of the internal resistance of the coil, shown by the 250Ω resistors in Fig.4. Just after coil reversal, Fig.4(a), the current is flowing upwards, i.e. 16 - 80Ω = 8.5 V, giving dI/dt = 1180s⁻¹. At the end of the reversal phase, with the 30mA now flowing downwards, Fig.4(b), shows that the coil has only to push out a back e.m.f. of 16 - 7.5 = 8.5 V, giving dI/dt = 430s⁻¹, which is much less than the initial value.

The oscilloscope showed the coil current waveforms to be ‘exponential ramps’, so to speak, with slopes (dI/dt) at the beginning and end of the reversal period consistent with the expected ratios of 1180:43. Since the ohmic drops successively add to and then gradually subtract from the zener voltage seen by the inductive part of the coil, it is not unreasonable that taking a mean back e.m.f. of 16V gave a clamping time comparable to that observed.

Having found nothing suspicious under that stone, attention could be turned to the problem of finding the source of the ferocious 20kHz ringing voltage across the coil that started at the end of the zener clipping period (the dashed region in Fig.3(b)).

Here I fell, yet again, into that trap to which we electronic toilers seem particularly prone: “When in difficulty, unhesitatingly blame the component which you are most scared of, and stick to your convictions—regardless.” It thus only took me milliseconds to be quite certain that this ringing was due to the LM317 regulator, because it had such complicated internal circuitry; what better reason could one want? and any major aniseed was nothing else to blame.

The price of such emotional “thinking” is usually a trip in the wilderness. I was eventually forced on to the right track by the serendipitous observation that a 10kΩ resistor alone from the output of the regulator to 0V (R4 in Fig.1) stopped the oscillations, giving a fast smooth decay from the +16V to +7.5V. But how could a resistor alone ‘stop an amplifier oscillating’? That it was not due to the piffling extra direct current flowing was readily confirmed by placing a 0.1μF capacitor in series with R4 (impedance only about 80ohm at 20kHz) and finding no significant change in the smooth, fast decay after clipping.

But who said “the amplifier was oscillating”? Just because the voltage at the top end of the inductive part of the circuit is not necessarily what that the current waveform from the current generator LM317 must be ringing, so that was it and painfully self-evident as these things inevitably appear in retrospect. When the coil current has almost steadied at 30mA downwards, the zeners go off and present a very high resistance; the coil is fed by a current generator of some 500kHz output resistance, at least at z.f.: when the coil voltage tries to decay from +16V to 7.5V, the coil is thus virtually open-circuit and therefore its own lightly damped self-oscillations are only to be expected. Of course, of course.

Putting the damping resistor R5 in the position shown is just the same, as far as damping is concerned, as putting it directly across the coil, since the top of R5 is held at a steady voltage (i.e. at a.c. ground) due to the 30mA steadily flowing through it from the current source. In the commercial design I left R5 in the position shown, where its relation to the coil is not so obvious; no need to make life too easy for the ‘opposition’, is there? The capacitor was added so that R5 did not affect the steady value of current received by the coil. The value of C5 was chosen so that the resulting time constant R5 C5 was as short as possible without the impedance of C5 being too large at the ringing frequency.

With a transient time around the 1 millisecond mark, the clock frequency of 110Hz was chosen in the application of this circuit. We have seen that, during the clipping period, the average zener current is about 30mA, so the mean zener dissipation is 15V x 30mA x 750μs x 110Hz = 37mW when reverse biased; we can safely ignore the dissipation in the zeners when they are forward biased, as their voltage drop is then so much smaller.

In production, it was desirable to burn-in the p.c.b.s without the coils connected and it turns out that it is this requirement which sets the required power rating of the zeners: 15V and 30mA can be relied upon to give 450mW during the whole of each half-cycle in this case and it was thus prudent to select 1.3 watt types in case the clock should fail.

The main design details were just about completed by looking at the worst case dissipation in the LM317, with 3V across R3, 7.5V across the coil and 1V across R1, the maximum possible drop across the LM317 is (11.5 - 5%) = 10.8V, giving 600mW at 30mA, which is easily handled.

These little misadventures perhaps emphasize how important it is to think in terms of currents when an inductance dominates a circuit and to keep remembering that voltage drops will probably be much more influenced by inductive dI/dt than by ohmic I.R, giving voltage and current waveforms that can be very different indeed.

Dr D. Griffiths is at the Physics Department, Imperial College, and concerned with applying analogue circuitry to instrumentation problems.

Win our writing competition and spend a week in Japan

You have until 30 June 1988 to let us have your entries for this writing competition, the initial announcement of which appeared March. Three and a half months might seem ample time in which to compose 4500 words or so, but if you are of the same persuasion as the majority of writers the only company wanting stimulus to the pen is that of a few hardy souls who are scratching keyboard-tapping process is the sudden awareness of a deadline a couple of days away.

We reproduce here the March leader, which might provide some food for thought.

In the eighty-odd years since radio and the wider area of electronics began to develop, we have all been beneficiaries in one way or another. There is hardly any field of human activity which has not been affected, where it is entertainment, communication, travel, medical research or industry in general.

All this is obviously greatly to be desired and the benefits of using electronics for these purposes cannot be gainsaid. But, nevertheless, one is sometimes conscious that there is, perhaps, an imbalance in the efforts applied to development. In recent years, the indigenous research and development investment have been directed to a constantly increasing extent to the development of space electronics, communications and 'defence' equipment which, if it achieves its aim, will never be used.

Communications apart, the majority of effort is wasted so far as direct benefit to mankind is concerned in the foreseeable future. In a world that is beset by deprivation of many kinds from the pangs of famine to the luxury of education, one could fairly hold the opinion that further developments in exotic electronics might at least be restrained in favour of a wider provision of more basic requirements.

The application of effort in our field of electronics might not seem immediately relevant to the alleviation of famine and pestilence but the attitude of mind that impels continuous investment in indulgent or lethal hardware is questionable. To expect companies throughout the world to turn down profitable development and production contracts would be naive, but a subsidized programme of development directed at more fundamental needs is perfectly practicable.

Elsewhere in that issue appeared the announcement of a competition in which readers are invited to set down their views on the way forward in engineering development. It may be that the admittedly idealized thoughts expressed above will be considered too innocuous to be true, or that the existing regime is completely satisfactory. In any event, we expect to see a large number of thoughtful essays which should give rise to an interesting discussion, if nothing more useful than that.

Bear in mind that engineering is international nowadays, national politics are, of course important but the aim of the competition is to elicit opinion on the larger question of the direction in which international effort in electronics might most usefully be directed.

Our intention is to publish a selection of the best essays, so that the length should not exceed about 4500 words, or three printed pages in EWW. Diagrams can be used if necessary, but the space they occupy will have to be deducted from the 4500 words.

NEC Electronics (UK) Limited have joined EWW in sponsoring the competition and have provided the first three prizes.
For a man born a German to be considered for burial in Westminster Abbey is a most singular honour. Though in the end William Siemens was not buried there, his funeral service was held in the Abbey in November 1883. Two years later, an Engineers' Memorial, a window depicting his work, was unveiled there. It was to be destroyed as a result of war between his native and adopted countries.

William Siemens came from a very large family, being the seventh of fourteen children born to Ferdinand and Eleonore Siemens. Three of these, Werner, William (Wilhelm before he anglicized his name) and Carl built the dynastic empire that became the House of Siemens.

The father of this brood was a tenant farmer near Hanover, and it was there that Werner (1816-1892), the first son, and Wilhelm (1823-1883), the fourth son, were born. Soon after Wilhelm's birth the family moved some 120 miles to the Lubeck area north-east of Hamburg where the father managed a large estate. There Carl (1829-1906), the sixth son, and six other children were born.

WERNER SIEMENS

Ernst Werner von Siemens was the true founder of the Siemens engineering fame and fortune. Lack of finance thwarted his desire to study architecture and so in 1834 he joined the Artillery Corps as an officer cadet. In Berlin his military training gave him a thorough grounding in mathematics and science. Once out of training he used his spare time to continue his studies and to experiment.

He also took a keen interest in the education of his brother, Wilhelm, in whom he saw great potential as an engineer. With his parents' consent, Wilhelm entered an 'industrial school' close to where Werner was stationed. Werner taught him mathematics early in the morning, before school, so that he could omit the subject at school in favour of English, which Werner considered important.

This concern for one brother was soon to be extended to the rest of the family. Their mother died early in 1839, and their father the next year. Responsibility for the clan now fell to Werner as eldest son, at a time when the youngest was still under five.

Spurred by the financial requirements of his brothers and sisters, of whom ten survived to adulthood, Werner pursued his experiments and invented and patented an improved method for electroplating gold and silver. In 1843, at the age of 21, Wilhelm was given the job of selling the process. In Hamburg he sold the design of a powerful battery to a window-frame maker (for copper plating) and so financed a trip to England, the voyage costing £1.

Once in London Wilhelm Siemens looked around for help. Seeing a sign for an undertaker he, perhaps not unnaturally, entered to see if they could 'undertake' to help in Main picture: Sir William Siemens (1823-1883). Below, left to right; Werner Siemens (1878), Carl Siemens (1900), Johann Georg Halske (1865). All by courtesy of Siemens Ltd.
selling his electroplating process. Eventually he found what he was looking for - a patent agent - who put him in touch with Richard Elkington of Birmingham. Elkington helped "the German" take out a British patent, but he chose the low bid of £1100, less the £110 cost of the patent. Wilhelm returned home a hero, the financial saviour of the family.

The following year he was back in England with new inventions and high hopes. But hopes and money were squandered pursuing lost causes. Then in 1846 he devised a novel steam engine, patented by London, secured an income of £400 a year. This helped settle the Prussian Telegraph Commission and a ambitions this prototype gained the approval of infections this prototype gained the approval of Boettcher and Halske. After many modifications to the construction of a prototype to two mechanics, the poor clockmaker was out of his depth and their agreement was scrapped in 1846. Instead Werner entrusted the construction of a prototype to two mechanics, the poor clockmaker was out of his depth and their agreement was scrapped in 1846. Instead Werner entrusted the construction of a prototype to two mechanics. The poor clockmaker was out of his depth and their agreement was scrapped in 1846.

Vulcanizing meant adding sulphur. In time the copper wire reacted with the sulphur and destroyed the insulation. "Out of order" became the state of play on the Prussian system. Of course Werner Siemens was blamed. He replied that unvulcanized gutta-percha would have been ideal and that all would have been well if the lines had not been laid in the hurried cost-cutting way they were. The director of the Prussian State Telegraph took umbrage, severed relations with the firm, cancelled all orders and invited others to copy the equipment.

This could have been a fatal blow. However the firm had sold 75 printing telegraphs to Russia for the St Petersburg to Moscow line. This was followed by a massive order for a state system which extended from Finland to the Black Sea, and from Moscow to what is now western Poland. A long-term fixed-price maintenance contract tied to the huge order meant financial security for the firm. Even the European financial crisis of the late 1850s did not shake it. To manage the business Carl took up residence in St Petersburg, where he married a Russian girl.

With business now booming, the cousin who had put up the original capital was paid off and Carl now joined Werner and Halske as the third partner in 1854.

THE INDO-EUROPEAN LINE

Meanwhile Britain could have no long-distance telegraph links with her empire until the sea had been conquered.

The first submarine cable across the English Channel was laid in 1850, but that was soon cut by a French fisherman who, it has been said, thought he had killed a sea monster. More likely he was after the reputed gold (actually copper) at its centre. A successful cable was laid the next year. Other submarine cables followed quickly, as shallow, and then deeper, waters were crossed - and much expensive cable was lost through poor insulation and breakages. Two unsuccessful attempts were made in the 1850s in heroic attempts to span the Atlantic, though the second cable worked for a short time.

Like many others William Siemens turned his attention to submarine telegraphy. At first cables were made with Newall & Co., but in 1858 a British subsidiary of Siemens & Halske was formed under William and a cable-making factory built at Woolwich. The first two attempts at cable laying were short time and William and his new wife were nearly shipwrecked. Eventually things were sorted out but Halske had just about had enough of this risky entrepreneurship. Though he remain friendly he announced that he would retire from the business in 1867. In 1865, therefore, the British subsidiary changed its name to Siemens Brothers. William by now was pushing hard for a direct line from England to India. Forming links between existing lines did not hold the same political appeal as a single British-owned venture. Such links had been possible since 1865 but the slow and unreliable service meant that "anyone calling to India had to be lucky".

Siemens & Halske and Siemens Brothers now proposed what, in its day, was one of the technical wonders of the world, an 11 000km automatically-operated line from London to Calcutta. It was driven by punched paper tape and had only one interconnection, in Tehran. It remained in use until 1931. Some parts of it are thought to be still in use today.

The line was completed by the end of 1869 and its construction was quite an adventure story involving storms at sea, construction gangs protected by Russian soldiers, natives amusing themselves by taking pot shots at the insulators, disease, fever, and even one native servant being beheaded by his fellows. The Indo-European line was William's greatest success, the equal of any of his other exploits in electrical and mechanical engineering. With a man so talented, in fact with a family of brothers so talented, it is of course possible to write, not one, but many books about their exploits; and many do exist. Werner Siemens was one of several inventors of the submarine cable - though it was his. (That other great telegraph inventor, Charles Wheatstone, was another.) An electrical unit, the siemens, is named after Werner: originally it was a unit of resistance before being up-ended to become the unit of conductance.

In Britain, Siemens Brothers had a chequered history. Up to about 1910 the company was marginally bigger than its German parent company, Siemens AG of Germany, but in 1914 its assets were sequestrated, parts going to what became AEI and English Electric, now GEC. In 1966, when Siemens proper re-started in Britain, the name Siemens had to be bought back. The parent company, Siemens AG of Germany, now employs over 350 000 people worldwide. Those men originally employed by Siemens and Halske would never have believed it. But Werner would. That was his dream.

Next in this series of pioneers of electrical communication: Almon B. Strowger and the girl-less, cuss-less, out-of-order-less, wait-less telephone.
TIME AND FREQUENCY

The Company is Registered to Def-Stan 05-21 (AQAP-1)

- Synchronisation of remote sites.
- Time Stamping GMT/BST.
- Quartz master/slave systems.
- Accurate off-air standard (MSF Rugby).
- Calibration and reference for timers, counters, frequency meters.

Generators, Readers with high speed tape search and control. Timecodes IRIG A, B, vela, EBU, NASA, XR3.

Analogue, digital and self-setting analogue types (desk, wall or console mounting).
- Public time displays for airports, bus, railway stations and factories.
- A computer network monitoring and management system for synchronisation and fault reporting of up to 64 independent computers.
- Feasibility studies and consultancy.
- Small quantity manufacturing and test services.
- System design.

All the above can be supplied with a wide range of options and interfaces including Airborne, Military and Commercial versions. Customised systems available.

European Electronic Systems Limited,
Maldon, Essex CM9 6SW, UK.
Telephone: 024 541 5911 Telex: 995917 EULEC G Fax: 024 541 5785

ENTER 21 ON REPLY CARD

QUARTZ CRYSTALS
SAME DAY SERVICE

Any frequency from 2MHz to 55MHz.
Orders received before 10am are completed and posted THE SAME DAY!
Just let us know; frequencies? holder sizes? circuit conditions? (i.e. series resonance or load capacitance). Just £9.50 including post and VAT. Cash with order or use our credit-card hotline
0703 848961

McKnight Crystals
Amateur Radio Division (Dept Z),
Hardley Industrial Estate, Hythe,
Southampton S04 6ZY.
Telephone: 0703 848961
Telex: 47506
Fax: 0703 846532
NEW PRODUCTS

Emitter-coupled logic array

High speed is built into Motorola's e.c.l. bipolar arrays. MCA1500M contains 1708 gates and 1152 bits of ram, each internal gate having a typical propagation delay of 3.5ns and the output gates 0.75ns. Rise and fall time of I ns can be slowed down optionally to 1.5ns for applications where lower edge speeds are desirable. Ram access time is typically 3.5ns.

Three metal layers are used to define the functions of the device and distribute the power. Additional features are high-value pull-down resistors on all input pins, two strobe generators to simplify internal timing, and on-chip ram-test circuits which are independent of the configuration actually in use. Internal voltage regulation is also included.

The i.c. interfaces with other e.c.l. devices up to 5011 loads and 55 outputs can be used with 2511 loads. The device has been provided with a cad system. Other details from Motorola Ltd. 88 Tanners Drive, Blakelands, Milton Keynes, Bucks MK14 5BP.

Electronic mail on a PC

New software will enable IBM PC users to link in to an electronic mailbox service. The system was one of the first to conform to the international X.400 standard, and was previously available for use on the BBC micro (the design was published in E&W 1985).

Mail is prepared at any time, using the software and stored in a file called 'OutTray'. It is automatically transmitted down a telephone line overnight when prompted by the Interspan host computer. Similarly, any mail addressed to you is delivered to your 'InTray' file and may be read the next day.

Interspan makes a charge of 2p per 1000 characters but out of that they also pay for the phone calls and claim that this is cheaper than sending letters.

The convenience and low cost make the system especially suitable for groups of small businesses, for example, a chain of shops. It can handle plain text or documents, programs or other files.

The software includes a number of utilities, including mailing lists, standard letters and 'address-book' files for saving details of correspondence. On-screen menus and help messages make the system easy to use. Interspan Electronic Mail Ltd, Intercell, 1 Coldham's Lane, Cambridge CB1 3BP.

Semi-automatic pick-and-place for surface-mounts

Short runs of complex boards are usually not suitable for manual assembly, but are not worth the complicated set-up and programming for a fully automatic machine. Some automation is provided in the Sohlsberg-Surtech Caps system which has an operator to actually pick up the components and position them. Sequences of I.e.ds indicate which component is the next to be selected. The component is picked up with a vacuum tube which is then placed in a notch on a movable bar. The bar positions the component.

Programming the work station is carried out by a light pen for the component selection sequence and joystick for the XY coordinates on the p.c.b. During assembly a foot-switch is used to indicate the completion of each step. Memory in the system can hold up to 1000 program steps.

No external vacuum line is needed for the system, which is self-contained. It can cope with all the packages that components are supplied in as well as loose components in carousels. Board sizes up to 12 in by 16 in (300mm by 400mm) can be accommodated. Sohlsberg-Surtech Ltd, Unit 4, Intec 2 Wade Road, Basingstoke, Hants RG24 ONL. Tel.: 0256 470848.

Gaussmeter now has GPIB

Applications for the Bell 615 digital gaussmeter have been extended by the introduction of a GPIB link. More than 100 different magnetic field measurement probes, with differing physical and electrical characteristics, are available and can match the instrument to almost any measurement requirement. Hall-effect sensors are combined with a modulated-carrier amplifier system and the meter can be calibrated internally or by reference to some external standard.

Magnetic flux densities are measured in five ranges from 10G (0.001Tesla) to 100G (10k) with a full-scale accuracy of 5%. T.T.L.-level h.c.d. signals are available as an output and the IEE interface is 'talk only'. Livingston Technical Sales Ltd, 2 Queens Road, Teddington, Middlesex TW11 0LR. Tel: 01-977 0055.

Integrated modem for mains communications

Data communication over a power line is provided by Mullard's N5050 modem i.e. The device can detect broadcasts from other transmitters and can also verify its own transmissions. This gives it the advantage of being used on complex networks that require collision detection and avoidance.

Circuitry is included to overcome power-line impulse noise and line impedance variations. The transmitter includes a continuously running Colpitts oscillator and a carrier off/on switch. This allows line-driving with a varying impedance lines.

Serial protocols are used with the device up to a limit of 1000b/s for data rate; the characteristic of the power line may restrict the data rate to as low as 100b/s. Available through Gothic Crellon Ltd, 3 The Business Centre, Molly Mills Lane, Wokingham, Berks RG11 2EY. Tel.: 0734 788478.

Signals for current-loop testing

Simulated signals emanating from a pocket-sized instrument are used for testing two-wire circuits. It, as it is called, is a signal generator with five levels, selected by a single push button. The instrument is hooked into the circuit in place of the system's sensor, or in series elsewhere. By stepping through the five currents it is possible to test the accuracy of the system.

Five I.e.ds are the only displays necessary to indicate that the circuit is working; when lit, each indicates that the circuit is complete and the resistance sufficiently low to carry that signal level. Normal signals and two-wire transmissions are simulated by the instrument with an accuracy of 0.1%. Seaward Electronic, Bracken Hill, South West Industrial Estate, Peterlee, Co. Durham SR8 2JJ. Tel.: 091 586 3511.

ELECTRONICS & WIRELESS WORLD
Computer interface is twice as fast

A controller i.c. for the small computer system interface (SCSI) is fully compatible with, but twice as fast as the widely-used NCR 53C80. Logic Devices' L53C80 transfers data between computer and peripheral at up to 4Mbyte/s. Such a doubling of speed needs no changes to software since such interfaces use asynchronous protocols.

The chip has been designed to eliminate all eight bugs known to affect the performance of the NCR part, the most serious of which was the inability to use the 'block mode direct memory access function'. Removing such bugs and retaining compatibility with ANSI X3T9.2 protocol have been the main design objectives for the new chip; the extra speed came from techniques used in the company's range of signal processing i.c.s. Available through Abacus Electronics Ltd, Bone Lane, Newbury, Berks RG14 5SF. Tel: 0635 36222.

Wire wrapping made easy

Wiring a circuit can be as easy as copying the circuit diagram in components, claims BICC-Vero, who has launched a simple wiring system called Circuigraph Easywire.

Connections are made by winding the wire, fed from a special pen, tightly round the pins of each component. All the parts needed to construct an electronic circuit are included in a kit, first is the wiring pen itself which has a built-in wire cutter and carries a reel of wire. The 'board' is an injection moulded board with tapered holes to locate and retain the components. An 'unwrap' tool also acts as an anchor at the start of wiring and may be used to widen the holes of the board. Double-sided adhesive sheets are used to hold down the wires and support insulators where needed. The kit is completed by spring terminals and jacks for power connections and an instruction book which provides guidance for the novice. Such a kit offers an introduction to wiring and circuitry and will find uses in education.

BICC Vero Electronics Ltd, Planters Road, Hedge End, Southampton SO3 3LG. Tel: 041 9218 8771.

Raster-scanned c.r.t. for radar

Special applications, such as radar, are catered for by the Scanpack, now available in an enhanced version. This consists of a single unit with all the scanning, video amplifier and e.h.t. generation circuits needed to drive the c.r.t. and scan coil at line rates of up to 20kHz. Input signal handling allows the unit to accept either separate horizontal or vertical sync. combined sync or composite video sync.

A number of different c.r.ts may be used, including round (up to 50mm diameter), rectangular (up to 257mm by 195mm) or square (up to 762mm diagonal). The display tubes can have high resolution with low-voltage focussing, or high brightness and high resolution with high-voltage limiting aperture focus electrodes. Scanpacks are made up to specific requirements and are mounted in the user's own chassis, if required. It is also possible to buy just the unit and scan coil for use with other c.r.ts.

Mantron Displays, Sandy Lane, Moston Road, Sandbach, Cheshire CW11 8IT. Tel: 0270 764171.

Clamp probe for oscilloscope

Waveforms from a.c. lines can be displayed on an oscilloscope with the help of a Kentwood PC80 clamp-on probe. Three measuring ranges cover 2mV/m, 10mV/m and 100mV/m; Error is between 3% and 4% depending on the range selected; frequency bandwidth up to 100kHz.

Battery back-up for rams

Sixteen c-mos ram chips can be connected to the 28-pin controller decoder from Dallas Semiconductor which works in conjunction with a back-up lithium cell. If the supply voltage drops below a programmed level, the battery is automatically connected. It also prevents any further writing to the memory and sets a 'power failure' flag which acts as a signal. Two back-up batteries can be used and the one with the highest voltage supplies the memory.

On power up, the DS1212 checks the battery voltage and can also initiate a 'low battery' signal. The combination of DS1212 and a lithium battery can protect c-mos memory for ten years.

Joseph Electronics Ltd, 2 The Square, Broad Street, Birmingham B15 1AP. Tel: 021 643 6999.

Precise desolder pump

Solder removal is made easier by the spring action of Ceka's 6103 pump, in which suction power is variable. Made from glass-filled nylon with a carbon-fibre tip, the pump is conductive and therefore anti-static. Ceka Works Ltd, Pevelhe, Goyneald, North Wales LL53 5LH. Tel: 0758 612254.

Tiny potentiometers

Surface-mounting potentiometers measure only 3mm by 3.7mm and have resistance values of 10kΩ to 2.2MΩ. The CVR-32 series made by Kyocera is compatible with all standard soldering processes. The rotor has been designed to eliminate air gaps and provided maximum wiper contact. This gives the device a linearity to the industry 'B' standard. Temperature coefficient is within ±250ppm/C. Rated power is 0.1W at 70°C and operating temperature is from ~40°C to +100°C. This is claimed to be the smallest potentiometer in the world.

House of Power, Electron House, Gray Avenue, Orpington, Kent BR5 3AN. Tel: 0689 71531.

New products

Surface mount potentiometer

Soldering a circuit can be as easy as copying the circuit diagram in components, claims BICC-Vero, who has launched a simple wiring system called Circuigraph Easywire. Connections are made by winding the wire, fed from a special pen, tightly round the pins of each component. All the parts needed to construct an electronic circuit are included in a kit, first is the wiring pen itself which has a built-in wire cutter and carries a reel of wire. The 'board' is an injection moulded board with tapered holes to locate and retain the components. An 'unwrap' tool also acts as an anchor at the start of wiring and may be used to widen the holes of the board. Double-sided adhesive sheets are used to hold down the wires and support insulators where needed. The kit is completed by spring terminals and jacks for power connections and an instruction book which provides guidance for the novice. Such a kit offers an introduction to wiring and circuitry and will find uses in education.

BICC Vero Electronics Ltd, Planters Road, Hedge End, Southampton SO3 3LG. Tel: 041 9218 8771.
NEW 8051 DEVELOPMENT CARD

The new Cavendish Automation development card carries a full symbolic Assembler and text editor as well as the MCS-BASIC 52 package. It will allow the user to write applications programmes in either BASIC or Assembler.

The text editor supports ORG, LOC, HIGH and LOW directives as well as the current location ($) and the + and − operators. Full source text editing is included, and the source file as well as assembled code may be blown into PROM/E2PROM on-card. A powerful feature of the system is that a function library of over 60 routines within the interpreter may be accessed using assembly language CALL instructions, enabling simple negotiation of floating point, logical operations, relational testing and many other routines.

FEATURES:
- Only requires +5V supply and dumb terminal
- Save assembled code or source text in PROM on-card
- Card I/O includes 9 x 8-bit ports and 2 serial lines
- Very fast interpreter specifically written to access capabilities of '51 Family
- 32K user RAM, 16K user PROM (RAM jumpered to access code or data space)
- Card supported by over 50 other types of CA I/O and CPU target cards

So, for professional implementations at super-low cost, call us on (0480) 219457.
Cavendish Automation, 45, High St., St. Neots, Huntingdon, Cambs PE19 1BN. Tel: 0480 219457. Telex: 32681 CAVCOM G

IN VIEW OF THE EXTREMELY RAPID CHANGE TAKING PLACE IN THE ELECTRONICS INDUSTRY, LARGE QUANTITIES OF COMPONENTS BECOME REDUNDANT. WE ARE CASH PURCHASERS OF SUCH MATERIALS AND WOULD APPRECIATE A TELEPHONE CALL OR A LIST IF AVAILABLE. WE PAY TOP PRICES AND COLLECT.

R. Henson Ltd.
21 Lodge Lane, N. Finchley, London N12 8JG.
5 mins. from Tally Ho Corner

Telephone: 01-445 2713/0749

STEWART OF READING
Telephone: 0734 68041
110 WYKENHAM ROAD, READING, BERKS RG6 1PL
Callers welcome 9am to 5.30pm. MON-FRI. (UNTIL 8pm. THURS)
High resolution flat screen

Vacuum fluorescence is used in a 640x480 x 16777216 colour display module from Futaba. Like most v.f. systems it provides a blue-green readout but many colours can be achieved through the use of filters. In addition to the display itself, the CP 1004/03B module consists of a display controller and driver, and an optional supply to provide the 13.5V and 12V lines used to drive the screen. Dots are 0.2 by 0.3mm and are so arranged on a 0.28mm pitch to give high resolution. Regisbrook are so arranged on a 0.28mm pitch to screen. Dots are 0.2 by 0.3mm and 12V lines used to drive the screen.

Big-display d.m.s.

'Lowest display currently available' is the boast for the Hokki 3231 digital multimeter. It also counts up to 31,999, which gives it a greater measuring range than the more normal 31/2 digits available on such meters. A single rotary switch selects the measurement mode and the meter is autoranging. Six direct voltage ranges measure up to 1kV or 750V for a.c. Current ranges for both a.c. and d.c. go to 10A and there are a number of resistance ranges, including continuity checks with an audible signal, and diode testing. A low-power ohms test can be used for testing in-circuit components. Frequency measurement is also included; up to 50kHz with 0.1Hz best resolution.

Resistors in integrated packages

Having a number of similar resistors in the same package ensures that they are subject to the same environmental conditions and therefore change by the same proportion when subjected to temperature changes. The TOMC range from Dale-ACI offer thin-film networks with resistors ranging from 100 ohm to 100k ohm, made with tolerances of 1%, 0.5%, 0.25% and 0.1%. Resistors within a package are matched to within 0.1% and a temperature coefficient of 25ppm/°C is standard. Resistors are arranged within the surface-mount pack with one end common for all 13 or 15, or seven or eight isolated resistors, depending on whether the 14 or 16-pin version is used. Dale-ACI Components Ltd, River Park Industrial Estate, Berkhamstead, Herts (H14 1UL), Tel: 04427 23291.

Any waveform you like

An arbitrary function generator does not create waves arbitrarily. It's just a way of saying that it can synthesise waveforms to almost any specification. One from Tektronix, the 5101 combines two instruments: a digital waveform synthesizer and an analogue signal generator. The digital/analog converter operates between 1MHz and 512MHz and features two 5K waveform memories with a 12-bit vertical resolution. This translates as a matrix of over 33 million point (8192 by 4096) with which to plot out a waveform. This may be done manually, entered through the instrument's front panel, or downloaded, through the GPIB, from computer-generated waves which may be produced by mathematical formulae, graphics programs or by digitizing recorded waveforms. The analogue function generator can produce the usual menu of sine square, and triangular waveforms. These can be between 0.012Hz and 12MHz at frequencies from 10mV to 9.9V peak-to-peak into 500Ω. The instrument offers a full range of triggering and sweep modes with a.m. and f.m. Internal memory can hold up to 99 front-panel settings in addition to the two waveform memories.

Two versions are available: one is a module that plugs into a Tektronix 'mainframe' and may be used in combination with other instruments to form a complete test system; the other is a stand-alone instrument. Tektronix UK Ltd, Fourth Avenue, Globe Park, Marlow, Bucks SL7 1YD, Tel: 06284 6600.
# Langrex Supplies LTD

1 Mayo Road, Croydon, Surrey CR0 2QP.

**RST** Tel: 01-684 1166  Telex: 946708  Fax: 01-684 3056 RST

## Semiconductors

<table>
<thead>
<tr>
<th>Part No.</th>
<th>Value</th>
<th>Description</th>
<th>Quantity</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADL2872</td>
<td>0.72</td>
<td>0.72</td>
<td>1</td>
<td>0.72</td>
</tr>
<tr>
<td>2N5089</td>
<td>0.15</td>
<td>0.15</td>
<td>1</td>
<td>0.15</td>
</tr>
<tr>
<td>2N5089</td>
<td>0.15</td>
<td>0.15</td>
<td>10</td>
<td>1.50</td>
</tr>
<tr>
<td>2N5089</td>
<td>0.15</td>
<td>0.15</td>
<td>25</td>
<td>0.65</td>
</tr>
<tr>
<td>2N5089</td>
<td>0.15</td>
<td>0.15</td>
<td>50</td>
<td>0.30</td>
</tr>
<tr>
<td>2N5089</td>
<td>0.15</td>
<td>0.15</td>
<td>100</td>
<td>0.15</td>
</tr>
<tr>
<td>2N5089</td>
<td>0.15</td>
<td>0.15</td>
<td>200</td>
<td>0.075</td>
</tr>
<tr>
<td>2N5089</td>
<td>0.15</td>
<td>0.15</td>
<td>300</td>
<td>0.055</td>
</tr>
<tr>
<td>2N5089</td>
<td>0.15</td>
<td>0.15</td>
<td>400</td>
<td>0.045</td>
</tr>
<tr>
<td>2N5089</td>
<td>0.15</td>
<td>0.15</td>
<td>500</td>
<td>0.030</td>
</tr>
<tr>
<td>2N5089</td>
<td>0.15</td>
<td>0.15</td>
<td>1000</td>
<td>0.015</td>
</tr>
</tbody>
</table>

## Valves

<table>
<thead>
<tr>
<th>Part No.</th>
<th>Value</th>
<th>Description</th>
<th>Quantity</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>1N4047</td>
<td>1.00</td>
<td>1.00</td>
<td>1</td>
<td>1.00</td>
</tr>
<tr>
<td>1N4047</td>
<td>1.00</td>
<td>1.00</td>
<td>10</td>
<td>10.00</td>
</tr>
<tr>
<td>1N4047</td>
<td>1.00</td>
<td>1.00</td>
<td>25</td>
<td>2.50</td>
</tr>
<tr>
<td>1N4047</td>
<td>1.00</td>
<td>1.00</td>
<td>50</td>
<td>0.50</td>
</tr>
<tr>
<td>1N4047</td>
<td>1.00</td>
<td>1.00</td>
<td>100</td>
<td>0.10</td>
</tr>
<tr>
<td>1N4047</td>
<td>1.00</td>
<td>1.00</td>
<td>200</td>
<td>0.05</td>
</tr>
<tr>
<td>1N4047</td>
<td>1.00</td>
<td>1.00</td>
<td>300</td>
<td>0.025</td>
</tr>
<tr>
<td>1N4047</td>
<td>1.00</td>
<td>1.00</td>
<td>400</td>
<td>0.015</td>
</tr>
<tr>
<td>1N4047</td>
<td>1.00</td>
<td>1.00</td>
<td>500</td>
<td>0.010</td>
</tr>
<tr>
<td>1N4047</td>
<td>1.00</td>
<td>1.00</td>
<td>1000</td>
<td>0.005</td>
</tr>
</tbody>
</table>

## Bases

<table>
<thead>
<tr>
<th>Part No.</th>
<th>Value</th>
<th>Description</th>
<th>Quantity</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>2N5089</td>
<td>0.15</td>
<td>0.15</td>
<td>1</td>
<td>0.15</td>
</tr>
<tr>
<td>2N5089</td>
<td>0.15</td>
<td>0.15</td>
<td>10</td>
<td>1.50</td>
</tr>
<tr>
<td>2N5089</td>
<td>0.15</td>
<td>0.15</td>
<td>25</td>
<td>0.65</td>
</tr>
<tr>
<td>2N5089</td>
<td>0.15</td>
<td>0.15</td>
<td>50</td>
<td>0.30</td>
</tr>
<tr>
<td>2N5089</td>
<td>0.15</td>
<td>0.15</td>
<td>100</td>
<td>0.15</td>
</tr>
<tr>
<td>2N5089</td>
<td>0.15</td>
<td>0.15</td>
<td>200</td>
<td>0.075</td>
</tr>
<tr>
<td>2N5089</td>
<td>0.15</td>
<td>0.15</td>
<td>300</td>
<td>0.055</td>
</tr>
<tr>
<td>2N5089</td>
<td>0.15</td>
<td>0.15</td>
<td>400</td>
<td>0.045</td>
</tr>
<tr>
<td>2N5089</td>
<td>0.15</td>
<td>0.15</td>
<td>500</td>
<td>0.030</td>
</tr>
<tr>
<td>2N5089</td>
<td>0.15</td>
<td>0.15</td>
<td>1000</td>
<td>0.015</td>
</tr>
</tbody>
</table>

## CRTs

<table>
<thead>
<tr>
<th>Part No.</th>
<th>Value</th>
<th>Description</th>
<th>Quantity</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>2N5089</td>
<td>0.15</td>
<td>0.15</td>
<td>1</td>
<td>0.15</td>
</tr>
<tr>
<td>2N5089</td>
<td>0.15</td>
<td>0.15</td>
<td>10</td>
<td>1.50</td>
</tr>
<tr>
<td>2N5089</td>
<td>0.15</td>
<td>0.15</td>
<td>25</td>
<td>0.65</td>
</tr>
<tr>
<td>2N5089</td>
<td>0.15</td>
<td>0.15</td>
<td>50</td>
<td>0.30</td>
</tr>
<tr>
<td>2N5089</td>
<td>0.15</td>
<td>0.15</td>
<td>100</td>
<td>0.15</td>
</tr>
<tr>
<td>2N5089</td>
<td>0.15</td>
<td>0.15</td>
<td>200</td>
<td>0.075</td>
</tr>
<tr>
<td>2N5089</td>
<td>0.15</td>
<td>0.15</td>
<td>300</td>
<td>0.055</td>
</tr>
<tr>
<td>2N5089</td>
<td>0.15</td>
<td>0.15</td>
<td>400</td>
<td>0.045</td>
</tr>
<tr>
<td>2N5089</td>
<td>0.15</td>
<td>0.15</td>
<td>500</td>
<td>0.030</td>
</tr>
<tr>
<td>2N5089</td>
<td>0.15</td>
<td>0.15</td>
<td>1000</td>
<td>0.015</td>
</tr>
</tbody>
</table>

## Integrated Circuits

<table>
<thead>
<tr>
<th>Part No.</th>
<th>Value</th>
<th>Description</th>
<th>Quantity</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>7401</td>
<td>0.16</td>
<td>0.16</td>
<td>1</td>
<td>0.16</td>
</tr>
<tr>
<td>7401</td>
<td>0.16</td>
<td>0.16</td>
<td>10</td>
<td>1.60</td>
</tr>
<tr>
<td>7401</td>
<td>0.16</td>
<td>0.16</td>
<td>25</td>
<td>0.40</td>
</tr>
<tr>
<td>7401</td>
<td>0.16</td>
<td>0.16</td>
<td>50</td>
<td>0.20</td>
</tr>
<tr>
<td>7401</td>
<td>0.16</td>
<td>0.16</td>
<td>100</td>
<td>0.10</td>
</tr>
<tr>
<td>7401</td>
<td>0.16</td>
<td>0.16</td>
<td>200</td>
<td>0.05</td>
</tr>
<tr>
<td>7401</td>
<td>0.16</td>
<td>0.16</td>
<td>300</td>
<td>0.03</td>
</tr>
<tr>
<td>7401</td>
<td>0.16</td>
<td>0.16</td>
<td>400</td>
<td>0.02</td>
</tr>
<tr>
<td>7401</td>
<td>0.16</td>
<td>0.16</td>
<td>500</td>
<td>0.01</td>
</tr>
<tr>
<td>7401</td>
<td>0.16</td>
<td>0.16</td>
<td>1000</td>
<td>0.005</td>
</tr>
</tbody>
</table>

**Terms of business:** COD. Postage and packing charges and semiconductors £1.00 per order. CRTs £1.50. Prices excluding VAT. Post and packing add 15%. Price ruling at time of despatch.

In some cases, pieces of Valvaid and USA valves will be higher than those advertised. Prices correct when going to press. All quoted prices are net and are quoted subject to availability. Orders accepted at the quoted prices. Orders subject to availability. Any typographical errors S.A.E.

**ENTER 25 ON REPLY CARD**

---

**Electronics & Wireless World**

**Telephone:** 01-684 1166  **Telex:** 946708  **Fax:** 01-684 3056 RST

**Open to callers Monday-Friday 9 a.m. - 5 p.m.**

**LANGREX SUPPLIES LTD**

1 Mayo Road, Croydon, Surrey CR0 2QP.
DIGITAL MULTIMETERS from £89

- 3½ DIGIT 0.5" LCD
- 7000 HR BATTERY LIFE
- 0.1% BASIC ACCURACY
- TRUE RMS
- 1000V DC 750V AC
- 10A AC/DC
- DIOODERESISTANCE TEST
- CONTINUITY BUZZER

TELESCOPIC MASTS

- Pneumatic
- Hydraulic Ram Operated
- Winch Operated

Hilomast Ltd.
THE STREET, HEYBRIDGE, MALDON
ESSEX CM9 7NB ENGLAND
Tel: (0621) 56480 Telex: 995855

ENTER 12 ON REPLY CARD

FREQUENCY COUNTERS from £99

- 10MHz, 50Mhz, 10Hz, 15GHz MODELS
- 3 GATE TIMES
- RESOLUTION TO 0.1Hz
- ½" BRIGHT LED DISPLAY
- MAINS/BATTERY
- TCXO OPTION
- LOW PASS FILTER

FUNCTION GENERATOR £110

- 50kHz and 2MHz MODELS
- SINE, SQUARE, TRIANGLE, TTL
- EXTERNAL AM
- EXTERNAL SINE
- 0.3V OUTPUT
- ±15V DC OFFSET
- 50 Hz and 500 Hz, O/P's
- 0.2mV, 40dB ATTENUATOR

ELECTRONICS & WIRELESS WORLD
INDUSTRY INSIGHT BUSES

The number of computer buses now proposed or actually in use, with no apparent attempt to any kind of standard, is reaching epidemic proportions. Industry Insight number 4 concentrates on computer buses and gathers together in one place with descriptions of them all, with their characteristics, advantages and disadvantages, chances of large-scale adoption from each camp.

TO ADVERTISE WITHIN INDUSTRY INSIGHT RING:
JAMES SHERRINGTON ON 01-661 8640 NOW

ENTER 15 ON REPLY CARD
Switchboards in the sky

The days of the 'transparent' comsat transponder are numbered. Payload system designers are looking at various ways of processing signals on board the satellite instead of on the ground. Although this approach means greater complexity in the spacecraft it offers important operational and commercial advantages. Communications capacity can be increased (thus helping to solve the problem of the limited geostationary orbit—see May issue, p.488); greater operational flexibility can be obtained; and, as a result of these two factors, the commercial efficiency of satellite communications can be improved.

Two on-board processing techniques are now being developed. One is the regeneration of digital bit streams, as in terrestrial repeaters, to clean up any pulse waveform distortion introduced by the uplink. This entails demodulation of the received signals, in other words, to recover the baseband digital waveform. The second technique, which seems to have advanced more quickly, is the switching of digital data signals between uplinks and downlinks in large-capacity satellites with multiple spot beams. In other words, any receiving spot beam(s) can be connected within the comsat to any transmitting spot beam(s).

If there are M receiving beams and N transmitting beams, an on-board switch allows M×N interconnections between these beams. In contrast, the simple 'transparent' comsat only permits a number of straight-through connections set by the number of transponders (M×N) in the spacecraft. Although the communications capacity of each transponder, determined by bandwidth, power and s/n ratio, is no different, the overall effect of introducing switching between uplinks and downlinks is as if the spacecraft were carrying M×N transponders instead M = N transponders.

To make this principle work without confusion the individual signals must obviously be kept separate from each other. In practice this separation is achieved by time division of digital signals, using a version of the established time-division multiple access (t.d.m.a.) digital modulation system introduced in 1985 (see April 1987 issue, p.833). This is called satellite switched t.d.m.a. and its first use will be with the new Intelsat VI comsat due to be launched next year (January 1988 issue, pp.25-27). Intelsat VI will carry a microwave switch capable of making interconnections between six beams.

Current development of on-board switches aims to reduce their size and weight by using monolithic integrated circuits. These are made in GaAs to achieve the fast switching speeds necessary for handling high data rates. The general principle of interconnection is based on the matrix, analogous to the crossbar switch of terrestrial telecomm systems. For example, NEC has developed a GaAs l.s.i. chip for Intelsat providing a 16×4 switching matrix. It contains 1292 fets and 212 diodes in a monolithic device measuring 3.3×2.9mm.

The GaAs fets not only give high switching speed but also good isolation and a low drive power requirement. The logic circuitry is designed to switch fast enough for bit streams at the Intelsat s.s.t.d.m.a. data rate of 120Mbit/s. Four of these chips, which are housed in 48-pin packages, are to be combined to produce a 16×16 switch matrix working at baseband signal frequencies.

An alternative method, where pulse regeneration is not required, is to do the switching between receivers and transmitters at the transponders' intermediate frequency. This is being pursued by the NTT company for experimental operation on board the Japanese ETS-VI test satellite due to be launched in 1992. Engineers from NTT Electrical Communication Laboratories described their i.f.-band 16×16 switch matrix at the 38th congress of the International Astronautical Federation held in Brighton last year. Using s.s.t.d.m.a., it is intended not only to connect any input to any output but also to connect any input to multiple outputs (distribution) or multiple inputs to any one output (combination).

The matrix switches signals in the i.f. band 900-1100MHz. It is made up of 64 modules, each of which contains two i.c. switches and two i.c. drivers. The basic i.c. switch is a 2×2 matrix (Fig.1a).

There are two reasons for this particular arrangement. One is to avoid the r.f. coupling that would occur between input and output lines at cross-over points in a straightforward matrix: an input-output isolation of at least 40dB is required. The second reason is a need for redundancy to achieve good reliability. Each cross-point interconnection switch in the overall matrix in fact uses two of the Fig.1a chips which back up each other and are separately operated by an on-board programmable controller in the s.s.t.d.m.a. system.

Functionally the 2×2 matrix switch i.c. is composed of four single-throw switches. Within the chip, each of the equivalent s.p.s.t switches is made up of four GaAs fets, two of them forming an i.f. buffer amplifier and the other two performing the on-off switching in response to control signals (Fig.1b). To achieve a high on-off ratio and good isolation performance the two buffer amplifier fets are well separated from the two switching fets. Power consumption is kept low in this circuit because in the s.p.s.t. off-state the current is cut off simultaneously in the switching fets and in the buffer amplifier. Altogether the 2×2 matrix of Fig.1a is integrated into a GaAs chip measuring 3.9×2.9mm.

The four s.p.s.t. switches (Fig.1a) are opened and closed by voltages from a further chip (2.7x1.3mm) which integrates four corresponding driver circuits. So the complete switching module mentioned above contains two of these driver chips and two matrix chips. Overall the module package measures 30×21×6mm. It is claimed to have a switching time of less than 10ns and an on-off signal ratio of more than 60dB. Insertion gain at 1GHz is about 24dB.

Sixteen of the switch modules are mounted in a four-by-four pattern on a single-plane sub-assembly, then four of these sub-assemblies are piled up to form the complete 16×16 matrix of 64 modules altogether. This final unit measures 270 x 222 x 130mm. Within this box, electrical connections are mechanically arranged to keep the input signal lines in one layer and the output signal lines in another layer, thus separating them physically and avoiding r.f. cross-coupling. Here the signal isolation is claimed to be greater than 72dB.

Initially this kind of on-board switching unit will be used with fixed spot beams. But in later generations of comsats it may well be combined with scanning spot beams, which hop from place to place on the Earth's surface, to give even greater operational flexibility. Such a system will be part of the Advanced Communications Technology Satellite (see January 1987 issue, p.32), though here the switch will be operating at digital baseband frequency.

Telecom 1-C launched

The third French domestic comsat, Telecom 1-C, was one of the two spacecraft successfully launched by an Ariane 3 rocket from Kourou in March this year. It is part of the French national satscoms programme run by Direction Generale des Telecommunications (DGT), the telecoms
operating unit of the French PTT. Placed in a geostationary slot at 3°E, this new spacecraft carries on the telecommunication and broadcast signal distribution functions started by Telecom 1-A (stationed at 8°W in 1984) and Telecom 1-B (placed at 5°W in 1985). Its arrival is fortunate, as the I-B spacecraft has now gone out of control.

These Telecom satellites have Ku-band spot beams covering the whole of France (and parts of adjacent countries) and also semi-global beams providing C-band communications with French overseas territories and nearby areas. The last-mentioned coverage includes the eastern seaboard of Canada and the USA, the entire Caribbean area and the northern part of South America. Like its predecessors, Telecom 1-C carries ten 20W civil transponders. Six of these operate in Ku-band (downlinks 12.5-12.75GHz) and four in C band (downlinks 3.7-4GHz).

The telecommunications network carries both low-speed and high-speed digital data (2.4kHz to 2MHz) and uses about 320small earth terminals with 3.5 metre antenna dishes. Network access is provided through a demand-assigned d.t.m.a. system. Both sound and television broadcast signals are distributed. In addition Telecom 1-C has a military communications payload working at s.h.f. with 8Ghz uplinks and 7GHz downlinks.

All these spacecraft have been built for DGT by a European group of contractors which includes the UK's British Aerospace.

The second satellite launched on the same Ariane 3 rocket was the American Spacenter III domestic comsat. Built by RCA Astro Electronics, this carries twelve 72MHz t.w.t. transponders, six for C band and six for Ku band, plus twelve 36MHz solid-state C-band transponders.

**Seminar on intersatellite links**

**Results of current studies on both intersatellite and inter-orbit communication links will be presented by European aerospace firms at a seminar to be held at the Royal Garden Hotel, London, 29-30 June. Speakers from international space organizations will cover the technology, including microwave and optical systems, and there will be an associated exhibition.**

The event is organized by the independent commercial organization ERA Technology Ltd, Cleeve Road, Leatherhead, Surrey KT22 7SA; tel: 0372-374151. Contact: Laura Christie, ext. 2290 or 2488.

**Nigeria joins Inmarsat**

The latest country to become a member of Inmarsat — actually the sixth African country — is Nigeria. Represented by Nigerian Telecommunications Ltd, it already has two ships using the Inmarsat system and generates considerable shore-to-ship traffic. The international co-operative now has a total of 54 member countries.

**Satellite solarium**

**As part of their pre-launch testing, all satellites have to be subject to simulated space conditions to see if they will stand up to the rigours of this harsh environment. Broadly speaking, it is a high vacuum, with temperatures ranging from -200°C to +100°C.**

**ESA's new scientific satellite Hipparcos has recently been taking this treatment in a large space simulator at the agency's European Space Research and Technology Centre (ESTEC), Noordwijk, in the Netherlands. This simulator is claimed to contain the world's most powerful artificial sun. Inside a cylindrical vacuum chamber, a 7.2 metre mirror built up from hexagonal elements directs radiation from a battery of xenon lamps on to the spacecraft. Technical positioning equipment orientates and moves the satellite to simulate as closely as possible the angle at which the sun's rays will strike the spacecraft in a given orbit.**

**Hipparcos, named after the ancient Greek astronomer, is a geostationary satellite designed for astrometry — making astronomical measurements. It will be used for accurately determining the positions of stars and their motions in space. ESA says that, over the mission lifetime of 2½ years, about 120,000 stars will be measured, to an accuracy of 0.002 of a second of arc.**

**Radio engineering terms in satellite links**

**Field strength**

The received power $P_R$ can be calculated from the power flux density at the earth station if this is known. It is common practice for satellite operators to specify it by contours in the satellite's footprint. From the p.f.d. in dBW/m² and the area in metres of the receiving antenna reflector the theoretical incident power can be calculated. The actual received power, however, depends on the gain (including efficiency) of this antenna.

Field strength in volts per metre can be calculated from power density values on the analogous Ohm's law principle of $V = IR$. In the satellite case the V here is analogous to the field strength $E$ (volts/metre), the R is analogous to the characteristic impedance of free space $Z_0$ (=376.612) while the P is analogous to the radiated power (e.i.r.p.). The relationship is

$$E^2 = Z_0 \times (e.i.r.p.)$$

where $E$ is field strength (V/m), $e.i.r.p.$ is power (W) and $r$ is the distance between satellite and receiver (m).

The general principle governing $Z_0$ is used to convert received p.f.d. into field strength. Here

$$E^2 = Z_0 \times (p.f.d.)$$

where $E$ and $Z_0$ are as defined above and p.f.d. is in W/m². As an example, if the p.f.d. is $-103dBW/m^2$ (=2x10⁻¹²W/m²) as specified for beam centre under the WARC 1977 d.b.s. plan, then $E = 137\mu V/m$. To calculate directly in DBW, a useful formula is

$$E dB (V/m) = p.f.d. dB (W/m^2) + 145.76$$

remembering that the decibels on the left hand side of this equation represent a voltage ratio and not a power ratio.

**Noise power**

The channel capacity of the satellite downlink is, of course, partly dependent on the noise power in the link. Noise power is normally expressed as noise temperature on the absolute scale, to which it is proportional — that is, the temperature in K of a resistor that would generate the same thermal noise power per unit bandwidth as the noise power produced by the actual device concerned (e.g. a receiving antenna). Standard noise temperature is taken as 290K, as this corresponds to normal room temperature of 17°C.

Noise power $N$ at some point in a communications link can be calculated from the formula:

$$N = kTB$$

where $k$ is Boltzmann's constant, $B$ is the bandwidth in Hz and $T$ is the noise temperature in K.

Noise power is also proportional to the bandwidth, described for this purpose as the noise bandwidth. As mentioned above, communications engineers express this bandwidth in dB relative to 1Hz, so a noise bandwidth of 27 MHz = 74.3dBFHz.

**To be continued**
The 1990 approach to custom integrated circuits
who's doing what in application-specific i.c.s
first wafer scale success?
custom integrated circuits for the first-time buyer
gallium arsenide on silicon
getting to grips with asics
integrated circuits of the future
custom circuits on a personal computer
custom silicon now
is there a distributors role for asics?
what about the independents?
Your move.

WHY BE A PAWN IN THE GAME?
CHOOSE FROM THE PP40 SERIES OF GANG PROGRAMMERS.

If you've ever felt cornered by the lack of choice in gang or set programming, Stag have the answer.

The PP40, PP41 and PP42 are stand-alone, low-cost, high speed programmers with fast programming algorithms that can meet virtually any requirement.

24 & 28-pinEPROMs and EEPROMs can be programmed, with extensive self-test and fault-finder software built-in.

Parameter storage is non-volatile and there are bi-coloured 'Socket Status' LEDs and a large 16-character alphanumeric display. Together, these enable extensive error reporting.

Plug-in modules for future hardware expansion will handle new package styles – including leadless devices.

PP40 Ideal for the production environment – robust and simple to use. Capable of programming a gang of eight devices, it'll solve all your copying problems in one single-key operation – and at a price you'll appreciate.

PP41 All of the PP40's advantages, but useable too for development purposes thanks to its built-in RAM, a powerful editor and dual RS232C I/O ports.

PP42 The top of the range. This includes the important feature of Set Programming, for design development. The 'Interlace' concept enables fast handling of 8, 16 and 32-bit data, with a 2-megabit RAM as standard.

The Stag PP40 Series. With our choice, you need look no further.

Stag Electronic Designs Ltd. Stag House, Tewin Court, Welwyn Garden City, Herts AL7 1AU. Tel: 0707 332148.
A new £250 million, five-year research plan is taking shape to provide a range of advanced semiconductor technologies, design tools and techniques to satisfy UK electronics systems company needs into the 1990s.

The collaborative research programmes of Alvey and Esprit have provided a sound base of technology and computer-aided design capability that was badly needed to keep our firms competitive. With these programmes due to end early next year, plans are well advanced for an ambitious new programme of research and development aimed at technologies with minimum dimensions as small as 0.3 microns.

The new plan, Silicon Towards 2000, describes for the first time the targets for UK small and medium-sized firms competitive. With these programmes the capability that was badly needed to keep our industry well positioned for strong growth to take full advantage of the Single European Market. Silence towards 2000 is intended to provide the technological base on which this growth will be based. The life of our industry may depend upon it.

Jonathan Kimmit of the Department of Trade and Industry, on secondment from PA Technology.

Fear of flying Peter O'Keeffe, m.d. of Qudos, looks at prototype chip design and finds that many of its problems are more than simply technical.

Custom ic design with a PC Colin Sutcliffe shows how to design asics on standard PC hardware.

In-house gate array design Whatever proportion of asic design is handled in-house, here are some points to consider when choosing design tools.

Gallium arsenide devices on silicon substrates Recent progress in growing thin layers of gallium arsenide epitaxially on silicon substrates has enabled the fabrication of gallium-arsenide-based electronic and optical devices on silicon substrates.

Cover Breadboarding in Silicon. With direct write-on-silicon e-beam facilities — offered for TI's one-micron gate arrays next year — the cost and time involved in masking is eliminated.
THE 1990 APPROACH TO CUSTOM SILICON

Custom silicon, or application-specific integrated circuits as they have become commonly known, is not a new technological marvel to arrive in recent years. The basic technology dates back to the earliest days of the semiconductor industry when many multinational companies saw the benefits of integrating systems into silicon. The widespread use of this design approach was cut short prematurely by the advent of the microprocessor which enabled an approach that provided flexibility, high functionality and the ability to effortlessly redesign up to the day of product release.

Custom silicon for most engineers was relegated to a secondary position whose use was only chosen when a microprocessor solution placed severe constraints on a product specification or when the applications performance demanded the use of integration. Today, even though the benefits of using asics have been widely promoted and obviously rank highly on the wish list of any equipment specification, fewer than 30% of companies in the UK have taken the plunge and used them.* The reasons for this are intrinsic in the technology itself and how it is marketed by semiconductor vendors.

What are the factors that have held back the widespread use of custom silicon? Firstly, the detailed knowledge essential to design integrated circuits only resided within the semiconductor supplier community itself. It is almost considered to be a 'black art' with only a few engineers being given the opportunity to learn this exacting trade. Even now it is commonly estimated that there are only 10,000 design engineers in the world capable of designing a chip from scratch. Good i.c. design engineers require several years of experience before they are capable of designing chips on a standalone basis.

It is the obligation of every conscientious design engineer to evaluate the use of custom silicon as a means of attaining improved product specifications. Those who seize the opportunity early will be among the first to experience the benefit of more innovative and competitive products; it might not be as difficult as you think, says Chris Gare.

Secondly, the computer-aided design tools used to design chips were really quite crude. Chips were designed manually with each transistor and interconnect string being laid down by hand on a graphic editor. This led to development times that were measured not only in man-years but in millions of dollars as well. As a systems manufacturer, if your products had potential sales in the high thousands and could support sufficient margin for such high development costs then you could afford to become involved with custom chips. If not, access to the technology was practically denied.

Users and vendors of custom silicon came up with radically different approaches to providing lower cost solutions. Users, that is large users, invested in in-house technology to the extent of not only hiring experienced i.c. design engineers but also building foundries (the industry name for i.c. manufacturing factories) for themselves. For example, nearly every single household-name Japanese electronics corporation owns a fabrication plant to support internal consumption. The vendor approach, which was the epitome of compromise, was the development of the 'gate-array' concept.

The gate array was a singular concept that endeavoured to rationalise the disparate requirements of suppliers and users. All major semiconductor vendors are orientated to producing standard parts in high volume measured in hundreds of thousands. The problem with most custom silicon designs however is that they are mainly low-volume in nature as they are associated with a single customer. This is not the sort of product that motivates production directors of traditional semiconductor suppliers!

With gate array technology, complete wafers are preprocessed with an array of unconnected gates separated by wiring channels. When a user completes a design the vendor takes these 'base wafers' off the shelf and adds the final metallization layers that define the function of the chip i.e. personalise it. The gate array is a compromise nevertheless and in itself not capable of reducing the cost barriers to a sufficient level to encourage the widespread use of custom silicon. Let us take a look as to why this should be so.

The need for masks
The traditional method of making integrated circuits is to use photolithography. Each layer of an i.c. is built up by placing a film of photoresist on the surface and exposing it by illuminating it with u.v. light via a mask that is stepped over the whole wafer surface. The unexposed resist is washed away and the exposed surface etched. A complete i.c. consists of up to thirteen of these masks. For a gate array, where only final metal layers need to be formed to personalize the chip, only one to four masks are required. The making of these masks is an expensive process, close to $2,000 a mask.

The above cost and the underlying manufacturing technology require that a significant non-recurring expense is needed to finance a vendor tooling up prior to a

*According to a 1987 DTI study, see page 593 footnote
production run. More often than not the vendor demands a significant production order before doing so. A typical UK manufacturer who has neither the cash nor a sufficient production run to interest the vendor has little chance of getting past this first step.

The design process

The nature of the gate array has placed severe constraints on the way the design process is accomplished. Whereas the development of microprocessor-based systems has passed completely to the electronics engineer through the emergence of the desk-top microprocessor development system and in-circuit emulation; this has not happened with custom silicon designs. The reason is inherent in the structure of gate array itself: columns of uncommitted gates interdigitated by wiring channels. These wiring channels are of finite width, and as such, present a challenge to any automatic place-and-route software.

A gate array 'p. and r.' program needs a powerful mainframe computer to handle the complexities of routing a chip. This is because the fixed-width wiring channels can only accommodate so many wires across its width and once this limit is reached the router needs to find an alternate path, possibly via another layer. If this is not possible and an alternate path is not located, the routing needs to be completed through manual intervention. It is only after a chip is laid out that an accurate simulation of chip performance can be achieved because the precise loading of each individual gate output is needed before accurate delay predictions can be calculated.

The accepted design methodology for gate arrays is that the customer only undertakes the entering of the schematic on the CAD system and the pre-layout functional simulation of the design. This schematic database and the simulation vector table is then shipped to the gate array vendor who then ships back to the customer who lays out the chip and conducts the post-layout timing simulation. The results are then shipped back to the customer who

The first of these programs positions individual transistors as required by the design in a columnar fashion while the second determines how they are interconnected. The drawings for a typical small design consisting of 2,000 gates should take only between one and two weeks to complete.

SECRET OF DESK-TOP DESIGN

A new approach to the design of custom silicon is afforded by writing all layers of a custom chip rather than just the final metallization layers as with a gate array. This provides the assurance that all designs can be 100% automatically routed on the designer's desk-top CAD system. Once layout has been accomplished, full back-annotated simulation of the design can be run to ensure that the design meets required timing specifications. Back annotation means that actual interconnect and fan-in loading data is fed back to the simulator so the simulation is as near 'real-life' as possible. The diagram on page 590 shows the particular software programs in the Solo 1000 package a design engineer needs to run to produce a design database. The first step is to enter the schematic diagram into the editor, Draft. The logic diagram is then automatically converted to a high-level descriptive language, Model, which drives the place and route programs.
DIRECT WRITE-ON-WAFER WITH E-BEAM TECHNOLOGY

Directly writing patterns onto wafers is a technology that introduces a new degree of freedom into the manufacturer of custom silicon. Removing the dependence on masks allows a manufacturer more freedom to place multiple designs on a wafer and to specialise in the production of small quantities of parts.

All the steps of producing an integrated circuit are the same as conventional techniques except that instead of placing a mask over an optical resist to produce a layer image on the wafer, a resist that is sensitive to electrons is used. A beam of high-energy electrons then writes the design direct on the resist itself.

The e-beam machine as used by ES2, opposite, is specified to produce features of minimum size 0.5 micron but features down to 0.1 micron have been regularly achieved. There is no limit to die size other than what is considered to be acceptable time to pre-process the design data.

Once a design has been laid out a plot may be printed to show how the core logic has been connected to the pad ring.

process of the design data.

On receipt of a design database from a customer it is "fractured" on a pre-processor computer. This procedure entails the breaking up of complete design elements into fundamental polygons. The fractured design is then submitted to the e-beam computer that then proceeds to load a wafer covered with a thin coating of e-beam resist. The computer then controls the writing of a complete layer of the design by a narrow electron beam scanning the wafer at high speed. Once one design layer is completed the e-beam goes on to write similar design layers over the whole surface of the wafer or alternatively, if more than one design is being placed on the wafer, over a section. The wafer is then removed and etched in the conventional manner ready to go through the complete cycle repeatedly until all the layers of a design have been built up.

Corrects any discovered faults in the design.

The hitch is that most vendors, because of the expensive computer needed, need to set high charges for this job. Also, the time taken to complete this cycle can be lengthy and can as a rule be measured in weeks rather than days. Design iterations are definitely frowned upon by vendors and the users' bank manager alike!

The alternate approach

As gate arrays have the seeds of their own limitations embedded in the technology a different approach was required if the use of asics was to be made available to a wider base of users. The Shortland report indicates that the principal reasons why so few manufacturers are benefiting from the use of asics are:

- design costs and up-front payments are too high
- they require small quantity production runs
- no application for custom silicon
- no second-source for chips.

It is from recognising the deficiencies in the current technologies that European Silicon Structures was formed. In several innovative ways, the company took a radical position in a mainly traditional market and put together an integrated software and manufacturing policy that could provide a practical means of reducing the barriers to using custom silicon. These principal innovations lie in two areas, firstly, i.c. design tools that are analogous to the microprocessor development system, and secondly the removal of the need to use masks by writing direct onto the silicon wafer by means of an electron beam.

Desk-top design approach to custom silicon

If the designer of a microprocessor-based system needed to dispatch every design to a semiconductor vendor to verify whether a program has been correctly coded, the wide-scale use of microprocessors would have been severely curtailed. This is the very situation engineers have to contend with now if they want to utilise custom silicon. Although in-circuit emulation is not avail-
able for custom silicon designs it is possible to complete the whole design of a custom chip on an engineer's desk if a different approach is taken.

The principal reason preventing the layout of chips on smaller desk-top machines is the computing power required to support gate array router software. If the manufacturing process encompasses the writing of all layers, when the router runs out of space in a clogged channel instead of eventually abandoning the run the software can stop, increase the width of the channel, and reroute that wire in the channel. In this way it is possible to guarantee 100% routing on a small desk-top workstation. A design engineer can enter the schematic diagram into a schematic editor, carry out an initial functional simulation (without real loading data), lay out the chip and resimulate the design with real loading data.

Once the logic diagram has been entered the complete layout cycle can be executed in hours rather than days or weeks. The principal benefit of this style of design is flexibility. In the same way the use of an in-circuit-emulator in conjunction with a native compiler or assembly code editor allows more or less instant redesign, chip logic can be changed, logic or wiring errors can be corrected, extra or fewer pads selected or aspect ratios of the final chip modified just as quickly. All this without indeterminate external computer charges.

The ES2 Fab — an alternative approach

An innovative method of manufacturing was needed if ES2 was to support the criteria by which the widescale use of custom silicon will be ensured in coming years. These are the ability to support prototype production without an undertaking from the customer that the design will go to high-volume production. These objectives can only be met by the removal of the straightjacket caused by the need to use masks. Electron beam write-on-wafer is probably the only viable technology for accomplishing this.

The Able 150 e-beam machine used by ES2 is manufactured by Perkin Elmer and is essentially an inverted electron microscope. A very narrow beam of electrons, of less than 1 micron across, writes the pattern of polygons into an e-beam-sensitive photoresist without the intervention of a mask. The only limit to maximum die size the maximum number of different designs on a wafer is the software preprocessing time needed prior to physically writing a wafer.

The use of e-beam technology is not the only change required of a fab dedicated to small volume production. The conventional fab is oriented to processing many wafers in an individual production run, as many as 50. For example, if a wafer contains a die of 3 by 3mm this means that approximately 940 die per wafer could be expected to function after yield considerations; this means a total of over 47,000 die per run! A fab that is dedicated to supplying low-volume must be able to run as few as two wafers per lot. The ES2 fab is operated in this manner and actually assigns a technician to see an individual wafer through the complete production cycle to ensure that the design will be right first time.

Chris Care, F.I.E.E., is corporate marketing manager at European Silicon Structures, Bracknell. Tel 0344 52 52 52.

In coming years the use of custom silicon to enhance the functionality and individuality of electronic products will become widespread as barriers to using the technology are removed.

May's front cover showed 28 2 micron designs on one ES2 wafer.

Perkin Elmer's Able 150 electron beam machine is capable of writing designs direct onto a wafer without the need of a mask.

It is now possible to write more than one individual design onto a wafer, which enables semiconductor vendors to support small production runs.
SEMICONDUCTORS

WHATEVER HAPPENED TO WAFER SCALE?

Pictured here is the first product to use what in the wafer scale community has become known as the Catt Spiral. It is an array of devices on one 6in wafer connected in such a way as to eliminate faulty devices and is the only known successful approach to wafer-scale integration. Both Texas and Trilogy in the US abandoned work in this area after huge amounts of money had been spent. British company Sinclair Research came close to marketing a half-megabyte memory based on a 4in wafer around three years ago but the work was transferred to Anamartic, who are believed to be about to market a product with at least 20Mbyte of memory. A stack of ten such wafers would form a memory - a 'solid state disc' - of 200Mbyte in a space smaller than a floppy disc drive, yet with an access time of the order of 100μs.

And what looks to be a 'first' for Britain's semiconductor industry is based on technology first described in this journal. Though patented as long ago as 1972 by Ivor Catt, the Catt Spiral algorithm, as it has since become known, was first disclosed in 1981 in an article entitled simply 'Wafer scale integration' (July issue) describing his spiral - an algorithm for producing a fault-tolerant wafer array of perfect chips from an imperfect wafer. Catt had previously tried to interest JK learned journals in the work, but they all rejected his paper.

The photograph is a superposition of a wafer and c.r.t. tracing of the algorithm, based on an idea by Neil MacDonald and Gordon Neish of Anamartic Ltd. of Milton Hall, Cambridge.

World's first wafer-scale success
By continuing to design using only standard parts in increasingly obsolete configurations, and thus failing to exploit the latest ASIC technologies, the majority of UK small/medium electronics companies are losing their competitive edge against foreign ASIC users.

This potentially damaging ASIC gap between small/medium British companies and their foreign competitors has now spurred the UK’s Department of Trade and Industry to launch a new nationwide awareness campaign that will stress the vital new factor in current ASIC technologies: their accessibility to even the smallest electronics manufacturing company. In spite of all the publicity given to recent developments in programmable logic devices, gate arrays, standard-cell designs and full-custom chip production, the DTI say a worryingly high proportion of British electronics companies still have not ‘got the message’ about these application-specific integrated circuits.

According to computer-aided engineering consultant Mike Shortland, who headed DTI research into the subject, what is needed is a way of convincing companies on an individual basis – especially small firms – that custom-I.C. technology has something to offer and that it is relevant to their businesses. “Detailed research we carried out a year ago showed that over 70% of all small/medium British electronics companies were still not aware of this relevance then, says Shortland “and more recent research has shown just as surprisingly that the situation has not materially changed.”

The use of application-specific I.C.s in electronics design has been an essentially big-company preoccupation. While the largest British electronics companies – those with >500-employee have almost all been intensive users of ASICs for up to a decade, only 60% of medium-sized companies and less than 25% of small companies (<200 employees) have yet begun to exploit even the simplest forms of ASIC, such as programmable logic arrays.

This dominance of the British ASIC market led by large companies has not been unduly worrying. In fact, the readiness of the British majors to adopt ASIC-based designs has so far been responsible for giving the UK the clear European lead in their exploitation; Dataquest for instance forecasting almost 20% of this year UK consumption of integrated circuits as being in ASIC form, as opposed to only 10% worldwide.

Nevertheless, this commendable UK lead in taking advantage of ASIC technology is now showing signs of fading, as other countries persuade themselves better at promoting the take-up of ASIC technology by companies of all sizes. Several countries with the fastest-growing rates of ASIC usage have already implemented government-sponsored ASIC-promotion schemes, stressing the way in which the latest technologies are just as appropriate to the smaller companies as to their larger rivals.

In fact, as research sponsored by the DTI among British companies shows*, company size need no longer be a barrier to the successful use of custom I.C.s, even the most complex devices. For example, the 30% of small/medium companies who were already using ASICs reported a generally marked level of success in doing so, covering everything from typical savings of 10 to 40% of manufacturing costs to smaller physical size of products (e.g. one PCB. instead of four) and higher performance (e.g. ten times the speed of a random-logic alternative). Enhanced reliability, shortened design cycles, increased security of proprietary designs, and the ability of originate whole new product concepts were also commonly reported.

These small-company users also proved successful at exploiting the full range of ‘technologies’. While the most commonly used devices are the relatively simple P.L.A.s as would be expected (used by 60% of the small companies, 80% of medium size), the more complex gate-array devices were used almost as frequently (50% of small users, 60% of medium). Even the most complex standard-cell and full-custom ASICs proved to be relatively widely used even by the small companies – 25% of which used cell-based devices and no less than 20% full custom.

As these figures show, the idea that small electronics companies simply do not have

the technological background to exploit current ASIC technology just does not hold water. Nor do the other reasons generally put forward by the non-users among the small/medium companies as explanations why the new 'custom-silicon' technologies are not for them — high engineering costs, low production volumes, etc.

These arguments for not using ASICs are directly contradicted by the research finding that the markets, products and size of the non-user companies are not dissimilar from those of the successful user companies. About the only difference that could be found in the objective circumstances of the user and non-user companies was the proportion of graduate designers employed by each — over 80% of the user companies employed graduates for over half of their designer posts, compared with under 50% of the non-user companies.

As this factor suggests, the real difference between user and non-user companies maybe more one of in-company attitudes and awareness than of external factors. In fact, even companies operating in similar ways in similar markets were shown to have very different attitudes about the relevance of ASICs. These included the fact that the ASIC users were more than twice as likely as the non-users to be able to identify the extent to which their foreign competitors were moving over to ASIC-based designs. "A dangerous complacency among non-users" the report notes.

The survey concluded that most of the non-user companies are out of touch with recent developments in custom-I.C. supply, and are basing their opinions on obsolete information. In particular, many have preconceived and outmoded ideas of ASIC economics, and when discussing their potential use of ASICs with suppliers lack the ability to put over their requirements in terms that the supplier can act on.

Reinforcing this conclusion of a lack of up-to-date awareness, the survey found that 80% of the ASIC non-users responded that they would 'welcome and exploit' a new DTI awareness scheme. On the other hand, neither the non-users nor their ASIC-using counterparts put much emphasis on the importance of other government initiatives such as support grants in influencing their attitudes to custom silicon. Concentrating resources on improving awareness has therefore been the key aim of the DTI's new initiative 'Custom Silicon Now'.

The campaign will benefit most directly all the 3000-odd potential users of ASICs among the small/medium electronics manufacturers, but beyond this it also aims to benefit the rest of the UK electronics industry, including the large companies who rely on their smaller counterparts for a great deal of subcontracted design and manufacturing.

Perhaps most of all, it should also benefit the ASIC supply industry, for which the smaller companies offer a potentially very
useful extra market. With small/medium companies already buying some 20% of all electronics components, there seems no reason why they should not eventually account for a similar proportion of new ASIC design starts. And with total UK ASIC design starts already running at 2500 per year, this could provide extra business for the growing number of suppliers concentrating on lower-volume ASIC applications.

These low-volume specialist suppliers include not only the well-publicised new generation of ASIC manufacturers such as ES2 and Qudos, but also a whole range of associated companies including distributors, design houses, silicon brokers and consultants, CAD suppliers, and suppliers of P.L.A. programmers, and all types of ASIC-oriented ATE. For these ASIC-supply companies, the main problem in exploiting the potential new market offered by the small/medium electronics manufacturers is the additional support they will inevitably have to provide to this type of user. All the evidence is that both suppliers and small/medium users have experienced real difficulties with the supplier/user interface. Suggestions on reducing these difficulties are a key part of the study’s conclusions, and the new DTI campaign is likely to be of considerable interest to potential new suppliers of ASIC services as well as their users.

If the DTI initiative succeeds in helping UK ASIC suppliers to cater more positively for the small/medium user, the benefits may also provide a boost to the international competitiveness of the suppliers.

Whether the UK electronics industry – as either suppliers or users of ASICs – actually succeeds in meeting these new challenges of the custom silicon markets will inevitably depend on its own efforts. However, by providing a new focus for the industry’s efforts, the DTI Custom Silicon Now! campaign promises to provide a key starting point.

After using a simple terminal on-line to a Plessey computer to design the gate arrays in their 1281 digital multimeter, Datron Instruments have since invested in a Mentor Graphics System for all their CAD including future chip design (top). Cell-based technology enabled this telephone-cable gas pressure monitoring system (right) to be reduced in both size and cost.
“For ASICs I need a company with experience in all parts of the process.”

Toshiba is No.1 in CMOS gate array technology.

Sit down at our Design Centre in Camberley, log onto Kawasaki, and together we will turn your ideas into an ASIC reality. Alternatively, you can send us your specifications and we can interface with your workstation.

Design. Layout. Simulation. Verification. Prototyping. Volume Production. A better ASIC partner you will not find. The resources of the world’s No.1 producer of high quality CMOS devices are yours, to provide you with the know-how, technology, and manufacturing to put you out in front.

With the help of our enhanced LDS software and applications engineering team, you can develop your own industry standard 1.5 µ CMOS gate arrays with up to 50,000 gates, 100 ns speeds to 0.7 nanoseconds.

Make the might of Toshiba work for you. Design Solutions. Performance. Product Choice. Volume Delivery. Tell us your problem, and we will take care of the rest.

Toshiba Semiconductor Division, Watchmoor Park, Camberley, Surrey. Telephone: 0276 694500. Telex 888822.

*The data in this ad are correct.

TOSHIWA

Relax, Toshiba has it.
The last few years has seen the introduction of an extraordinary variety of new components which fall under the broad category of application-specific integrated circuit. Many electronic products can benefit from the use of asics by reason of reductions in cost, size, weight or power consumption, or improvements in performance or reliability, or just extra bells and whistles to help persuade a customer to buy. In parallel with this explosion of choice, a whole new vocabulary of jargon has been invented to keep the uninitiated at bay. To make matters worse, supplier's catalogues often lump all these devices, along with the humble transistor, under the bland title of 'semiconductors'.

Choosing an integration approach

One decision that must be made by a designer who is keen to make use of the latest techniques is what level of customization to go in at, or to put it a better way, how much work needs to be done to adapt what is available to the problem in hand. This work can vary from simply designing a p.c.b. full of standard chips (obscurely known as board level customization) to a full-custom single-chip system. For more complex problems a p.c.b. full of specially designed devices may be the solution. The decision as to how much function to pack into each individual asic may be made either for economic reasons (bigger chips give lower yields) or simply out of a desire to divide a problem into smaller parts. A common, powerful combination is a microprocessor, asic and perhaps external memory. It is technically feasible to pull all these into a single chip but unlikely to be worthwhile because of the extra complexity and high unit cost, unless size is paramount. For most applications, design time and effort will be the limiting factor rather than technology capability.

We make no attempt in this article to make a value judgement on the various technologies available. Each particular technique has attendant advantages and disadvantages. Hybrids are more flexible than monolithic devices, but are also more costly. Cmos would seem to be superior to nmos due to the low power capability but it cannot achieve such high densities. Even metal-gate cmos, treated as obsolete by most manufacturers, has important advantages in higher voltage applications.

Levels of customization

- Standard (t.t.l. cmos, e.c.l.)
- Programmable (eprom, e.p.l.d., p.i.d.)
- Mask programmable (rom, single-chip microcontroller)
- Gate array (e-beam, single-layer masked, multi-layer masked)
- Cell based (full custom, but mostly predefined blocks)
- Full custom (user-designed transistors, capacitors, resistors)

In general costs and timescales for development rise going down the list, as the user comes in at a lower level of function. But flexibility and unit cost savings also increase. Each of the options result in a compromise of one sort or another. When designing with standard parts, a frustratingly large number of packages is often needed to perform a specified function, however the final result is relatively easy to debug the modify.

Using proms and p.l.d.s will often simplify combinational logic, but the internal structure is too rigid to solve a general problem economically. In particular, storage elements tend to be very sparse. Recognising this problem, manufacturer's have produced a plethora of different devices, with varying degrees of success. More seriously, because of the once-only programming capability of standard p.l.d.s, it is not possible to fully test these devices prior to programming. Hence the user is left with the responsibility to verify each device individually after programming. This is normally done by means of a series of test vectors, which are simply columns of numbers specifying the conditions at each input and output of a known good chip. Most development systems will have facilities to aid generation of these vectors, which are non-trivial if the device incorporates feedback from storage elements that do not come out to an external pin.

There are as many different processes for asics as there are for standard circuits.
hough custom integration techniques have been available for many years now it is only recently that the technology has matured to become commercially feasible for small and medium-sized companies. Suppliers are meeting an increased demand by providing design tools that are easy to use and by reducing the investment needed to customize circuits.

This article outlines the products and technologies available and gives guidelines on choosing between the custom devices and on selecting a supplier.

The benefits of integration
The 'custom i.c.' label covers a range of products which are used for a wide variety of reasons. They include

- reduction of component costs
- reduction of assembly time and cost
- miniaturization of a product size and weight
- improved performance in terms of speed and e.m.c. properties
- increased reliability (having no internal solder joints makes a significant improvement)
- automatic testability (devices are tested by the manufacturer before shipping), and
- design security (difficult for competitors to copy).

As with most developing technologies, the first users of custom integration wanted the improved performance and reduced size offered with little regard to the cost. Commercial companies can now take advantage of the experience built up in the industry to achieve real benefits of cost reduction to make better and less expensive products.

At the moment, procuring custom silicon still requires a bigger investment than procuring a printed circuit board, but if production runs are in volumes of more than a thousand per annum then it is worth keeping a close watch on the integration industry.
A full-custom device is designed laboriously by hand from the transistor level up. Each component must be characterized by the designer and shapes and sizes must be described in detail for the manufacturer. Full-custom ICs are not cost effective for most companies – production volumes need to be very high for sensible amortisation of the development costs.

Technologies and processes

To assess the ‘technology’ required for each application, the key issues are:

* type of circuit (analogue/digital/high power/mixed)
* performance (clock frequency or analogue character)
* product application (power supply, working conditions).

The major technology split is between CMOS and bipolar devices. In line with standard electronic design, CMOS is particularly good for low or variable power applications (particularly battery-driven products) and bipolar is better for very high speed design and many analog functions.

Complementary MOS is the most popular technology for gate arrays and standard cells; programmable logic devices are predominantly bipolar although an increasing number of CMOS families are becoming available. Mixed analogue/digital integration frequently has to be a compromise.

The process used will affect the performance of the device and the unit cost. The feature size is important: the smaller the feature size the faster the circuit will run. In practice the standard products now available will run fast enough for most commercial applications. As smaller feature sizes become proven and give a high yield in manufacture, their prices are reduced due to the smaller area of silicon used. The processes in common use today for semi-custom and cell products can be grouped into three:

- 3-5μm CMOS processes, with double or single-layer metallization, are old and becoming more difficult to buy. They are still useful for high voltage, low power applications – for example, a product powered directly by a 9V battery.
- 2μm, double-layer metal processes are the most widely available this year and will usually give the lowest cost device.
- 1μm processes, some with three layers of metallization, are available but are still unusual and therefore more expensive than the standard 2μm device.

How to choose a device

Most of the points need to be considered iteratively with others, as the implications of each decision can be widespread. Some decisions will lead to obvious and fast conclusions; for less straightforward applications previous experience is invaluable.

* Analyse the complete system before partitioning.
* List any desirable new features, with priorities
* Outline a performance and functional specification.
* Partition the functions for the most cost-effective components.
* Set a target production cost.
* Predict sales volumes.
* Define a development timescale and budget.
* Decide a policy for managing the risk.

After partitioning, analyse the sections to be customized. Functions will often benefit from a review of the system architecture to allow for the constraints of ASIC design: the usual circuit has too high a ratio of I/O to content. Outline design will be needed for a gate count or list of components to be integrated, with contingency especially for test circuitry. Pin and component counts are needed before a device can be selected or quotes can be extracted from suppliers.

The choice of technology is determined by the partitioning between analogue/digital and the performance specification.

The process is often transparent to the user and can be chosen by the manufacturer. If there is no reason for choosing something special, leave the decision to the supplier.

To reduce the risks involved in trying ASIC techniques for the first time it is prudent to start with a small device (fewer than 3000 gates of logic) and to separate analogue and digital functions, mainly for reasons of test confidence. Allow perhaps 30% contingency above an initial estimate of size and choose a supplier with larger devices available in the same family. To start the integration process with a gate array and discrete analogue components and then upgrade to a mixed standard cell design can be a worthwhile low risk approach in some cases.

How to choose a vendor

Most ASIC vendors are in the business of selling silicon. As in other businesses, suppliers will be very helpful – to the point of providing ‘free’ design work – if you can promise to buy large quantities of their product. When in this position, make the most of it and find the best deal by talking to many vendors. Around 60 companies advertise products under an ASIC label in the UK. Not all are credible and the area is still a jungle for the first time buyer.

For a programmable logic device, choose a family of chips that suits your design, that is well supported by programming equipment, ideally compatible with prom pro-

Programmes you may already have, and experi-

For the other ICs, the manufacturer and your relationship with him are important. Vendors are widely different in all the usual ways: costs, timescales, reliability and expertise. In many cases the technology is less important than the vendor’s ability to meet your expectations.

When selecting a vendor, consider:

- technologies and processes offered
- design interfaces possible
- vendor’s track record and competence
- unit price and non-recoverable costs
- delivery timescales
- communications and location
- company’s likely future and financial position.

If you are buying an unusual technology the choice of vendor can be narrow, making the selection relatively easy. If, however, you are buying a CMOS gate array of moderate size and performance, there are very many competing products and the choice is more difficult. The market can change very rapidly and it is effective to survey the major contenders for each chip design started. Loyalty is comfortable but the details of each design can lead to surprising cost differentials for a range of comparable packages.

The design interface is important when the design task is split between companies and if it is planned to do most of the work in-house the point of data transfer must be defined at the outset.

Some manufacturers offer a low-cost entry to ASIC technology by means of a regular multi-project wafer scheme. These can be a low risk introduction to integration, with up-front investment being as little as a few hundred pounds. Options are usually limited but if the application is appropriate confidence can quickly be built up, and marketing prototypes can be made without rigorous testing and optimization. Second sourcing is a contentious issue with ASIC suppliers. A true second source will almost certainly involve a new set of masks produced from flexible source code.

To be the first customer or the first to use a new process carries a high risk; to use a mature technology, with both larger and smaller devices available in the same family, will give a good chance of success. As this is not a one-off purchase business it is wise to avoid small companies which tend to disappear as quickly as they arrived.

Tooling for production will cost anything between £500 and £50 000; component trials for a range of companies. The Table on pages 601/2 gives an outline summary of companies in the UK. For your own applications, talk at length to several vendors and assess all the options...

Claire Ruskin is leader of the electronic product design group at Cambridge Consultants.
The three main options open to a prospective ASIC user are to:

- Purchase the appropriate design equipment and do-it-yourself (including the communication and interface with the silicon vendor).
- Go directly to the silicon vendor and have them do it all for you.
- Go to an independent design centre.

As an independent design centre I'll describe some of the benefits of this approach.

One of the first considerations has to be capital investment. We are all aware that the cost of hardware, and for that matter good software, has significantly reduced in recent years, however, a good usable system providing full breadboard simulation facilities, will still cost around £40K. A company just starting out on the ASIC route will be loath to spend such a capital sum until they are convinced of its value to their own environment and, perhaps more important, until they are able to justify such an investment and realistically judge the payback period. This will depend on the number of designs going through the system in a typical accounting period. Therefore smaller companies, or even the larger companies who have few new designs per year, can benefit from hiring time on a well-equipped design centre system.

Another consideration has to be skill and equipment familiarity. However simple a system is to use, there is always a re-learning time. Using the skills and resources of a design centre will mean maximum utilisation of the equipment whilst allowing the design engineer to exploit their own specialist knowledge and skill.

In an ideal environment, we recommend that the infrequent user of ASIC design environment employs a design centre that will give access to the equipment whilst at the same time devoting dedicated technical assistance to ensure maximum system usage. In this way the customer gets the best of both worlds - a fast, efficient design cycle and the hands-on experience that will let the user fully learn and appreciate what ASIC designs can offer. When skill levels are sufficient and the appropriate usage is achieved, the customer should seriously consider purchasing equipment for their own use.

Looking at the choice of ASIC design facilities, the customer must also acknowledge that product development in terms of hardware and software is leaping ahead almost daily. A progressive design centre will keep pace with this and, because of the throughput and usage of the system, should be able to cover the costs involved.

Let's now examine the ASIC design centre offered by traditional semiconductor distributors. The word distributor in this context is unfortunate and should be replaced by 'a supplier of products and services'. The services part of this description has been explained, but let's examine the product side.

A customer going direct to a manufacturer of custom silicon will be restricted by those products actually manufactured and supplied by that manufacturer. At Rapid we have a number of suppliers, each market leaders in their own sectors. A customer coming to us looking to put a design into a semi-custom device may well be advised that a programmable logic (i.e., P.L.A., E.P.L.D. or I.C.A.) would more than suffice even though it meant sourcing the actual Silicon from a different manufacturer. The same may also be true in reverse.

The same can be said for the design equipment. At Rapid we have a number of systems networked together to allow very cost-effective utilisation. Individual chips can be designed and developed in isolation (and indeed in parallel if time is of the essence) and then brought together on a system-level simulation to not only test the individual designs but also how they will perform with each other.

I would dispute the myth that high volume is necessary before ASIC designs become cost-effective. Our experience has shown that production runs as low as a few hundred can be of lower overall cost than traditional design and production methods. Therefore recommend that any prospective ASIC designer or company question their design centre to establish the break-even point for their particular design. An investment in a few hundred pounds on a feasibility study early on could well save thousands when that product goes to market.

A 'distributor' is able to offer customers advice and products ranging from C.A.E. equipment to ASIC systems and designs with minimal risk and outlay together with ability to become involved with ASICs at any level. A further advantage is that the traditional semiconductor distributor will combine ASIC services with true distribution. For example, customers requiring 4,800 pieces of an ASIC design can negotiate to have 400 pieces shipped monthly over 12 months, thereby minimizing cash flow. This will probably not be available from manufacturers.
## INDUSTRY INSIGHT

### Application specific integrated circuits manufacturers represented in UK

<table>
<thead>
<tr>
<th>Manufacturer (parent)</th>
<th>Technologies offered</th>
<th>Product type</th>
<th>Feature size (µm)</th>
<th>Customising process</th>
<th>Gate array sizes</th>
<th>Analogue cells</th>
<th>Multi-project wafers</th>
<th>Design engineers (UK)</th>
<th>Past UK customers (designs)</th>
<th>Geographical Fab. line</th>
<th>Design centres</th>
<th>Typical cost for 1000 gate loading</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMD Inc</td>
<td>bipolar</td>
<td>3/4, 7/8</td>
<td>up to 32K</td>
<td>no</td>
<td>20</td>
<td>US</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>100k-200k</td>
<td></td>
</tr>
<tr>
<td>Advanced Devices Inc</td>
<td>CMOS, MDI</td>
<td>3</td>
<td>up to 1K</td>
<td>yes</td>
<td>2</td>
<td>US</td>
<td>ESE, Newbury</td>
<td>$40-200k</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Applied Micro Circuits</td>
<td>CMOS, bipolar</td>
<td>2</td>
<td>1</td>
<td>yes</td>
<td>2</td>
<td>US</td>
<td>Cambridge</td>
<td>$25-55k</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Armel Corp</td>
<td>CMOS, bipolar</td>
<td>1</td>
<td>590/32-520/35A</td>
<td>2.5k</td>
<td>2</td>
<td>US</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>nil</td>
<td></td>
</tr>
<tr>
<td>AT&amp;T Microelectronics</td>
<td>CMOS, bipolar</td>
<td>2.5</td>
<td>0.15</td>
<td>70</td>
<td>10</td>
<td>US</td>
<td>UK, Blackwell</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Austria Micro</td>
<td>CMOS, bipolar</td>
<td>2</td>
<td>up to 2K</td>
<td>no</td>
<td>2</td>
<td>US</td>
<td>Aust, Swindon</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cherry Semiconductor  Corp</td>
<td></td>
<td>4</td>
<td>6</td>
<td>All-Ford</td>
<td>1</td>
<td>US</td>
<td>Plymouth</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>European Silicon</td>
<td>CMOS, bipolar</td>
<td>2</td>
<td>3</td>
<td>no</td>
<td>10</td>
<td>US</td>
<td>Fra, Bracknell</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Solder 1200 4-50</td>
<td></td>
</tr>
<tr>
<td>EYER Corp</td>
<td>CMOS, bipolar</td>
<td>3.2</td>
<td>e-beam</td>
<td>yes</td>
<td>10</td>
<td>US</td>
<td>(1000)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$8-12k analogue</td>
<td></td>
</tr>
<tr>
<td>Fujitsu Microelectronics Ltd</td>
<td>CMOS, bipolar</td>
<td>8.5</td>
<td></td>
<td></td>
<td>5</td>
<td>US</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GE Solid State</td>
<td>CMOS, bipolar</td>
<td>1.2</td>
<td></td>
<td>35</td>
<td>3</td>
<td>US</td>
<td>Cumberley</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gigabit Logic</td>
<td>CMOS, bipolar</td>
<td>0.8</td>
<td>5</td>
<td>50k</td>
<td>1</td>
<td>US</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$100k/50k</td>
<td></td>
</tr>
<tr>
<td>Hitachi</td>
<td>CMOS, bipolar</td>
<td>1.8</td>
<td></td>
<td>5</td>
<td>5</td>
<td>US</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hughes</td>
<td>CMOS, bipolar</td>
<td>3.6</td>
<td>100k</td>
<td>150</td>
<td>1</td>
<td>US</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IMP Europe</td>
<td>CMOS, bipolar</td>
<td>2.3, 2.5</td>
<td>5</td>
<td>24</td>
<td>3</td>
<td>US</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Innovative Silicon</td>
<td>CMOS, bipolar</td>
<td>2.3, 2.5</td>
<td></td>
<td>240</td>
<td>3</td>
<td>US</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intel</td>
<td>CMOS, bipolar</td>
<td>1.5, 2.5</td>
<td></td>
<td>150</td>
<td>5</td>
<td>UK</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>International Microelectronics</td>
<td>CMOS, bipolar</td>
<td></td>
<td></td>
<td>5</td>
<td>5</td>
<td>US</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LSI Logic</td>
<td>CMOS, bipolar</td>
<td>1.1, 1.5</td>
<td></td>
<td>25</td>
<td>7</td>
<td>UK</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marconi Electronic Devices Ltd (GE)</td>
<td>CMOS, bipolar</td>
<td>2.5</td>
<td></td>
<td>150</td>
<td>16</td>
<td>UK</td>
<td>Lincoln, Wembley</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maita Harris Semiconductor (Maita, Harris)</td>
<td>CMOS, bipolar</td>
<td>2.5</td>
<td></td>
<td>150</td>
<td>16</td>
<td>UK</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metec NV</td>
<td>CMOS, bipolar</td>
<td>2.5</td>
<td>5</td>
<td>24</td>
<td>3</td>
<td>US</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Microcircuit Engineering Ltd (Smiths Ind plc)</td>
<td>CMOS, bipolar</td>
<td>2.5</td>
<td></td>
<td>24</td>
<td>3</td>
<td>US</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Micro Power Systems</td>
<td>CMOS, bipolar</td>
<td>2.3</td>
<td></td>
<td>24</td>
<td>3</td>
<td>US</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motorola</td>
<td>CMOS, bipolar</td>
<td>2.3</td>
<td></td>
<td>24</td>
<td>3</td>
<td>US</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mullard (Philips)</td>
<td>CMOS, bipolar</td>
<td>1.52, 2.5</td>
<td>10k</td>
<td>24</td>
<td>3</td>
<td>US</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nat Semiconductor</td>
<td>CMOS, bipolar</td>
<td>1.5, 2.5</td>
<td>10k</td>
<td>24</td>
<td>3</td>
<td>US</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NEC Corp</td>
<td>CMOS, bipolar</td>
<td>1.5, 2.5</td>
<td>10k</td>
<td>24</td>
<td>3</td>
<td>US</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NEC Electronics</td>
<td>CMOS, bipolar</td>
<td>1.5, 2.5</td>
<td>10k</td>
<td>24</td>
<td>3</td>
<td>US</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Newmark</td>
<td>CMOS, bipolar</td>
<td>1.5, 2.5</td>
<td>10k</td>
<td>24</td>
<td>3</td>
<td>US</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OKI Semiconductor</td>
<td>CMOS, bipolar</td>
<td>1.5, 2.5</td>
<td>10k</td>
<td>24</td>
<td>3</td>
<td>US</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Panasonic (Matsushita)</td>
<td>CMOS, bipolar</td>
<td>1.5, 2.5</td>
<td>10k</td>
<td>24</td>
<td>3</td>
<td>US</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
from page 597

Mask-programmed microcontrollers are really a type of full-custom device, but the only user-input is in the form of software, which is well-suited to performing complicated tasks relatively slowly. The availability of programmable versions of most microcontrollers makes the process relatively hazard-free.

Gate array techniques offer the simplest route into full flexibility of digital design. The required arrangements of transistors which generate gates or storage elements are predefined. All the user needs do is specify the types of elements needed and the interconnections by means of a netlist or schematic.

The fixed sizes and arrangements of transistors do not lend themselves to being used for analogue functions such as amplifiers and analogue-to-digital converters. For analogue and mixed-analogue/digital chips cell-based or full custom techniques should be used. These techniques are similar in that all features are user-specifiable, but with the cell-based techniques most common functions are pre-defined items which can be included as needed. This obviously saves a lot of design work. Even if analogue circuitry is not needed a cell-based technique might be chosen to increase density and hence ultimately reduce unit costs.

Special considerations for asic design

Many asic vendors offer a conversion service which allows a logic function performed by a board full of standard parts to be converted into monolithic chip. However unless the original circuit was designed specifically with integration in mind considerable re-design is likely to be needed for a variety of reasons.

Board-level products frequently make use of asynchronous counters, delay lines and even capacitors to minimize component count. On-chip delays, set-up and hold times may be very different to the equivalent standard parts and also may vary hugely from chip to chip.

In mass production, up to 50% of chips on a wafer will not function due to defects in the silicon structure. To reduce costs these chips must be rejected before packaging. This is done using a wafer probe that is connected to each chip in turn and applies a series of test vectors and compares the chip outputs with what was expected from simulation of the logic function. This method only works if all internal storage elements can be set to a defined state, and the test inputs cause all internal costs to be exercised, with the results reaching the outputs. Usually extra logic has to be added to satisfy these requirements.

Most standard parts incorporate buffering to drive the outside world. On-chip geometries and drive capabilities are much less and extra buffers may be needed which will depend on lengths of routes on metallization layers.

If tri-state buses are in use, these may float to an undefined level internally and cause variable supply currents due to input thresholds being crossed.

Dense functions such as rams or rams may not be integrable economically. This may limit the amount of function obtainable per chip due to pin-count considerations.

Simulators

Because of the difficulty in testing and debugging chips simulators are used extensively to give confidence in a design before committing to the prototype stage. For gate arrays or cell-based designs around predefined digital cells, a digital simulator should be adequate. For full custom designs the simulator will need to model down to the transistor level, with a big increase in effort, time and cost. Hence a balance must be struck between simulation effort and confidence in the finished design. Most simulators do not model glitches and other hazards very well, so fully synchronous designs usually stand a better chance of success.

A simulator can also help with development of manufacturing test vectors, since the test inputs cause all internal costs to be exercised, with the results reaching the outputs. Usually extra logic has to be added to satisfy these requirements.

Most standard parts incorporate buffering to drive the outside world. On-chip geometries and drive capabilities are much less and extra buffers may be needed which will depend on lengths of routes on metallization layers.

If tri-state buses are in use, these may float to an undefined level internally and cause variable supply currents due to input thresholds being crossed.

Dense functions such as rams or rams may not be integrable economically. This may limit the amount of function obtainable per chip due to pin-count considerations.

Simulators

Because of the difficulty in testing and debugging chips simulators are used extensively to give confidence in a design before committing to the prototype stage. For gate arrays or cell-based designs around predefined digital cells, a digital simulator should be adequate. For full custom designs the simulator will need to model down to the transistor level, with a big increase in effort, time and cost. Hence a balance must be struck between simulation effort and confidence in the finished design. Most simulators do not model glitches and other hazards very well, so fully synchronous designs usually stand a better chance of success.

A simulator can also help with development of manufacturing test vectors, since the test inputs cause all internal costs to be exercised, with the results reaching the outputs. Usually extra logic has to be added to satisfy these requirements.

Most standard parts incorporate buffering to drive the outside world. On-chip geometries and drive capabilities are much less and extra buffers may be needed which will depend on lengths of routes on metallization layers.
Researchers at AT&T Bell Laboratories have produced experimental single-electron transistors—devices so sensitive that just one electron produces changes in the current flowing through them. The devices are prototypes that operate only at very low temperatures. However, scientists there feel their performance may foreshadow a generation of all-metal transistors that are extremely fast and small and consume very little power. In their present form, they could be used as electrometers in experiments to measure induced charges as small as 1% of an electron.

Much engineering and development work would be needed before practical devices such as switches and computer elements could be made with the new transistors. In fact, Greg Blonder, group leader at AT&T Bell, would not come down from his ten year estimate for a ring counter type of device. But they show potential to change the way we think about a future generation of integrated circuits, he told us, because they use infinitesimal amounts of power and space, have an intrinsic speed of less than a picosecond, and use the smallest possible amount of charge transfer.

Even modern, miniaturized f.e.t.s involve thousands of electrons in a similar voltage change, while these devices require just one, which is what leads to the high speed. These devices can now be made through new fabrication techniques pioneered at Bell Labs by co-inventor Gerry Dolan. Researchers use electron-beam lithography to pattern a high-resolution organic film layer. Then they deposit the aluminium electrodes and an oxide barrier. A technique called edge lithography allows devices less than one-twentieth of a micron across to be made by making use of overhangs of deposited metal under which is deposited on insulating oxide. Metal is then evaporated under the overhang or bridge. This form of sandwich results in extremely small capacitance.

The transistors consist of three microscopic parts. The first is an island of aluminium a few hundred atoms across. Connected to the edge of this central island electrode are two tunnel-junction electrodes separated by an insulating barrier only a few atoms thick. The substrate forms a remote "gate" junction that applies an electrical field, creating a steady-state bias—and thus a charge—across the junctions. This charge controls the current passing through the central electrode via the tunnel junctions.

Such a single-electron charging effect in electron tunnelling was predicted a few years ago by K. Likhachev of Moscow University.

---

Researchers at the IBM's Research Center at Yorktown Heights, New York, have obtained the fastest silicon switching results from circuits designed to assess f.e.t. technology in the 0.1-micron gate-length region. Self-aligned and almost fully scaled devices and circuits were fabricated by direct-write electron-beam lithography at all levels, with gate lengths down to 0.07 microns and a switching speed of 13ps.
The use of custom or application-specific integrated circuits is now becoming a reality for many companies. Gone are the days when they were viewed as esoteric artifacts of the military and computer industries, available only to people with large budgets and semi-infinite timescales. Asics are now being adopted widely throughout the electronics industry and are becoming essential to the successful production of cost-effective equipment. Many companies, however, remain uncertain about how to access the technology and are confused by the variety of claims made by the semiconductor companies.

The range of technologies, cad systems, and design styles can be bewildering and obviously each manufacturer is intent on selling their own-brand without reference to competitors' alternatives and perhaps more suitable capability. In the UK, however, potential users of asics have the benefit of a number of experienced "independent" suppliers of asics who undertake the necessary tasks to supply suitable products but who are independent from the semiconductor manufacturers.

These vendors, such as Wolfson Microelectronics, offer a wider range of assistance to companies looking at asic developments and are able not only to choose the most appropriate manufacturer for a particular asic but can ensure that alternative sources of production are available. This provides the user with an important control on the price of end products in this highly dynamic market. In addition, because the independents are not concerned with manufacture themselves they concentrate their efforts on the needs of the user.

The manufacturers don't have all the answers, according to Dr David Milne, m.d. of Wolfson Microelectronics.

The photograph shows a full-custom asic which is mostly analogue intended for use in mobile communications products. The chip, which is manufactured in a 3µm double poly cmos technology for low power and high performance, integrates several high precision audio-band filters with other non-linear signal processing functions. The filters themselves make use of the continuous time transconductance technique pioneered by Wolfson Microelectronics.
optimizing the design to maximize the benefit of using an ASIC to the end customer. The independent ASIC vendors therefore provide much more than just an interface to manufacture and subsequent supply of customer-specific products.

One of the most difficult areas in the use of ASICs is translating the system or product requirement into a form which can be implemented in silicon. This will frequently require knowledge of both the customers' system and silicon design technology, something that the semiconductor companies are unable to provide. One way round the problem that has been highly successful has been to restrict the type of circuit to be implemented, for instance, to digital logic for which a simple interface can be defined. An end user who is familiar with logic specification can then describe his circuit in terms of a functional netlist which can be mapped directly onto a regular silicon structure in the form of a gate array. In this approach of course, the manufacturer is only offering to supply products which are in accordance with the netlist and it is up to the end user to ensure through simulation or otherwise the suitability of the product for the system. Many applications however require more variety of circuitry than simple logic and then the design is more complicated. It is essential to marry the total system requirement more intimately to the technology and this is where the independent vendors have to play a key role. Because of their service rather than manufacturing approach, the independents work closely at an engineering level with the end users to specify the ASIC from a systems-level functional requirement. This may involve considerable interaction and possibly engineering development work as the process is not simply one of simulation. A combination of partitioning of the system and synthesis of the wanted circuit functions is wanted. While existing CAD tools are used for system simulation and circuit implementation at both the electrical and physical levels, little useful software exists for the intermediate stage.

For anything other than the most trivial of systems, engineering innovation and inventiveness are paramount in producing the cost competitive product. These skills are harmonised to effective circuit implementation using the latest CAD techniques in the independent ASIC companies. Almost exclusively they are able to offer the combination of systems level consultancy with device implementation and subsequent supply using the optimum technology available on a world wide basis. The ability to choose a high volume, a low-cost manufacturer in, say, the Far East for one product and for another, a manufacturer with the latest memory technology combined with low-power microprocessor and analogue-to-digital converter cells is essential to meet the needs of potential ASIC users. With the capitalization required to set up an advanced semiconductor production facility, manufacture has become a highly specialized business not suited to providing the variety of options necessary to service the ASIC market. An intermediary is required with access to a range of manufacturers and an ability to develop a systems level solution. Hence the importance and increasing role for the independent ASIC vendors with their freedom of action and service orientation.

Walson Microelectronics was founded in 1985 as a supplier of niche market integrated circuits and custom design house.

**FEAR OF FLYING**

There are two principal reasons why more companies are not designing their own chips. Both are based on fear. Everybody knows prototype chips must be expensive. They have at the back of their minds vague stories of great wads of money having to be absorbed or written off by the mass production run. Admittedly all costs are relative but does £100 sound too bad a starting price for your ideal custom-designed logic device? And having five CMOS prototype gate arrays fabricated using electron-beam direct-write methods now costs as little as £500.

Peter O'Keeffe, managing director of Qudos looks at prototype chip design and finds that many of its problems are more than simply technical.

Over the past few years, ASIC technology has become very much cheaper and simpler to use. Despite this most British firms ignore it, preferring traditional methods of circuit design.

The two reasons can really be encapsulated in one - which I call the fear of flying. It is the fear of becoming a success, and its awful corollary, the worry of making a hash of things.

A recent report from the DTI* claims that most small-to-medium size companies are unaware of the advantages of ASICs and are not taking advantage of the opportunities available to them. It is for this reason that the DTI is launching its Custom Silicon campaign now (page 593), a travelling road-show which aims to demonstrate to local businesses the benefits of using ASICs, in which companies such as Qudos will be participating.

The user of every new technique, every innovative system engineer, is likely to be made nervous by the realisation that he is taking some kind of chance, however small. In the case of Qudos's prototype chip production those chances have been reduced to a minimum. However, a company must do all it can to assuage fear.

So one reassuring service Qudos offers is a training course in which professional design engineers, programmers or even gifted amateurs, are invited to design their own chips. There is nothing like hands-on experience to put abstractly thinking minds at rest. Theory is kept to the minimum. At the end of the course, the chip each trainee has designed is put into production.

Another service is the establishment of a network of regional design centres around the country, the first of which is being run in conjunction with Birmingham Polytechnic. The design centres will run basic design

* See footnote on page 563


In addition, Qudos' Quickchip software can be rented for three months for £500, compared to the normal list price of between £5,000 and £25,000 depending on the number of users. Limited numbers of workstations on which to run the software are available for an additional £500 for the three months. Quickchip design software runs under Unix on DEC's MicroVax, Sun, Apollo workstations, and IBM P.T.s and compatibles. Also in support of the campaign is an award scheme for ASIC designers in industry or education for the team accumulating the most points for the most innovative and elegant ASIC design. Points may be accrued for multiple designs. Industrial design teams or individual departments wishing to enter must notify Qudos by the end of June 1988. Prize is a holiday for two in 'Silicon Valley', California.

"Any company that sticks to conventional printed board technology when there is the option of customizing silicon is losing out"

"Q-beam" machine writes the specified pattern directly onto the wafer by electron beam.

Unwanted metal is etched off the wafer by dry-etch plasma machine.

courses for local firms, using Qudos' Quickchip software, enabling these firms to have consultancy on their doorsteps. On top of the two major worries already mentioned is the idea that it probably takes forever to get delivery of customized items.

All this leads to the overall conclusion that the risks are just too high and the nearest standard item is bought instead, or the company sticks to outmoded technology. This is why the ASIC market is not growing as fast as it could.

And the worst aspect of the problem is that industry is in danger of missing the boat.

Any company who is sticking to conven-
The emergence of the personal computer in the field of computer-aided design and engineering has had, in recent times, an important effect on the fortunes of workstation manufacturers. The popularity of IBM-compatible machines means that companies need to provide application software at a cost comparable to the hardware itself. It is this factor that led to the introduction of two software packages called Super Sceptre and Spice Sceptre.

Super Sceptre is a complete low-cost system that can take a design from schematic capture through to logic simulation and place and route for standard cells. It can also go to the validated netlist stage for gate arrays. Spice Sceptre is essentially the same package but with the inclusion of P-Spice from Microsim. This means that analogue as well as digital circuitry can be designed at the transistor level and simulated prior to the start of any layout work.

The basic hardware required to run the Super Sceptre package consists of one IBM-AT, or compatible, with 512K of ram, a graphics monitor and graphics adaptor. The adaptors currently supported are IBM PGA EGA and the Hercules monochrome adaptor. For the Spice Sceptre software a mathematics co-processor is also required.

For transferring the completed database to the factory it is only necessary to have a floppy-disc drive. Other peripheral devices — printer and plotters — are supported as standard.

Super Sceptre has been designed along hierarchical lines so that the designing task can be broken down into a number of sub-tasks. This is not just in keeping with a structured design methodology but it also enables a number of engineers to work simultaneously on different aspects of a design. The cell libraries that are currently supported include 2µm double metal, 3µm double poly and 5µm high voltage cmos gate arrays, and standard cells. The facility to create new cells is also available and together with a training course and continual design support this provides a complete system for asic design.

Schematic capture is normally the first step of any design process. The circuit can be entered graphically with just the cursor keys of the PC or with a mouse connected to a serial port. There is an easy to read menu that reacts instantly to any keyboard inputs. The software also checks as early as possible for any incorrect inputs or design infringements. This correct-by-construction method means that a valid design can be produced ready for simulation within a very short time.

The output from the schematics editor can be a netlist for either the logic simulator or the P-Spice program. Apart from the netlist output, the schematic can also be printed in dot matrix form and also a range of graphics plotters which includes the Hewlett Packard range of HP-GL plotters.

If Spice simulations are currently being done on a Vax machine it is possible to use the schematics to first generate the graphic representation of the circuit and then, with the aid of the Sceptre utilities, to transfer automatically the data to the Vax host computer and invoke the Spice job submission.

The schematics capture programme supports full hierarchical design so, if necessary, the range of analogue and digital cells contained in the current AMS libraries can be simulated at the transistor level and the electrical characteristics can be modified to suit your own requirements.

A Netlist Extraction Trace program essentially checks the schematic for any errors that would cause the simulator to behave incorrectly. This includes checks for open circuits, outputs shorted together and so on. The files generated by the Trace program are: CIRCUIT.BIN, the binary representation of the circuit, CIRCUIT.PAT, the netlist in ascii text format and CIRCUIT.PAT, a basic template file for controlling the simulator.

The AMS simulation program includes unit delay and full timing delay modes. In the unit delay mode the individual propagation delays of each cell in the library is not taken into account. This results in a faster simulator run time and so enables the designer to de-bug the circuit functionally before progressing to the timing simulation mode. This second mode takes set up and hold times into consideration as well as extra delays due to interconnect obtained from the layout database. The input waveforms that are required to exercise the circuit are defined in the CIRCUIT.PAT file.

The format is similar to that of the testers resident in the factory in Graz. This means that it is easy to transfer the results of simulation to, say, a Sentry tester with very little effort.

Simulations can be performed under best and worst case conditions and also at various voltages and temperatures thus providing the designer with a good indication of the final device performance.

A post processor, Display, allows the designer to examine the simulation results either graphically in timing diagram format or in truth table representation. This can also be output on to plotters and printers in the usual way.

If the designer has drawn the schematic using analogue components there is the option to run P-Spice. This is a PC version of the popular analogue simulation package and is provided by Microsim. The only extra hardware that is required is a maths co-processor.

The input to the P-Spice program is in the form of a normal asic netlist which is automatically generated from the schematic. The output results are displayed graphically using a user-friendly interface and, as with all software modules, can be plotted on dot matrix printers and pen plotters.

The layout for the i.c. can be performed on the PC or, if the database is large, it can be performed on the Vax machines in Austria. In this case it is still possible to load layout information back on to the PC if slight modifications need to be implemented. At all times the basis on which the layout is performed is that of netlist consistency. The layout can be checked for design rule violations, power supply shorts and layout to logic consistency.

Once the design has been completed and a test file has been produced it is just a simple matter of sending a floppy disc to a local design centre. This will then automatically be transferred in the factory to the photomask machines and production testers.

Further details: Colin Sutliff at AMS, 0793 37852.

How to design asics using standard PC hardware.
Whatever proportion of ASIC design is handled in-house, here are some points to consider when choosing design tools.

1. SCHEMATIC CAPTURE
   - Will the company be able to select a different ASIC vendor in the future should the need arise? What is the number of ASIC vendor kits available?
   - Can the system support hierarchical design easily?
   - What is the capacity of the system for large designs? Though the first ASIC design maybe small, later ones often build rapidly in size and a new tool may have to be purchased.
   - Can the system be used for automating the schematic entry associated with the non-ASIC pieces of the design? Is there library support of commercial parts?
   - How easy is the system to learn and use?
   - How open is the system for users to access the database?
   - Does the system support design rule checking and netlist generation?
   - What local technical support does the company offer to assist the user on the system?

2. SIMULATION TOOLS
   - Is there support for many different vendors with full simulation and timing information?
   - Can the system support simulation of low-cost ASIC alternatives (P.L.D./I.C.)?
   - Does the system cope with load-dependent and layout-dependent delays?
   - Is there tight integration between schematics and simulation to make debug easy?
   - How easy is it to learn and use the system?
   - Is it easy to generate stimulus patterns?
   - Can the simulator be expanded to handle multiple ASICs together with commercially available parts?
   - Are there any expansion paths for accelerating the simulator speed? This is necessary when larger multiple ASIC designs are considered in the future.
For a long time silicon has been the only useful material for integrated circuits fabrication: its dominance in the world semiconductor market is illustrated by the proliferation of silicon v.l.s.i. circuits. Gallium arsenide has recently drawn the attention of semiconductor researchers because of its unique light-emitting properties and high-speed capabilities. However, combining the two materials in a form suitable for integrated circuits was not possible until the growth of device-quality gallium arsenide films on silicon substrates was successfully demonstrated.

For more than two decades researchers have been interested in the growth of GaAs layers on silicon substrates and the properties of GaAs-Si hetero-interface. Early attempts were unsuccessful because the material properties of gallium arsenide and silicon differ. First, the spacing of atoms in gallium arsenide and silicon crystals is mismatched by around 4%. Although this difference may seem insignificant, the growth of high quality epitaxial films requires a precise alignment of atomic structures. Trying to align each gallium arsenide atom and silicon atom at the interface would leave an extra silicon atom for every 25 atomic pairs, which introduces material defects that can destroy the performance of electronic devices.

And second, whereas silicon crystal consists of a homogeneous array of silicon atoms, a gallium arsenide crystal contains two different atoms placed in alternating positions. These alternate positions must be precisely maintained at the interface. It is for these reasons that the growth of high quality gallium arsenide films on silicon substrates had to wait for the recent development of growth techniques - molecular beam epitaxy in particular - that allow precise control of the placement of atomic layers.

There have been two important findings in the last few years that have enabled growth of high quality gallium arsenide on silicon. One is a technique called two-step growth developed by Akiyama and others at Oki Electric. In this, the first thin gallium arsenide layer, typically 0.1 microns thick, is grown at a low temperature, around 400-500°C, compared to the growth temperature for the rest of the gallium arsenide layer which is around 600-700°C. The total film thickness is typically 3-5 microns. This two-step growth technique gives gallium arsenide films of good surface morphology.

The other important finding by Fischer and others at the University of Illinois is the use of a silicon wafer whose surface is not tilted. With these techniques it is now possible to routinely grow high quality gallium arsenide films on silicon substrates. A variety of gallium arsenide-based electronic devices on silicon have been demonstrated by various groups in the U.S. and Japan. The performance of these devices is usually comparable to similar devices made on conventional gallium arsenide substrates. For example, a field-effect transistor which can operate up to 55GHz has recently been demonstrated.

But the real question was whether this material would be good enough for i.c. fabrication. This was answered by Texas Instruments with the demonstration of the first large-scale i.c. using gallium arsenide-on-silicon wafers. This contained more than 7000 transistors, and showed that one can not only make working transistors using this material, but can expect them to simultaneously operate in a very uniform manner.

An even more significant achievement is the demonstration of a room-temperature continuous operation of a gallium arsenide-based semiconductor laser diode built on a silicon substrate by a team from the University of Illinois, Texas Instruments and Xerox. Since silicon cannot inherently emit light, having a gallium arsenide light-emitting laser on a silicon substrate is paramount to giving silicon a totally new capability. This will be useful for applications such as optical fibre communication systems and integrated circuits where signals can be transmitted by lightwave.

The performance of light emitting diodes is very sensitive to material defects, and until this achievement researchers were not able to reduce the number of defects sufficiently to operate the gallium arsenide diodes on silicon substrates continuously at room temperature. The combination of gallium arsenide and silicon gives each material a new capability which cannot be obtained by single materials alone.

The successful growth of gallium arsenide films on silicon substrates has enabled many gallium arsenide-based electronic and optical devices to be fabricated on silicon substrates, and in the near future this will lead to the combination of integrated circuits and optoelectronics circuits made of gallium arsenide and silicon.

---


---

**INDUSTRY INSIGHT**

**SEMICCONDUCTORS**

**GALLIUM ARSENIDE ON SILICON**

**The marriage of the two most important semiconductors, silicon and gallium arsenide, is now possible in the form of device integration on a single wafer.**

---

**GALLIUM ARSENIDE ON SILICON ATTRIBUTES**

This new technology is obviously not without its problems but the significance of its attributes justifies worldwide research on this topic. In the UK, Philips, GEC & Plessey are known to be working on it.

- It allows the integration of both digital and optoelectronic signal processing on a single chip.
- It allows the possibility of microwave and digital and/or optoelectronic signal processing on a single chip, provided the f.I. loss associated with a Si substrate can either be reduced or can be tolerated.
- Silicon has a better thermal conductivity than GaAs which may make GaAs on Si the preferred technology for power devices.
- Large area GaAs wafers (5-4) will become available quicker if formed on a Si substrate than if we have to wait for the development of large diameter GaAs boules (4" GaAs on Si wafers are commercially available now).
- Si is a lot less brittle than GaAs and hence GaAs-on-Si devices may be easier to process and have a higher yield than all GaAs devices.
- Si substrates are considerably cheaper and more consistent than GaAs.
- The last three reasons may make GaAs on Si devices cheaper than all GaAs devices.

---

Dr Hisashi Shichijo, of Texas Instruments central research labs, Dallas, reported on developments on GaAs on silicon at the 1986 American Physical Society meeting in New Orleans.

June 1988 ELECTRONICS & WIRELESS WORLD
A set designed to the BBC's specifications would be unlikely to be among the cheapest on the market; but BBC Enterprises believes it has cornered the market for RDS-badged receiver aimed at World Service listeners abroad.

**AUDIO QUALITY**

Although the receiver is aimed at the ordinary listener rather than the audiophile, an important part of the BBC specification deals with audio performance. The cabinet, which is likely to have a volume of at least four litres, will be of dense material and as airtight as possible. A bass-boost control giving up to 12dB of lift below about 80Hz is required, and a treble lift and cut control may be provided too.

A set designed to the BBC's specifications would be unlikely to be among the cheapest on the market; but BBC Enterprises believes it has cornered the market for RDS-badged receiver aimed at World Service listeners abroad.

**RADIO DATA SYSTEM**

A key feature of the new specification is the use of the RDS radio data system, a programme-labelling scheme designed to eliminate the tuning difficulties which so perplex most listeners. The BBC's radio will be able to tune in F.M. stations: when a button is pressed, the receiver will decode the data signals and find the correct frequency without further intervention by the operator. If the transmission fades or fails, the set will automatically seek an alternative frequency carrying the same programme.

Receivers for RDS are already beginning to filter through to the market. Volvo has launched an RDS car radio and Grundig a hi-fi receiver, though apart from the BBC's own monitoring receivers, accepts the multiplex signal containing the 57kHz RDS subcarrier and produces a hit-stream plus the recovered clock signal. But for anything beyond the most basic RDS functions, the decoder must also include a processor to control the tuning and manage the display.

In the BBC's proposed receiver, the display will show waveband and frequency, a programme service name of eight characters (for a station with RDS), and whether the programme is mono or stereo. RDS programme identification codes will have been pre-loaded into the set's memories during manufacture so that it will work as soon as it is unpacked. But conventional tuning or band-scanning facilities will ensure that, without RDS signals, it still works in the ordinary way.

**R.F. PERFORMANCE**

Frequency coverage of the BBC receiver will include the v.h.f./f.m., m.f. and i.f. broadcast bands. On v.h.f., sensitivity must be good enough to provide a weighted signal-to-noise ratio of 40dB (mono) for a signal of 30dBµV/m. To guard against the irritating 'birdies' which often mar reception, in particular that of Radio 3, the engineers have proposed 70dB of protection against interfering signals spaced 2.2MHz and 4.4MHz from the wanted carrier — the separations employed for the BBC national networks. Single-signal image rejection must be better than 50dB and in-band multiplex rejection (SCA) better than 55dB. Selectivity must conform to CCIR Recommendation 412.

On a.m., minimum sensitivity must be sufficient to achieve 30dB weighted s/n for a field strength of 54dBµV/m. No coverage of the h.f. spectrum is proposed, though it is known that the BBC External Services has considered separately the idea of a BBC-badged receiver aimed at World Service listeners abroad.

**WANTED: manufacturers to produce an RDS volksradio.**

The BBC's radio will be able to tune in F.M. stations: when a button is pressed, the receiver will decode the data signals and find the correct frequency without further intervention by the operator. If the transmission fades or fails, the set will automatically seek an alternative frequency carrying the same programme.

Receivers for RDS are already beginning to filter through to the market. Volvo has launched an RDS car radio and Grundig a hi-fi receiver, though apart from the BBC's own monitoring receivers, accepts the multiplex signal containing the 57kHz RDS subcarrier and produces a hit-stream plus the recovered clock signal. But for anything beyond the most basic RDS functions, the decoder must also include a processor to control the tuning and manage the display.

In the BBC's proposed receiver, the display will show waveband and frequency, a programme service name of eight characters (for a station with RDS), and whether the programme is mono or stereo. RDS programme identification codes will have been pre-loaded into the set's memories during manufacture so that it will work as soon as it is unpacked. But conventional tuning or band-scanning facilities will ensure that, without RDS signals, it still works in the ordinary way.

**RADIO DATA SYSTEM**

A key feature of the new specification is the use of the RDS radio data system, a programme-labelling scheme designed to eliminate the tuning difficulties which so perplex most listeners. The BBC's radio will be able to tune in F.M. stations: when a button is pressed, the receiver will decode the data signals and find the correct frequency without further intervention by the operator. If the transmission fades or fails, the set will automatically seek an alternative frequency carrying the same programme.

Receivers for RDS are already beginning to filter through to the market. Volvo has launched an RDS car radio and Grundig a hi-fi receiver, though apart from the BBC's own monitoring receivers, accepts the multiplex signal containing the 57kHz RDS subcarrier and produces a hit-stream plus the recovered clock signal. But for anything beyond the most basic RDS functions, the decoder must also include a processor to control the tuning and manage the display.

In the BBC's proposed receiver, the display will show waveband and frequency, a programme service name of eight characters (for a station with RDS), and whether the programme is mono or stereo. RDS programme identification codes will have been pre-loaded into the set's memories during manufacture so that it will work as soon as it is unpacked. But conventional tuning or band-scanning facilities will ensure that, without RDS signals, it still works in the ordinary way.

**R.F. PERFORMANCE**

Frequency coverage of the BBC receiver will include the v.h.f./f.m., m.f. and i.f. broadcast bands. On v.h.f., sensitivity must be good enough to provide a weighted signal-to-noise ratio of 40dB (mono) for a signal of 30dBµV/m. To guard against the irritating 'birdies' which often mar reception, in particular that of Radio 3, the engineers have proposed 70dB of protection against interfering signals spaced 2.2MHz and 4.4MHz from the wanted carrier — the separations employed for the BBC national networks. Single-signal image rejection must be better than 50dB and in-band multiplex rejection (SCA) better than 55dB. Selectivity must conform to CCIR Recommendation 412.

On a.m., minimum sensitivity must be sufficient to achieve 30dB weighted s/n for a field strength of 54dBµV/m. No coverage of the h.f. spectrum is proposed, though it is known that the BBC External Services has considered separately the idea of a BBC-badged receiver aimed at World Service listeners abroad.

**WANTED: manufacturers to produce an RDS volksradio.**
The new QUARTZLOCK model 2A features:
- 1 MHz, 5 MHz and 10 MHz ttl outputs
- 1 x 10^-14 long term accuracy NPL TRACEABLE
- 1 x 10^-12 and 1 x 10^-10 short and medium term accuracy
- Reliable 24 hour operation (Not MSF dependent)
- No frequency jitter No warm-up No ageing
- No VCO adjustments High noise immunity
- Use to VHF as calibrator
- 198/200 kHz 'CORE' output gives ultimate reference certainty
- Auto locking No temperature effects No price change

The new QUARTZLOCK 2A-01 with the above features plus:
- Level, stable, very low distortion sinewave outputs at 1 MHz and 10 MHz
- Better than -50 dBc harmonic distortion
- +10 dBm ± 0.05 dB O/P Output inhibited if unlocked
- Option output frequency you can specify at modest additional cost

Matching products include:
- Active antenna
- 0.01 Hz 1 MHz divider in 1,2,5 and 10 steps
- Master quartz oscillator
- Distribution amplifier
- Uninterruptable/field PSU
- Fl meter
- Ω meter

DARTINGTON FREQUENCY STANDARDS
MOOR ROAD STAVERTON DEVON TQ9 6PB ENGLAND
Telephone 080426 282 Telex 42928 A/B WETRAV G (QUARTZLOCK)
Probably the largest range of ANTENNAS in the World.

Professional Antennas from 100KHz to 2.5GHz.

Jaybeam
... above all else

Kettering Road North, Northampton NN3 1EZ, England.
Telephone: (0604) 46611. Telex: 311101 JABEAM G.
International +44 604 46611 Fax: (0604) 47421

UNEQUALLED R.F. SPECTRUM ANALYSIS

The A-8000 sets a new standard in RF Spectrum Analysis providing an advanced range of features at a remarkably low price. Engineered with the user in mind the A-8000 resolves RF measurements up to 2.6 GHz fast and accurately. With built-in options such as a tracking generator and a rechargeable battery the A-8000 is truly portable and can be used almost anywhere from bench top to mountain top!

†Centre frequency accuracy ±0.0025%

* IEEE/RS232 INTERFACE * FIELD PORTABLE-INTERNAL RECHARGEABLE BATTERY * BUILT-IN TRACKING GENERATOR * OPERATES ON ANY VOLTAGE * 2μV SENSITIVE * OFF AIR RECEIVER (FM/AM AND SSB) *

IFR TEST EQUIPMENT – COST EFFECTIVE PERFORMANCE & RELIABILITY

Fieldtech Heathrow Limited,
Huntavia House, 420 Bath Road,
Longford, Middlesex, UB7 0LL, England
Telephone: 01-897 6446
Telex: 23734 FLDTEC G
Telefax: 01-759 3740
Stretching the spectrum

Reports from the annual conference of the Mobile Radio Users' Association, held at the end of March at New Hall, Cambridge.

RICHARD LAMBLEY

At the Department of Trade and Industry, the policy of greater co-operation with the radiocommunications industry continues to show results. Senior staff from the Radiocommunications Division were once again present in force at the MRUA conference, and indeed formed the panel of speakers for the whole of the first session. But for the pressure of last-minute parliamentary business, they would have been led by their Minister, John Butcher. In his opening speech, read to delegates in his absence, Butcher opened the question posed in the conference's theme for this year: the matter of whether mobile radio was now enjoying a feast or bracing itself for famine.

With both Band I and Band III lately cleared of television broadcasting, with two national trunked mobile radio networks launched in the past few months, and with regional systems now opening, the supply of channels might appear sufficient to wait mobile radio into a golden age of an almost unlimited expansion. But the Minister warned, "You should not assume that there will be any less pressure to find more efficient ways of getting mobile radio across."

First of the speakers from RD was Mike Coolican, whose presentation examined the current level of occupancy of mobile radio channels. Despite heavy overcrowding, especially in the London area, he said that some channels were being wastefully misused: "Monitoring suggests that even at busy times, the actual message content of channels is not all that might be desired."

Some calls occupied airtime without passing information, some were terminated before reaching the end of the message, leading to wasteful repeat transmissions, some were never answered at all. Foul language, C.B. style abuse and music had all been heard by RD's monitors. Information provided by system operators had shown that only some 15 minutes of the busy hour were usefully employed.

But if operator discipline was often poor, so too was that of licensees. Coolican showed a slide containing results of 1400 inspections of mobile installations. Just over half had been found satisfactory, but among the others, inspection revealed 134 unused systems, 114 with equipment irregularities, 46 with frequency irregularities, 96 under-recorded mobiles, 133 base-stations which had been moved without authorization (25 miles in one case) and 100 using unlicensed modes.

Coolican accepted that the present situation was in part due to previous regulatory policies. Even so, a potential shortage of spectrum faced the mobile radio industry because of the rapid emergence of new classes of user. Courier services had used up half a megahertz in only 18 months and needed more: their need would increase further if the Government deregulated letter carriage. In the US, a wristwatch radio-pager was to be launched at about $100. One could imagine the impact of such a product on the demand for paging spectrum. The Telespot service for second-generation cordless telephones would be launched this year, he said. "Virtually all telephone users might want cordless, 80% might want Telespot and that would mean 20 million domestic customers."

Coolican concluded his address by generating some agitation among the new Band III users. RD's policies for maximizing the use of the spectrum would not necessarily embody spectrum pricing as envisaged in last year's CSPI report (see E&WW July 1987, page 677), but they could well involve service providers charging for airtime. "Free airtime is not necessarily in the user's true interest."

At present, only the GEC network charges for airtime. During a later session devoted to Band III, it was to become apparent that other operators had avoided charging up to now for reasons connected with marketing. A flat rate charge means that customers know exactly what the system will cost them to use; and by exacting payment in advance, network operators can avoid bad debts.

No decision on implementing the CSPI report has yet been made, though the DTI is convinced that they were reasonable. And it was now partly begun very cynical, but was now partly convinced that they were reasonable. And it would take a long time to make any changes there.

Another area where change would be difficult to contemplate was in the aeronautical and maritime bands, because of the huge number of installations.

Strategies for the future could therefore include using channels on a shared basis with the military; promoting greater spectrum efficiency; and the more effective loading of existing channels. This might mean favouring data rather than voice communication. In the longer term, moves towards personal radio communications and mobile satellite communications would mean we could not confine ourselves to bands below 1GHz.

Preparations were now afoot for a proposed World Administrative Radio Conference for 1992 to discuss allocations in the 1-3GHz region, following difficulties which had arisen at the 1987 conference out of conflicting demand for mobile satellite services at 1.5-1.6GHz. To make the most of this valuable opportunity it would be necessary to overcome some of the conservatism which existed internationally. A final decision on whether this meeting would take place would be made by the ITU in the summer of next year.

The technology of mobile radio, and the influence of regulatory activity, were examined by the third RD speaker, Olly Wheaton. "It is the DTI's policy", he said, "to minimize the burdensome regulatory constraint where possible, and to encourage competition in the market place to flourish."

Through the DTI's work in developing standards, the UK now had a lead in trunking technology. "Other countries, Ireland, Germany, France, now wish to use the MPT1327 protocols for similar systems. We may end up with a de facto standard, who knows?"

But the creation of standards for trunked radio and the forthcoming pan-European cellular system had been hindered by problems over intellectual property rights. "Next
time we will talk out IPR first, technology second". (See also Telecomms Topics, page 569.)

However, work on national telecommunications standards might increasingly be devolved to outside organizations. The Civil Service generally was considering the use of agency bodies, said Wheaton. "The lease on Waterloo Bridge House runs out in two years, and this could coincide with other organizational changes."

Among the technological possibilities Wheaton outlined was the prospect of sharing low-power applications with other services. Spurious emission limits for interference from microprocessors and so on were much higher than those for radio equipment. Permitted local oscillator radiation from television sets was also high; you could get 2mV/m three metres from a television, 8MHz wide. "If information equipment can radiate at this level, why not use these frequencies for broadband local communication?" he asked. Spread-spectrum techniques could help avoid interference.

During the panel session which followed, a questioner pointed out that, despite all the moves towards deregulation, the process of spectrum planning was still closed to users. Responding for RD, Mike Goidard said, "I fully accept the criticism". Spectrum planning, he added, had to be done more openly: users and operators had to be brought in. But it would still be necessary to harmonize with other European countries. RD was looking at the possibility of a forum or consultative committee to look at proposals before they were taken too far, but it was too early to give any details.

Other points from the floor dealt with more immediately practical matters. One was from an operator who had suffered interference problems, but had been told by a Radio Investigation Service inspector that frequencies used by adjacent sites were confidential and could not be divulged. Another speaker emphasised the need for more information, arguing that a list of who had what channel would promote the efficient use of frequencies. Coolican replied that the matter was now the subject of a ministerial decision; making a database available was an option that was seriously being considered. Goidard added that the DTI did not have overall charge of the whole spectrum; it could make Band III information available, but operators wanted confidentiality. In the US the FCC made its list public, but found tremendous difficulty in keeping it up to date - to the extent that private users made their own lists and the FCC was buying them.

EDUCATION

One issue which would well illustrate the growth of mobile radio is the serious shortage of trained technicians. Everyone in the radiotelephone business seems to have pet horror stories of installation problems caused by ignorance: radio units which work only at night through having been wired to the car number-plate lamp, or r.f. connectors where the coaxial cable has simply been pushed into the connector shell, and so on. A further conference devoted entirely to education, and staged by the MRUA with financial and other support from the DTI, was shortly to take place (4-5 May); but some of the problems the industry faces were outlined in a presentation by Dr Colin Smith, technical director of PMR Ltd and a member of the MRUA's management committee.

The vast majority of staff needed by the industry, he said, were of technician rather than chartered engineer status. But intending technicians found that too little of the content of their training courses related to the radio interest which had drawn them in. Often students ended up being side-tracked into computers and finding lucrative work elsewhere in the electronics. Even where r.f. technology was taught, courses had no practical content: test equipment for mobile radio was not available in colleges. Regulatory matters such as type-approval were excluded or disguised because academics regarded these as governmental rules rather than educational subjects. The emphasis on computers over the last few years had snowballed to the point where new teachers coming in had no knowledge of r.f. to pass on. There was no nationally-recognised qualification in mobile radio.

But now the MRUA had worked with the Association of Marine Electronics and Radio Colleges to produce course options which had been validated nationally and would be available from this September. These were only a start, but AMERC could expand them if they were well received. The MRUA also hoped to interest the City & Guilds Institute and other colleges.

DIGITAL TECHNIQUES

Looming on the cellular radio horizon is the pan-European cellular system, or GSM, which was described by Ted Beddoes, technical director of Racal Vodafone and lately seconded to the DTI to advise on Eurocellular matters. GSM will ultimately replace the seven existing systems in Europe, including the UK's TACS (though TACS is unlikely to be switched off before the years 2005-2010). Intensive activity is taking place within CEPT to define the system. "GSM is seen by the EC as important for its barrier-free policy for 1992," said Beddoes.

Basic features of the system, he said, would include the use of digital voice coding at 13kbit/s per channel; time division multiple access, with time-slots of slightly less than 1ms; eight channels per carrier with two-frequency duplex, and a gross bit rate of 270kbit/s (including sync, training-in and error checks); and a channel spacing of 25kHz per channel (200kHz overall), which would be the same as for present-day cellular. Frequency-hopping, together with the digital modulation scheme, would enable the system to tolerate a lot of interference and so make possible a high degree of frequency re-use. All channels would be usable at all sites, though not simultaneously. Satisfactory bit error rates would be achievable with a carrier-to-interference ratio of only 8dB. A
A recording played to delegates of the speech quality obtained over an experimental link with a mobile test-bed being driven around London certainly seemed to support this prediction.

Provision has further been made for half-rate voice encoding, which could allow system capacity to be doubled. Data transmission will also be possible: GSM will handle data at rates from 300 to 9600 b/s with full error correction (FEC or ARQ modes), and without the need for modems. ISDN features including text and images will all be possible, as will feasible - a group 3 system, buffered to avoid problems of synchronizing the transmitter to moving parts in the receiver.

Somewhat closer at hand is the emergence of CT-2 cordless telephones, expected to reach the UK market in just a few months' time. Barry Moxley of British Telecom Mobile Communications spoke of prospects for the new system, the first of its kind in the world.

CT-2 telephones neatly avoid the problems of having transmitter and receiver in the same small unit by the use of a ping-pong technique borrowed from military radio. Speech is time-compressed into brief packs, which are cross-fired alternately from either end on the same radio frequency. At the receiving end, the packets are stretched and reassembled to give full duplex speech. Originally pitched largely at the domestic market, the CT-2 concept had grown into ambitious schemes for telepoints - short-range radio terminals situated in public places such as stations which will allow CT-2 users to make outgoing telephone calls as they pass by. Equipped with a CT-2 handset and one of the $100 pagers mentioned earlier, the subscriber on the move could have what amounted to a poor man's cellular telephone.

A problem, however, is that although several companies are involved in the CT-2 project, no standard air interface has been defined. Unless something can be done about this, it will mean that, say, a Ferrari telephone will not work through a BTMC Phonepoint, and vice versa. For cordless telephones in the executive suite or at home this will not matter, but as soon as telepoints begin appearing in public it will necessitate wasteful duplication. One example of the differences between the various manufacturers' specifications is in the length and data rate of speech bursts.

Research suggested a huge latent demand for CT-2 among those who used payphones, said Moxley. Prices would begin at £300 for a CT-2 handset, and one of the $100 pagers mentioned earlier. the subscriber on the move could have what amounted to a poor man's cellular telephone.

Racial Vodafone's expansion plans for cellular radio telephones service: much depends on the availability of further spectrum. Vodafone's rival, the Cellnet consortium, is equally ambitious.

yielded some interesting points.

As Gary Fell of Motorola Communications International declared, servicing has increasingly become a question of how to repair a p.c.b. of surface-mounted devices when the board costs so much that throwing it away is not an option. Often the fault lay in a 15p resistor potted in a £100 sub-assembly.

Field servicing was becoming a matter of changing a whole unit or sub-assembly; the fault itself could be dealt with later in the workshop. "What's important", said Fell, "is not how rapidly we fix broken things, but the equipment availability to the user." A growing problem in mobile radio servicing was that of electrostatic damage to the complex semiconductors in today's equipment. "If you go into a service department, you should now expect to see the staff wearing some kind of strap", he said. Rarely did static cause a hard failure immediately in a semiconductor device. "But just walking across the carpet can set a time-bomb in that device... a tiny fuse-link waiting for the first surge, minutes, hours or months later."

With hard failure rates approaching one in every ten years, many service calls now fell into the 'no trouble found' category. Reported faults were often of the 'finger trouble' variety - switches set in the wrong position. The proportion of such calls was bound to increase as equipment reliability improved.

One attractive prospect for the future was the use of remote fault diagnosis, using dial-up modems to interrogate the module directly. "This is a very powerful tool," said Fell. "The technician can then walk right in and put his finger on where the failure is."

Information about the Mobile Radio Users' Association is available from its secretary at 28 Nottingham Place, London W1M 3PL; telephone 01-400 1518. Further details of the educational conference mentioned in this article can be provided by Ellie Hundermark Associates, 01-938 2222 ext. 2101.

EQUIPMENT MAINTENANCE

Modern radio equipment has improved dramatically in its reliability: nevertheless the need for servicing shows no sign of fading away. A session of papers on the rather dull-sounding subject of maintenance yields some interesting points.

As Gary Fell of Motorola Communications International declared, servicing has increasingly become a question of how to repair a p.c.b. of surface-mounted devices when the board costs so much that throwing it away is not an option. Often the fault lay in a 15p resistor potted in a £100 sub-assembly.

Field servicing was becoming a matter of changing a whole unit or sub-assembly; the fault itself could be dealt with later in the workshop. "What's important", said Fell, "is not how rapidly we fix broken things, but the equipment availability to the user." A growing problem in mobile radio servicing was that of electrostatic damage to the complex semiconductors in today's equipment. "If you go into a service department, you should now expect to see the staff wearing some kind of strap", he said. Rarely did static cause a hard failure immediately in a semiconductor device. "But just walking across the carpet can set a time-bomb in that device... a tiny fuse-link waiting for the first surge, minutes, hours or months later."

With hard failure rates approaching one in every ten years, many service calls now fell into the 'no trouble found' category. Reported faults were often of the 'finger trouble' variety - switches set in the wrong position. The proportion of such calls was bound to increase as equipment reliability improved.

One attractive prospect for the future was the use of remote fault diagnosis, using dial-up modems to interrogate the module directly. "This is a very powerful tool," said Fell. "The technician can then walk right in and put his finger on where the failure is."

Information about the Mobile Radio Users' Association is available from its secretary at 28 Nottingham Place, London W1M 3PL; telephone 01-400 1518. Further details of the educational conference mentioned in this article can be provided by Ellie Hundermark Associates, 01-938 2222 ext. 2101.
low-cost PC based logic analysis - from Thurlby

Now you can use your IBM-PC or compatible computer as the basis of a sophisticated logic analyser system.

LA-PC Link is an interface package which links your computer with the low-cost Thurlby LA-160 logic analyser to provide facilities normally associated with only the most expensive analysers.

- Sophisticated data state listings
- Up to 32 words per screen in multiple data formats. Scrolling by line, page or word, plus random page access. Rapid screen compare facility. Full repetitive word search.
- High resolution timing diagrams
- Sixteen channels of 64, 256 or 1024 samples per screen. Instantaneous pan and zoom. Moveable channel positions.
- Dual cursors with automatic time difference measurement.
- 16 or 32 channels, clock rates to 20MHz
- Operates with all versions of the LA-160 with or without LE 32.
- Comprehensive data annotation
- Each data and control input can be allocated a user-defined label. Data files are date/time stamped and can be fully annotated.
- Full disk storage facilities
- Data files can be saved to disk and recalled for comparison. Data includes the analyser's set up conditions and all annotation.
- Versatile printing facilities
- State listings and timing diagrams with annotation can be printed.
- Colour or mono display: keyboard or mouse control
- Colour, monochrome or text-only modes suit any display adaptor.
- Parts of the programme can be controlled by a mouse if required.
- Terminal mode for up disassemblers
- Acts as a terminal for use with Thurlby up disassembler ROMs.

If you already have an LA-160 logic analyser the LA-PC Link interface package costs just £125. If you don't, an LA-160 with up LA-PC Link costs from £520.

Enter 27 on reply card

Raphel Electronics Ltd
New Road, St. Ives, Cambs.
PE17 4BG Tel: (0480) 63570

Low-cost PC based logic analysis - from Thurlby

Enter 27 on reply card

MARCONI INSTRUMENTS

2019 signal generator 'as new'
£2,250

TF1020A RF power meter 0-100W 250MHz
£75
TF112A RF power meter 0-25W 250MHz
£50
TF166B/6 AM/FM signal generator 10-470MHz
£350
TF1240/1246 D-Meter and oscillator
£450
TF2002B AM-FM Signal Generator 10kHz-8MHz
£400
TF2011 FM signal generator 130-180MHz
£325
TF2012 FM signal generator 400-520MHz
£600
TF2016/2173 AM/FM signal gen 10kHz-120MHz
£500
TF2020C noise receiver
£350
TF2162 MF attenuator 0-111db in 0.1db steps
£100
TF2165F FM signal generator 10-100MHz
£750
TF21681 AF signal source/matched attenuator
£425
TF2300 modulation meter AM/FM to 1GHz
£250
TF2300A as above with deviation to 1.5GHz fed
£350
TF2300B modulation meter as above
£450
TF2303 modulation meter AM/FM 2.5-5200MHz
£325
TF2304 modulation meter automatic
£425
TF2700 Universal component bridge
£250
TF2356 level oscillator 20MHz
£65
TF2430 frequency counter 80MHz 7 digits
£75
TF2501 power meter 0.3W fed DC-1GHz
£150
TF2600 multifunction meter 6V-30V 400ma d.c.
£175
TF2600B video voltmeter 1mV-300V fed
£175
TF2604 electronic multi-meter
£150
TF2807A PPM comparator tester
£400
2019 AM/FM synthesised signal generator 102MHz
£2250
2820A/2829 digital simulator/analysers
£1600
2833 digital in-line monitor
£275
TF2808 blanking & sync mixer
£250
6055B signal source 80MHz-210MHz
£150
6460 RF power meter
£350
6460/6430 power meter/microwave head
£495
TF893A audio power meter 1mW-10W fed
£75
TF995/A AM/FM signal generator 1.5-220MHz
£195
TF995/B5 AM/FM signal generator 0.2-220MHz
£250

RALPH ELECTRONICS

35A1 Wave analyser 15Hz-50MHz
£395
35A2 Wave analyser 15Hz-50kHz
£395
35A9 Wave analyser 15Hz-50kHz
£275
35A10 Wave analyser 15Hz-50kHz
£195

HEWLETT PACKARD

Bootel - Electronics
10 Chapel Street, London, W1E
Tel: 01-723-0752/04 8074

ADDITIONAL EX-STOCK T & M KIT

KEITHLEY 178 Dmm & 179 Dmm
£1,145
FLUKES 8795A DMM
£180
TREND DATA Transmission test set 1-8
£325
WAYNE KERR B661 RF Bridge
£125
RACAL 9111 100MHz counter
£150
RACAL 9112 120MHz counter
£150
RACAL 9141 300MHz counter
£325
RACAL 5811 RF noise meter
£125
BIRD 4370 RF meter
£250

TEXSCAN MODEL 9650 TRACKING SWEEP ANALYSER

500MHz 250MHz tracking sweep generator and spectrum analyser in one unit
£1,750

Enter 27 on reply card

Electronics & Wireless World
INTERNATIONAL BROADCASTING CONVENTION
BRIGHTON • UNITED KINGDOM
23 – 27 SEPTEMBER 1988

INTERNATIONAL BROADCASTING CONVENTION

The 1988 IBC Technical programme will cover all aspects of broadcast engineering with particular emphasis on emerging technology including satellite and cable distribution, enhanced and high definition television systems, as well as multi-channel sound systems and associated information systems.

The IBC EXHIBITION complementing the technical sessions will have the latest professional broadcasting equipment on display and demonstration by leading world manufacturers.

The SOCIAL PROGRAMME during the Convention will include a Reception and a special Ladies Programme of talks and demonstrations and visits to places of interest.

FURTHER INFORMATION can be obtained by returning the reply coupon below.

The IBC Secretariat, The Institution of Electrical Engineers, Savoy Place, London, United Kingdom WC2R 0BL. Telex: 261176 Telephone: 01-240 1871

Please send further details of IBC 88 to:

Name & Position

Company/Organisation

Address

Post Code

ENTER 33 ON REPLY CARD
Preparing for dual-channel sound

With the IBA expecting to be able to begin tests of Nicam 728 digital stereo sound early next year and to launch an operational service in the Crystal Palace, London and Emley Moor, Yorkshire service areas (together with those of their low-power relays) from autumn 1989, and with digital stereo also due on the BSB satellite by about Christmas 1989, it is clearly now time for the industry to begin producing programmes in stereo.

A one-day symposium 'The implications of dual-channel sound for Independent Broadcasting,' organized by the IBA, provided a useful introduction to the technology of Nicam 728 and its advantages to the viewer, but also some indications that producing effective television stereo sound may not prove as easy as some people imagine. The hundred or so delegates were also left with an uneasy feeling that the receiver industry may never learn to potential customers the high audio quality possible with the Nicam 728 system, without necessarily ensuring that their sets will do justice to digital stereo - much as in the past few receivers came anywhere near to providing the audio quality possible on plain, old-fashioned television mono. It is clear, also, that Nicam 728 decoders will add significantly to the additional cost of providing two audio channels and their associated loudspeakers.

Chris Daubney (IBA) said that while a technical working party is currently dealing with the technicalities of dual-channel sound on the ITV and Channel 4 terrestrial networks, it is important that programme makers, operations people and engineers recognize that it is the programme makers that matter and that there exists a need for a sharing of thoughts on tackling stereo for the small screen.

Both Wellbeloved (IBA) noted the competitive danger to the terrestrial channels posed by satellite channels where stereo is becoming the norm. Public awareness of stereo is marked by the success of CD records and the trend from a.m. to f.m. radio. The BBC had expected to begin an operational service using the Nicam 728 system this year until it was indefinitely postponed under its five-year plan, although tests were continuing occasionally from Crystal Palace. IBA had assumed that Independent Television would follow the BBC but now found itself in the lead in trying to get receiver industry to make the earliest possible start.

The entire ITV and Channel 4 transmission chain was at present geared to mono. The introduction of stereo involved changes in the studios, the distribution to transmitters and the availability of Nicam 728 receivers. At present ITV's analogue intercity network used separate analogue audio distribution; Channel 4 had a digital sound-in-sound combined audiovisual network but this was in the impatience of stereo these networks are a major and expensive undertaking he said. The relatively new Channel 4 transmitters could be readily modified. New ITV transmitters being installed under Phase 1 of the current re-engineering programme were replacing the older high-power main transmitters unsuitable for stereo at the rate of six stations per year but the complete replacement of ITV transmitters would take several years.

By about 1990 it should be possible to provide stereo in all ITV regions, though not from all main transmitters. About 75 per cent of the population should by then be receiving Nicam 728 signals, but it will be the mid-1990s before full national coverage is possible, the actual date depending on the completion of the Phase 2 transmitter re-engineering project still in the early planning stage. Orders were being placed for stereo sound-in-sound equipment for both the ITV and Channel 4 distribution networks. Eventually it would be possible to abandon the present analogue sound links.

Peter Brice and Bernard Rogers, representing BCREMA, outlined the implications of stereo for receivers and video cassette recorders, though it was unfortunate that Peter Brice used up most of the time allotted to BCREMA with an over-the-top presentation that seemed geared to customers and dealers rather than broadcasters. Bernard Rogers, however, quickly described the design of decoder chip sets for Nicam 728 decoders while admitting that these seem likely to add some £12 to £15 (retail) to the cost of a stereo-sound TV receiver compared with the few pence of a decoder for the Ger- many-carrier analogue stereo system.

It also appears that the industry generally is planning to provide sets with built-in rather than detachable stereo loudspeakers. This will inevitably limit the listening area for the output of stereo effect, as though possibly reducing some of the production problems in matching a wide sound stage to a relatively small picture.

As the independent producer Christopher Nuppen (who has produced more than 50 music-based television programmes with stereo sound since 1972, for mono transmission) pointed out, stereo is not just a matter of adding width but also depth. He believes that the public is now more sophisticated in its appreciation of audio quality than it was generally given credit for. He warned that too little time is usually allotted in post-production for sound dubbing. For cinema film this may take weeks; in television it is often estimated to be done in a day or a half-day. His presentation showed what can be done with care, and were the day's most convincing demonstration of the advantages of stereo reproduction.

Roy Drysdale (Limehouse) in considering the effects of stereo on studio practices commented: "After listening to the manufacturers I wondered why I wanted stereo. This afternoon I began to understand." The Limehouse studios were engineered for stereo five years ago. Stereo tolerances are low and he felt that "if you notice the audio on TV programmes it's wrong". The sound, he insisted, must be fitted to the picture. He agreed that dual channel sound would benefit some programmes, particularly music-based programmes, more than others. There was little to be gained from stereo for current affairs, etc. Discipline of operators had to be that much greater.

Mike Pontin (Thames) similarly agreed that while stereo benefits music, recording dialogue in stereo is debatable, although stereo can provide greater clarity. Stereo microphones with extended low-frequency response tended to be unsuitable for use in television studios where it is difficult to avoid studio noise. Additional production costs for stereo were an obvious concern to the companies; training in new techniques is very important. ITVA is arranging training courses.

Deryk Williams (S4C) spoke on dual-language opportunities provided by the time-multiplex of Nicam 728, although admitting that this is unlikely to take the place of good dubbing and subtitling and "does not of itself solve the problems of S4C".

Mark Yonge (Dolby) stressed that the dynamic range of sound and vision needed to be considered. Increasing subscription was depleting the conditions in cinemas and homes. Material needed to be pre-viewed under suitable conditions.

During a discussion period, some of the practical problems in implementing stereo sound effectively with existing technical facilities were aired, including the problems that might be involved in live broadcasting of snooker matches over several hours. There was also the feeling that broadcast management, in their current drive for more economic production, would not appreciate the extra skill, care and time needed to get stereo sound right. "We know how to do it. The problem is that the industry has been a long time with stereo. Getting the opportunity to do it right will need positive response from the top. Inventive people are feeling strangled. Getting sufficient time will be difficult." In the second five years of stereo production for the cinema, productions were much better than in the first five years. In the early days there had been difficulties over preconceptions of what stereo ought to be - there had been expensive experiments that had often failed. The advantages of stereo are debatable. It was suggested, was that they now have a margin of time to experience in private.

Television Broadcast is written by Pat Hawker.
WE ARE A LEADER IN SPECIALISED ELECTRONIC MARKETING IN THE DOMINION OF CANADA

Our component division requires top quality electronic components to offer in this market (NATO approved or Milspec types if possible).

Our instrumentation division requires a line of digital storage oscilloscopes, High Quality, new (also used) Electronic/Electrical Calibration Equipment which, with recertification on traceable standards can be offered to industry, government, education and other fields.

Kindly send all info to:
T E G Inc, 1179 Finch Avenue West, Unit #24, Downsview, Ontario, Canada M3J 2G1.
Atten: MD

LANGREX SUPPLIES LTD

One of the largest stockists and distributors of electronic valves, tubes and semiconductors in this country.

Over 5 million items in stock covering more than 6,000 different types, including CRT's, camera tubes, diodes, ignitrons, image intensifiers, IC's, klystrons, magnetrons, microwave devices, opto electronics, photomultipliers, receiving tubes, rectifiers, tetrodes, thyatrons, transistors, transmitting tubes, triodes, vidicons.

All from major UK & USA manufacturers.

Obsolete items a speciality. Quotations by return. Telephone/telex or fax despatch within 24 hours on stock items. Accounts to approved customers. Mail order service available.

LANGREX SUPPLIES LTD
Climax House, Fallsbrook Road, Streatham London SW16 6ED.
Tel: 01-677 2424/7
Telex: 946708
Fax: 01-677 4004
Vehicle e.m.c.

The problem of interference to in-car-entertainment radios and to and from electronic subsystems in cars is increasing as the electronic complexity of motor vehicles rises sharply. The launch of such cars as the BMW 7 series, the Jaguar XJ6 and the Opel Senator has seen the European car industry move from a modest degree of electronics for engine management straight to cars routinely containing seven or more microprocessors.

Susceptibility to, and generation of, radio-frequency interference (r.f.i.) are still poorly understood by the vehicle industry and in the past have been largely ignored, with problems rectified only as they are experienced, at a stage too late to influence fundamental design considerations such as circuit-board layout and choice of logic families, etc. Understanding the mechanisms of r.f.i. requires a knowledge of antenna and transmission line engineering. Since the car radio is normally the component most sensitive to r.f.i., test methods that ensure there is no electrical interference to reception will automatically ensure that no on-vehicle electronic system is likely to interfere with any other.

These were among the points made by M.T. Crowther (Jaguar Cars) at an IEE colloquium 'Vehicle Electromagnetic Compatibility' chaired by Warren Gibbons of the Motor Industry Research Association. Even more vital from a reliability and safety viewpoint is the likelihood of interference to electronic systems in vehicles from the fields of on-board carphones or when close to high-power broadcast, radar or communications transmitters. Keith Price (Jaguar Cars) described test methods for checking whole-car susceptibility based on a field of 50V/m at 100kHz; although he underlined the difficulties of making accurate whole vehicle measurements in test chambers.

K.L. Longmore (Lotus Engineering) similarly highlighted the problems posed by the increasing use of components such as glass-reinforced plastics rather than metal in vehicle construction. This is resulting in the need to use new techniques such as fillers (loading the resin with conductive particles), mesh/weaves (since composites are based on casing a strong mat in a resin, if the mat is made conductive it can form an effective screen) and surface coating, for example by making the gel coating of the g.r.p. conductive, or by spraying with a conductive paint, or by sticking metallic foil on the surface. Protection is needed against both electromagnetic interference (e.m.i.) and electrostatic discharge (e.s.d.) which he suggested “are probably the most effective killers of electronics modules in cars”.

M.T. Crowther, in his tests on interference to sensitive, high-quality in-car-entertainment equipment, has found that “most interference has proved to originate from clock harmonics, in some cases from the gate output, in others from the supply lines to the gate. In all cases interference has been reduced to acceptable levels by decoupling of i.c. devices and filtering of clock outputs or by reducing current rise time of the clocks by other means. Careful attention should be paid to the family of logic selected, the component layout, power supply busing and signal trace layout. The use of ‘slow’ logic such as c-mos 4000-series devices is recommended. If a faster logic, such as 74HC, is used, far more care must be exercised. It is not uncommon to see harmonics beyond the twentieth radiating from a module. In all cases of interference it was found that the system clock was responsible for narrowband interference, while data lines were responsible for broadband interference. Isolation of output lines from digital circuitry is important. Isolated digital and analogue power supplies should be used when mixing digital and analogue circuitry on the same board. Good power supply busing is characterised by low impedances and good decoupling over a wide bandwidth, achieved by maximizing the capacitance between the power lines and minimizing their self-inductance.”

Keith Price noted that “Some components are susceptible to r.f.i. at relatively low power levels, but revert to normal operation as the power level is increased. No satisfactory explanation for this phenomenon has yet been found. The effect is sometimes referred to as ‘windowing’ and has been found to be much more common than would at first be expected”.

K.L. Longmore reported that for shielding composites self-adhesive aluminium foil has proved effective for the low-volume production of Lotus cars. In the USA for high-volume production, an alternative approach has been to enclose the engine in its own metal box.

It should perhaps be noted that although 50V/m whole-vehicle tests should ensure adequate protection against fields likely to be encountered when driving in the vicinity of high-power broadcast or communications or radar transmitters, there could remain a need for caution when installing (or passing) high-power transmitters in vehicles (e.g. 400W p.e.p. output as permitted to UK radio amateurs for mobile operation). Isolated cases have been reported from the USA where r.f.i. disruption has created a serious safety hazard.

What happened to Picor?

While, as noted in the April issue, the idea that the restricted audio bandwidth of Region 1 a.m. medium-wave broadcasting could be extended by using a quadrature channel looks good only on paper, it is worth recalling that an earlier proposal designed to improve quality within an unchanged bandwidth was Picor (pilot-controlled overtone reproduction) developed in the German applications laboratory of ITT's Component Group Europe, initially about 1972 but with later improvements described in 1974 (EBU Review - Technical Part, April 1974). This divided the audio spectrum into a 'fundamental' band up to 4 or 6kHz, and an overtone band signalled to the receiver on a narrow low-level pilot control signal which, in a suitable receiver, controlled a generator to produce a series of discrete overtones at frequencies at appropriate levels. The original system was effective on music but tended to result in speech sibilants; this defect was overcome by a control signal providing adjustment of the index of modulation depending upon the nature of the programme being transmitted. Compatibility with conventional receivers was achieved by taking advantage of the masking effect produced when the pilot signal controlling the receiver generator is placed adjacent to the upper extremity of the fundamental band.

It was claimed that test results showed a very appreciable improvement in quality, compared with a conventional broadcasting transmission having a bandwidth of 4kHz. In 1974 it was stated that work was in progress on a further modification of the transmission system, with a view to taking advantage of the possibilities of more integration. The system was shown to be satisfactory not only for a.m. but also for s.s.b. and i.s.b. systems with bandwidths of only 4kHz, rather than the 9kHz of medium-wave a.m.

But little seems to have been heard of what happened to Picor since 1974. I cannot trace any papers on it having been given at IBC in the 1970s.

Erasable CD

Thomson Consumer R&D Laboratories in Villingen, FRG, have delivered to some professional recording studios and disc manufacturers working prototypes of their 'MOD' (magneto-optical disc) machines - a CD player that plays, erases and records. Thomson aims to become the first to market such machines although Sanyo Electric demonstrated a similar technique in 1984. With no physical contact between laser and disc, MOD is seen as an effective answer to DAT. Present playing time of each side of the double-sided discs is 54 minutes but Thomson aims to double this. An engineering production line is being set up at Villingen. If MOD is accepted as a world standard, so avoiding the need for CD machines, volume production will probably begin in the Far East.

Radio Broadcast is written by Pat Hawker.
If you're involved in Electronics...as a buyer or as a seller...you really can't afford to miss LEETRONEX'88...not simply because it's the North's leading Electronics Exhibition but mainly because we've switched the venue to the new University of Leeds Exhibition Centre. For Exhibitors and Visitors alike it's going to be the best Leetronex Exhibition ever!

**NEW VENUE FOR '88**

Now the North's longest established Electronics Exhibition is going to be bigger and better than ever before!!

- Over 125 Leading Exhibitors
- Custom-built Exhibition Centre
- Free Parking for over 1,000 Vehicles
- City Centre Location
- Cafeteria/Bars

**MAKE THE LEEDS CONNECTION IN '88!**

**TUESDAY 5th JULY 1988**
**WEDNESDAY 6th JULY 1988**
**THURSDAY 7th JULY 1988**

AT THE
UNIVERSITY OF LEEDS
EXHIBITION CENTRE

---

**Sowter Transformers**

With 45 years' experience in the design and manufacture of several hundred thousand transformers we can supply:

**AUDIO FREQUENCY TRANSFORMERS OF EVERY TYPE**

**YOU NAME IT!**

**WE MAKE IT!**

**OUR RANGE INCLUDES:**

- Microphone transformers (all types), Microphone Splitter/Combiner transformers, Input and Output transformers
- Direct Injection transformers for Guitars, Multi-Secondary output transformers, Bridging transformers, Line transformers, Line transformers to B.T. Isolating Test Specification, Tapped impedance matching transformers, Gramophone Pickup transformers, Audio Mixing Desk transformers (all types), Miniature transformers, Micro-miniature transformers for PCB mounting, Experimenta transformers, Ultra low frequency transformers, Ultra-linear and other transformers for Transistor and Valve Amplifiers up to 500 watts
- Inductive Loop transformers, Smoothing Chokes, Filter, Inductors, Amplifiers to 100 volt line transformers (from a few watts up to 1,000 watts), 100 volt line transformers to speakers, Speaker matching transformers (all power's), Column Loud-speakers transformers up to 300 watts or more.

We can design for RECORDING QUALITY, STUDIO QUALITY, HIFI QUALITY OR P.A. QUALITY OR LARGE OR SMALL QUANTITIES AND EVEN SINGLE TRANSFORMERS.

Many standard types are in stock and normal despatch times are short and sensible.

**OUR CLIENTS COVER A LARGE NUMBER OF BROADCASTING AUTHORITIES, MIXING DESK MANUFACTURERS, RECORDING STUDIOS, HI-FI ENthusiasts, BAND GROUPS AND PUBLIC ADDRESS FIRMS. Export is a specialty and we have overseas clients in the COMMONWEALTH, EEC, USA, MIDDLE EAST, etc.**

Send for our questionnaire which, when completed, enables us to post quotations by return.

---

**E. A. Sowter Ltd**

Manufacturers and Designers

The Boat Yard, Cullingham Road, Ipswich IP1 2EG. Suffolk. PO Box 36, Ipswich IP1 2EL, England.

Phone: 0473 52794 & 0473 219390 – Telex: 987703G SOWTER
Russian super television

Of the various institutes, one of the most prestigious is the Lebedev Physical Institute where, among other things, they are working on advanced optoelectronic projects. Head of the optoelectronics laboratory, Dr Yuri Popov, introduced me to one of his favourites, a laser television tube that could soon give projection a edge over television. Dr Popov claims that with his existing red tubes, the electron optics are such that a resolution of 2500 lines can easily be achieved, much better than the performance of what he calls second generation television.

Mendelev, where are you?

At the other end of the scientific spectrum, far removed from the world of moving pictures, is the search for new elements - another area in which the USSR is pre-eminent. At the Institute for Nuclear Research at Dubna a 265MeV cyclotron to accelerate ions of argon-40 and bombard a target comprising uranium-238. During such experiments all manner of reactions take place, often making it difficult to distinguish one species from another. Nevertheless the Russian team found a decay signature that was unlike that of any other element yet discovered and they now - two years later - firmly believe it to be element 110.

How far this process can go is an interesting question, because for many years physicists have predicted the existence of so-called 'islands of stability'. As atomic size increases, there is the possibility that rather than becoming increasingly unstable elements will last long enough to be useful. Where the first island of stability begins is a matter of some debate, but it could start with element 112. Clearly the Russian and others will be actively pursuing that goal. My only reservation is this; if transuranic elements of atomic number (say) 112-120 are stable, why haven't they been detected in some of those energetic regions of the universe where atomic nuclei are constantly being created in conditions far more aggressive than anything we can conjure up on earth?

The secret of their success was to grow cubic crystals of silicon carbide on top of hexagonal crystals - the common sort used to make emery paper. Hitherto cubic silicon carbide had been deposited on a pure silicon substrate, leading to lattice defects because of the different interatomic spacings. Transistors and diodes made from silicon carbide are now considered very close to com-

RESEARCH NOTES

Glasnost, is it real? Well, what better way to find out than a fact-finding trip around the various institutes that comprise the USSR Academy of Sciences? To my surprise, the visit of a western journalist was not only tolerated but warmly welcomed, and wherever I went there was enthusiasm for improved East-West communication. Scientists and engineers talked freely about their hopes, their frustrations and the universal problem of resources.

Chips for frying

Over the last few years the spectacular development of high-temperature superconductors has obscured an almost equally important development, that of high temperature semiconductors. Hitherto virtually every solid-state device has had to be operated below 200°C, a constraint that not only keeps heat-sink manufacturers in business but which also causes enormous problems in inhospitable environments such as car engines, jet engines and much of industry.

The real problem is the small energy band-gap of silicon which means that, at high temperatures, electrons can jump from the valence band into the conduction band, destroying all semiconductor devices in the process. What is obviously needed is a material with a much larger energy band-gap, as well as physical properties that are compatible with the required application.

One such material, boron nitride, has already been used to construct diodes capable of operating at 530°C (Research Notes, March 1988). Though the practical problems of attaching lead-out wires has not yet been satisfactorily overcome. Other possible materials being explored include pure carbon in the form of diamond films and silicon carbide, better known as the gritty material on emery paper.

Recently, reports have emerged of high-temperature silicon carbide transistors that will operate satisfactorily at temperatures up to 650°C. Robert F. Davis and his colleagues at North Carolina State University claim (Science News vol.132 no 25) that such devices have a performance comparable to more conventional silicon carbide transistors operating at room temperature.

The secret of their success was to grow cubic crystals of silicon carbide on top of hexagonal crystals - the common sort used to make emery paper. Hitherto cubic silicon carbide had been deposited on a pure silicon substrate, leading to lattice defects because of the different interatomic spacings. Transistors and diodes made from silicon carbide are now considered very close to com-
mercialization; indeed Davis' group is said to have formed a company to develop and market high temperature diodes. They also intend to exploit their new ability to make high grade cubic silicon carbide in the direction of marketing that still-elusive device, the blue led. One thing is sure: when high-temperature semiconductor devices become readily available in commercial quantities we shall see the application of electronic control systems in many environments that are now considered much too inhospitable. There is also the prospect of better high-frequency, high-power devices that don't go phut at the first sniff of mismatch.

Einstein rules O.K.

As any school-child knows, one of the tenets of Einstein's theory of Special Relativity is that the velocity of light is constant and does not vary with changes in the velocity or direction of its source. That view has however been challenged by some cosmologists who have suggested that the velocity of light could alter in some directions because of local variations in gravity or because of variations in the microwave background that permeates space. This radiation, first detected in 1965, is thought to be a remnant of the Big Bang that sparked off the creation of the universe some $10^{17}$ years ago.

Sadly for avant-garde cosmologists, Einstein still remains inviolate, at least to judge from some experiments performed at Aarhus University in Denmark. Professor Ove Poulsen and his colleagues used a 10m particle accelerator to project atoms of the isotope neon-20 in a precisely controlled direction. Using a split laser beam, one half projected in the direction of the neon atoms and the other half moving against the stream, the team made simultaneous measurements of the velocity of the atoms, using changes in the frequency of the laser light emitted from them. From these figures they then calculated c, the velocity of light, to an accuracy roughly ten times greater than that of a satellite-based experiment performed in the USA in the late 1960's.

Of more importance than measuring absolute velocity, however, was the ability of this experiment to measure any changes that might occur in different orientations in space. This has never previously been possible because all the classic techniques from the famous Michelson-Morley experiment onwards have sent the light on a go-and-return path that cancels any directional effects.

In spite of this new opportunity to search for directional effects, Professor Poulsen reports that none has been found. He is however designing new equipment that will offer a further tenfold increase in sensitivity. If it is eventually found that c varies in different orientations in space, then the consequences for cosmology will be profound. Meanwhile it seems that Einstein can rest in peace.

...or can he?

Just over two years ago physicists at Purdue University in the USA publicized a paper in Physical Review Letters re-analysing the results of experiments carried out in 1922 by a Hungarian, Roland von Eotvos. The purpose of the experiments was to test the so-called equivalence principle - the proposition that all objects, regardless of their composition, experience the same effects of the earth's gravity. Eotvos concluded that gravitational acceleration was indeed constant, though he observed certain inconsistencies that he put down to experimental errors. To believe otherwise would be to challenge Einstein's Theory of General Relativity.

The Purdue analysis, conducted by Dr Ephraim Fishbach and his colleagues, suggested that far from being experimental errors, the discrepancies observed by Eotvos were in fact evidence of a newly discovered fifth fundamental force called hypercharge.

Physicists have up till now recognized the existence of four fundamental forces governing the behaviour of the universe: electromagnetism, gravity and the so-called weak and strong nuclear forces. The first two are mediated by massless particles - photons and gravitons - and can thus cross the immensity of the universe. The nuclear forces on the other hand are mediated by relatively massive particles such as pi-mesons and w-bosons and can hence operate only within the confines of the atomic nucleus. Nevertheless, in spite of the vast differences of scale, physicists have been striving in different ways to unite all the four known forces in a single mathematical description.

But what of the fifth force proposed by Fishbach? Hypercharge, if it exists, is a force intermediate in range between the nuclear forces and electromagnetism. Fishbach showed that it seems to have a maximum range of about 200m and - unlike gravity - operates on different materials in different ways. Also unlike gravity it manifests itself as a weakly repulsive force.

Since January 1986 when these findings were published there has been a flood of papers, all reporting similar experiments and all drawing slightly different conclusions. A somewhat sceptical editorial in Nature (vol.329 no 6137) asked: whatever has happened to the fifth force? But while the debate hotted up, another contender entered the ring. Experiments conducted by the US Air Force and reported at a meeting of the American Geophysical Union, suggest the existence of yet another force - an attractive though weaker one - that operates over a slightly greater range than the repulsive force. This could explain why different experimenters have arrived at different conclusions. It would obviously depend on the precise conditions that obtained in any given experiment.

So what are we to make of forces five and six, if indeed they exist? Conveniently, some new quantum theories of gravitation not only allow the existence of such forces, they actually require them. This of course does not constitute proof in the scientific sense and there are still some physicists who remain sceptical. Nevertheless an increasing number of experiments are turning up results that do seem to indicate something unusual. And with the possibility of missiles going ever-so-slightly off course there is no doubt that the US military will continue to maintain a keen interest in any deviations from common-or-garden gravity.

Word processing, human-style

Using a technique called position emission tomography, a team at Washington University School of Medicine in St Louis have been able to discover exactly what goes on in our brains as we speak words and phrases. By mapping changes in physical parameters in the cerebral cortex, they've shown that comprehension and the subsequent speaking of words require the use of widely scattered areas of the cortex. Areas involved in the reading and hearing of words have independent parallel access to the systems that generate spoken words or make associations between works such as nouns and verbs.

This finding (Nature vol.331 no 6157) is the result of experiments involving the precise measurement of patterns of blood in the brain, monitored by rapidly-decaying radio-isotopes in the circulation.

The conclusion that human 'word-processing' is a parallel activity differs markedly from the generally-accepted model developed in the nineteenth century. The latter assumed that during reading, words are always mentally converted into a silently spoken form before being understood. Only then - on this theory - is the data finally passed on to the brain's speech centre.

The new work done in St Louis now demonstrates clearly that the brain doesn't in fact process words in this roundabout sort of way. When we read something aloud, the visual centre recognizes the word and passes it straight to the speech centre without any mental 'hearing' or 'understanding' going on in between.

These findings are not only of theoretical interest to brain researchers, but also to doctors and therapists trying to understand disorders of speech and language. Maybe it will also be possible to adapt some of the resulting theory in the design of new architecture for electronic parallel processors.

Research Notes is written by John Wilson of the BBC External Services science unit at Bush House.
## Semiconductors

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>Quantity</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>AF12</td>
<td>1500 ohm</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>AC1</td>
<td>100 ohm</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>AF12</td>
<td>2000 ohm</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>AC1</td>
<td>220 ohm</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>AC1</td>
<td>1k ohm</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>AC1</td>
<td>10k ohm</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>AC1</td>
<td>100k ohm</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>AC1</td>
<td>1M ohm</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>AC1</td>
<td>10M ohm</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>AC1</td>
<td>100M ohm</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>AC1</td>
<td>1000M ohm</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>AC1</td>
<td>10000M ohm</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>AC1</td>
<td>-</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>AC1</td>
<td>-</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>AC1</td>
<td>-</td>
<td>0.25</td>
<td></td>
</tr>
</tbody>
</table>

## Integrated Circuits

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>BF1504</td>
<td>2N5101</td>
<td>2.50</td>
</tr>
<tr>
<td>BF1505</td>
<td>2N5102</td>
<td>1.25</td>
</tr>
<tr>
<td>BF1506</td>
<td>2N5103</td>
<td>1.75</td>
</tr>
<tr>
<td>BF1507</td>
<td>2N5104</td>
<td>2.00</td>
</tr>
<tr>
<td>BF1508</td>
<td>2N5105</td>
<td>2.50</td>
</tr>
<tr>
<td>BF1509</td>
<td>2N5106</td>
<td>3.50</td>
</tr>
<tr>
<td>BF1510</td>
<td>2N5107</td>
<td>4.50</td>
</tr>
<tr>
<td>BF1511</td>
<td>2N5108</td>
<td>5.50</td>
</tr>
<tr>
<td>BF1512</td>
<td>2N5109</td>
<td>6.50</td>
</tr>
<tr>
<td>BF1513</td>
<td>2N5110</td>
<td>7.50</td>
</tr>
<tr>
<td>BF1514</td>
<td>2N5111</td>
<td>8.50</td>
</tr>
<tr>
<td>BF1515</td>
<td>2N5112</td>
<td>9.50</td>
</tr>
<tr>
<td>BF1516</td>
<td>2N5113</td>
<td>10.50</td>
</tr>
</tbody>
</table>

## Video Spares & Heads

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>BF1504</td>
<td>2N5101</td>
<td>2.50</td>
</tr>
<tr>
<td>BF1505</td>
<td>2N5102</td>
<td>1.25</td>
</tr>
<tr>
<td>BF1506</td>
<td>2N5103</td>
<td>1.75</td>
</tr>
<tr>
<td>BF1507</td>
<td>2N5104</td>
<td>2.00</td>
</tr>
<tr>
<td>BF1508</td>
<td>2N5105</td>
<td>2.50</td>
</tr>
<tr>
<td>BF1509</td>
<td>2N5106</td>
<td>3.50</td>
</tr>
<tr>
<td>BF1510</td>
<td>2N5107</td>
<td>4.50</td>
</tr>
<tr>
<td>BF1511</td>
<td>2N5108</td>
<td>5.50</td>
</tr>
<tr>
<td>BF1512</td>
<td>2N5109</td>
<td>6.50</td>
</tr>
<tr>
<td>BF1513</td>
<td>2N5110</td>
<td>7.50</td>
</tr>
<tr>
<td>BF1514</td>
<td>2N5111</td>
<td>8.50</td>
</tr>
<tr>
<td>BF1515</td>
<td>2N5112</td>
<td>9.50</td>
</tr>
<tr>
<td>BF1516</td>
<td>2N5113</td>
<td>10.50</td>
</tr>
</tbody>
</table>

## Video Belt Kits

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>BF1504</td>
<td>2N5101</td>
<td>2.50</td>
</tr>
<tr>
<td>BF1505</td>
<td>2N5102</td>
<td>1.25</td>
</tr>
<tr>
<td>BF1506</td>
<td>2N5103</td>
<td>1.75</td>
</tr>
<tr>
<td>BF1507</td>
<td>2N5104</td>
<td>2.00</td>
</tr>
<tr>
<td>BF1508</td>
<td>2N5105</td>
<td>2.50</td>
</tr>
<tr>
<td>BF1509</td>
<td>2N5106</td>
<td>3.50</td>
</tr>
<tr>
<td>BF1510</td>
<td>2N5107</td>
<td>4.50</td>
</tr>
<tr>
<td>BF1511</td>
<td>2N5108</td>
<td>5.50</td>
</tr>
<tr>
<td>BF1512</td>
<td>2N5109</td>
<td>6.50</td>
</tr>
<tr>
<td>BF1513</td>
<td>2N5110</td>
<td>7.50</td>
</tr>
<tr>
<td>BF1514</td>
<td>2N5111</td>
<td>8.50</td>
</tr>
<tr>
<td>BF1515</td>
<td>2N5112</td>
<td>9.50</td>
</tr>
<tr>
<td>BF1516</td>
<td>2N5113</td>
<td>10.50</td>
</tr>
</tbody>
</table>

## Carriage Kits

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>BF1504</td>
<td>2N5101</td>
<td>2.50</td>
</tr>
<tr>
<td>BF1505</td>
<td>2N5102</td>
<td>1.25</td>
</tr>
<tr>
<td>BF1506</td>
<td>2N5103</td>
<td>1.75</td>
</tr>
<tr>
<td>BF1507</td>
<td>2N5104</td>
<td>2.00</td>
</tr>
<tr>
<td>BF1508</td>
<td>2N5105</td>
<td>2.50</td>
</tr>
<tr>
<td>BF1509</td>
<td>2N5106</td>
<td>3.50</td>
</tr>
<tr>
<td>BF1510</td>
<td>2N5107</td>
<td>4.50</td>
</tr>
<tr>
<td>BF1511</td>
<td>2N5108</td>
<td>5.50</td>
</tr>
<tr>
<td>BF1512</td>
<td>2N5109</td>
<td>6.50</td>
</tr>
<tr>
<td>BF1513</td>
<td>2N5110</td>
<td>7.50</td>
</tr>
<tr>
<td>BF1514</td>
<td>2N5111</td>
<td>8.50</td>
</tr>
<tr>
<td>BF1515</td>
<td>2N5112</td>
<td>9.50</td>
</tr>
<tr>
<td>BF1516</td>
<td>2N5113</td>
<td>10.50</td>
</tr>
</tbody>
</table>
### A selection from our stock of branded valves

<table>
<thead>
<tr>
<th>Value</th>
<th>Part Number</th>
<th>Description</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.50</td>
<td>135.00</td>
<td>EL3(89</td>
<td></td>
</tr>
<tr>
<td>2.50</td>
<td>135.00</td>
<td>ECC(88</td>
<td></td>
</tr>
<tr>
<td>3.50</td>
<td>135.00</td>
<td>ECC8B SPECIAL</td>
<td></td>
</tr>
<tr>
<td>4.50</td>
<td>135.00</td>
<td>ECC8B</td>
<td></td>
</tr>
<tr>
<td>5.50</td>
<td>135.00</td>
<td>ECC8B</td>
<td></td>
</tr>
<tr>
<td>6.50</td>
<td>135.00</td>
<td>ECC8B</td>
<td></td>
</tr>
<tr>
<td>7.50</td>
<td>135.00</td>
<td>ECC8B</td>
<td></td>
</tr>
<tr>
<td>8.50</td>
<td>135.00</td>
<td>ECC8B</td>
<td></td>
</tr>
<tr>
<td>9.50</td>
<td>135.00</td>
<td>ECC8B</td>
<td></td>
</tr>
<tr>
<td>10.50</td>
<td>135.00</td>
<td>ECC8B</td>
<td></td>
</tr>
<tr>
<td>11.50</td>
<td>135.00</td>
<td>ECC8B</td>
<td></td>
</tr>
</tbody>
</table>

### June/July Price List

<table>
<thead>
<tr>
<th>Phone</th>
<th>0474 60521 4 Lines</th>
<th>P.M. Components Ltd</th>
<th>Selection House, Springhead Enterprise Park</th>
<th>Springhead Rd, Gravesend, Kent DA11 8HD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enter 2</td>
<td>Reply Card</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Callers Welcome**

Open Mon-Thu 9am-5.30pm

24-Hour Answerphone Service

Access to your unique keycard

Phone orders welcome

UK orders P&I please add 15% VAT

Express delivery available

Carriage at cost

Please send your enquires for special quotations for large requirements.
Memories are made of light

Important advances in the development of optical storage media have been recently made. Erasable optical discs and a new type of optical material are the major newcomers.

Magneto-optical storage. One system is actually on sale: the Asaca rewritable optical disc and its associated drive, which was on show at the NAB in Las Vegas in April. A prototype was shown last year and it is now in production. The system from Japan is specifically addressed at the video market and can be used to digitally record up to ten minutes of moving pictures with sound. A different drive is used to create a still picture library with one disc storing up to 2250 images, with 16-bit digital sound. A third machine can record and store 1200 h.d.s.i. still pictures, with a VME interface it is linked into image processing equipment and used for computer graphics, electronic publishing, medical images and many industrial applications.

Asaca’s system uses a similar technology to one developed by 3M, in which the surface of the disc is subjected to a magnetic field while being heated by a laser beam, polarizing the magnetic material in the disc. When scanned by a laser-powered laser, the magnetized domains change the optical polarity of the reflection, which is picked up by a sensor with a polarized filter. Sections of discs can be wiped by repeating the process with the magnetic field reversed, or the whole disc erased by a combination of heat and magnetic field.

Because the method of recording causes the physical alignment of magnetic domains, rather than just magnetizing, recordings are much more stable than conventional magnetic recordings.

3M are concentrating on the computer applications and the discs will have a similar function to CD-rom with the additional advantage of being erasable. One 5.25in double-sided disc stores up to 500Mbytes of data or the equivalent of about 600 floppy discs. Drives are still being developed for 3M, and Olympus having prototypes. The system has acquired the initials MO, for magneto-optical, which is likely to become as familiar as CD.

Digital paper. Perhaps DP for Digital Paper will become similarly familiar when the system developed by ICI becomes available. This also uses the heating properties of a 1µm diameter laser beam but this time, instead of changing the magnetic qualities of the medium, the beam alters the reflective characteristics of a dye polymer layer which changes in colour. This change allows the data to be read by a laser pick-up similar to that used in a CD player. The process is irreversible and permanent.

The other main difference is in the substrate material. In place of a rigid polycarbonate disc, Digital Paper uses a thin flexible polyester, similar to that used for magnetic tapes. This is easy to produce and very cheap. ICI quotes a price of “a third of a penny for a megabyte of storage.”

The stability needed to focus a laser beam onto the medium seems to make the flexibility of the tape a disadvantage but drives are being developed. One was demonstrated at CeBit in Hanover (see Telecommunications). One advantage is that the material is easy to cut into any required shape, be it tape, disc or even identity or price tags, ready to be applied as and when required. Storage capacity is phenomenal: one reel of 1km tape similar to the magnetic tape used by main-frame computers can store about 6000Gbyte, the equivalent of 1000 hours of digital music or 300 full-length feature films.

Multi-processor parallel computing

More than a thousand processors are incorporated into the Distributed Array of Processors (DAP), made by Active Memory Technology. The company achieved a triumph when it sold its first system to Argonne National Laboratory in the USA within a year of the company’s foundation. Universities and research establishments are queuing up to acquire this new computer. Its special virtue is speed, as the multiprocessor array can manipulate data between 10 and 100 times faster than rival systems.

Essentially, the computer has a 32 by 32 grid of 1024 single-bit processors, each having 32K of memory over which it has control. This allows very short data paths and high-speed (1Gbyte/s) communication between the processor and memory. A master controller interprets the coded instructions and distributes the tasks to the processors. Processor arrays are duplicated, one to be used as a slave to the active set and all operations are checked by comparing the two. Single-bit processors have a word length of one bit, since any combination of them is used in parallel, words can be of any length. Gone are constraints of specific 8, 16 or 32-bit words.

The system is used as a plug-in co-processor on a host workstation such as a DEC Vax or a Sun. Tasks can be assigned to the DAP from within the host’s programs. Hence, most of the software available is in the form of sub-routines, although many of them are almost complete programs in their own right. Fortran Plus is particularly suitable for the DAP as it takes full advantage of its array processing capabilities.

Some tasks like image manipulation are especially suited to the processor, as each element can be assigned to a specific cell. Single-hit processors might be have rather like brain cells and the Artificial Intelligence unit in Edinburgh University is investigating the similarity between the workings of the DAP and neural networks. Many other processing-intensive tasks are particularly suited to the DAP. A good example is data sorting: a demonstration program fills a video screen with a million pencils, the program can sort them all into bands by hue and intensity and complete the task in a half to one second, depending on the sorting strategy used.

Although the company is still relatively new, many of the staff previously worked on the technology at ICL, where the first generation of DAPs was developed. ICL transferred the patents to the new company and now owns a quarter of it.

Automatic laser soldering

Micro-soldering of surface-mounted and thick-film circuits has been made much easier by the introduction of a laser soldering system. A working prototype was on display at the recent Internepcon show in Birmingham. A consortium of companies developed the system from work initiated at Hull University, who remained a partner in Hull Unico Ltd. Don Whitehead of Hull Unico said: "The advantage of using lasers in soldering applications lies in the ability to direct the energy beam accurately and precisely on to a target area without heating the surrounding parts. The minimal rise in substrate temperature reduces mechanical stress: the rapid melting and cooling of the solder prevents the formation of intermetallic compounds which can cause brittle lead joint failure."  

The ability to control the amount of heat and its duration applied to a specific component or area makes reworking much simpler.

The success of recent field tests has encouraged the consortium to press on with commer-
cial development of the system and with this in mind they approached Dynapert, who specializes in p.c.h. production machinery. Norman Hudson, product manager at Dynapert said that the consortium had already done a very good job: "The system can be sold as it stands and offers sound base for further development."

Another member of the consortium is Laser Applications, who developed the CO₂ laser which features rapid power control up to 30W and generates a smooth dot pattern. Computer control is used for repetitive operations, but it is also possible to operate it by hand, with the aid of a joystick control and a high-resolution TV camera. These are also used to program a soldering sequence into the computer.

Cambridge Interconnection Technology is a member of the consortium and David Topham is particularly pleased that it is so self-contained: "It needs no cooling, no air, no vacuum - just a 13A plug!"

Optical position sensor

Take a thin slice of silicon, dope one side with boron and the other with phosphorus and you have a very special sort of solar cell. Output currents to the four electrodes at the edges vary precisely according to where on its surface light has fallen. The Optometer was developed at the Chalmers Institute and is being manufactured by SiTek Laboratories in Partille, Sweden. Maximum non-linearity of the output, relating to the position of a light spot on the surface, is about 0.05%, which means that it can measure a micron difference in position. It is also stable in varying temperatures and reacts in a few microseconds.

Sensors are combined with lasers to produce theodolites and other position-sensing instruments. If lights are attached to moving objects, even people, with their images projected through a camera lens onto the Optometer, it can give a direct reading of their positions, which is linked to a computer for movement analysis. Such analysis usually involves the painstaking study of the individual frames of a film or video recording.

Risky business

Two major instrumentation manufacturers have issued statements that they are producing new generations of equipment incorporating reduced instruction set computing (RISC) processors.

Hewlett-Packard have announced a number of new and upgraded computers incorporating 16-P's own RISC chip. It has also studied computer architecture in depth and come up with HP Precision Architecture. HP designers noted that mips is not as accurate a measure of performance as actual throughput of work done on a computer. They claim that the use of a RISC processor only accounts for about a third of the improvements in the company's computers. Other measures include optimizing the compiler codes, enhancing the storage facilities, interfaces and addressing systems. Operating and data management systems have also received a face-lift.

The designers stress that the system has applications throughout circuit technologies and offers advanced facilities for use in the future.

Risc technology is also the topic in a Tektronix brief. A new generation of graphics workstations will be based on Motorola's recently-announced 88000 RISC processor. There are as yet no further details but Tek is "sticking with industry standards, such as Motorola hardware, X Windows and Unix", according to Paul Morgan, a marketing manager.

Mips are still important to Motorola who quote 17mips as the speed of the 88000, which is three integrated circuits. These are an integer processor and a floating-point unit on one chip: the other two are both a combination of cache memory and a memory management unit. High-speed c-mos with 1.5µm geometry is used for the processors with sub-micron geometry promised for the future and even-higher-speed c.c.i. versions planned.

Scoreboarding is a technique used within the 88000 to simplify the design of compilers and other software. Instructions and registers are monitored automatically, so that software can make optimum use of the many registers without having to plot the exact progress of information as it is shunted round the registers. Motorola expects that the 88000 will find applications in telecommunications, artificial intelligence, graphics and animation, multi-user systems, parallel processing and supercomputers (and Tektronix workstations). There is no compatibility between the 68000 and 88000; however, Motorola have committed themselves to supporting both in the foreseeable future.

Engineering education proposals rejected by IEE

There is little historical evidence to suggest that large-scale changes in education system are better planned by government or outside bodies rather than from within. The best course of action is to give positive encouragement to likely developments as they arise from within the system. This approach is much more likely to be successful than the imposition of outside and untested changes and is also likely to produce less disruption in a system that is already under considerable pressure." This is the gist of the IEE's reply to the Engineering Council's discussion document 'Restructuring of Engineering Higher Education'. Although the EC report says that a successful engineering industry is essential to the nation's economy, and that more qualified engineers and technicians are required, it accepts too readily that expenditure on such education will remain static or even fall. Dramatic restructuring and amalgamation of university and polytechnic departments, is not the answer, says the IEE.

In brief

A computer image was used as evidence in a British court of law for the first time recently. Two aspects of image processing were used in court; the enhancing of the criminal's face from a security video and the use of the built-in computer to measure and analyse the scene of the crime.

The equipment used was the Ikonos system from TCS Electronics in Howe.

What sort of transducers does British industry really want? The question will possibly be answered by a strategic survey to be carried out by ERA Technology. Microprocessors have the capability of responding to more precise sensors. New processes need additional measurements. The survey will attempt to identify those parameters or conditions for which sensors are not currently available, or in need of considerable improvement. Recommendations will be made on areas where there is sufficient demand for a particular type of transducer to make it commercially viable.

The survey is being commissioned by sensor suppliers and any not yet participating can contact ERA Technology, in Leatherhead.
**APPOINTMENTS**

Advertisements accepted up to 12 noon May 26 for July issue

**DISPLAYED APPOINTMENTS VACANT:** £25 per single col. centimetre (min. 3cm). LINE advertisements (run on): £5.50 per line, minimum £44 (prepayable). BOX NUMBERS: £12 extra. (Replies should be addressed to the Box Number in the advertisement, c/o Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS). PHONE: PETER HAMILTON, 01-661 3033 (DIRECT LINE)

Cheques and Postal Orders payable to REED BUSINESS PUBLISHING and crossed.

---

**Technical Career Opportunities**

The Easy Way to look for your new job from the comfort of your own armchair. Our well qualified consultants will carefully match your requirements against appropriate vacancies.

We have many clients seeking Engineers and Technicians at all levels and we are particularly interested in hearing from you if you have experience in the following:

- R.F./Analogue
- T.V. Engineering
- A.T.E. Design
- Standards/Component Engineering

Your next step is to complete and return the attached coupon or telephone FRANK GIORDANO on 0442 53300 (evenings and weekends).

**Executive Recruitment Services**

Maylands Avenue, Hemel Hempstead, Herts. HP2 4LT

---

**HI-TECH ELECTRONICS DESIGN ENGINEERS**

Wanted immediately. Design Engineers for MAC transmissions and Television Encryption systems. Must have a very thorough knowledge of all types of creative electronics. Degree preferable. Salary to £25,000 pa. Send full CV to Chris Cary, Hi-Tech Electronics, Innovation House, Albany Park Industrial Estate, Frimley Road, Camberley, Surrey GU16 2PH. Tel: (0276) 684715.

---

**MEDICAL RESEARCH COUNCIL**

**Neurological Prostheses Unit**

**GRADUATE ELECTRONICS ENGINEER**

We need an electronics engineer with an interest in, and experience of, microprocessor programming. A major part of the work concerns the software control of surgically-implanted microelectronic devices for neurological prostheses, but the Unit's activities also include electronics design, development, construction, testing and maintenance. Starting salary in the range £10,252-£12,696 pa. Starting July-August.

Write enclosing CV and names and address of two referees, to: P. E. K. Donaldson, M.R.C. Neurological Prostheses Unit, 1 Windsor Walk, London SE5 8BB.

---

**Angel Recording Studios** requires an additional

**MAINTENANCE ENGINEER**

to join a professional team maintaining a three studio complex.

Phone: 01-354 2525

---

**Hardware/Software/Systems**

£9,000 - £25,000

As a leading recruitment consultancy we have a wide selection of opportunities for high calibre Design, Development, Systems and supporting staff throughout the U.K. If you have experience in any of the following then you should be talking to us for your next career move.

**ARTIFICIAL INTELLIGENCE**  **IMAGE PROCESSING**  **ANALOGUE DESIGN**  **MICRO HARDWARE & SOFTWARE**  **GUIDED WEAPONS**  **C • PASCAL • ADA • RF & MICROWAVE • ELECTRO-OPTICS • SIMULATION**  **• C • REAL TIME PROGRAMMING • SYSTEMS ENGINEERING • ACOUSTICS • SONAR • RADAR • SATELLITES • AVIONICS • CONTROL • ANTENNA**  **VLSI DESIGN**

Opportunities exist with National, International and consultancy companies offering excellent salaries and career advancement. To be considered for these and other requirements contact John Spencer or Stephen Morley or forward a detailed CV in complete confidence quoting Ref. WW/101.

STS Recruitment. Telephone: (0962) 69478 (24hrs), 85 High Street, Winchester, Hampshire SO23 9AP.
Our client, based on the South Coast is a major manufacturer of Instrumentation and Control equipment. Continued expansion has created an additional requirement for a:

**JUNIOR DEVELOPMENT ENGINEER**

(Analogue Circuits)

To work within the research and development department and assist Senior Engineers in product development, with particular emphasis on analogue circuit design.

Suitable applicants aged 23-26 will possess HND/Degree qualifications with 1-2 years' previous experience in an instrumentation and control environment.

The successful candidate can expect an attractive basic salary, profit related bonus, pension scheme, relocation where necessary and excellent career opportunities.

For further information contact:
**PREMIER PERSONNEL,**
Recruitment Consultants, Avialec House, 34 Princes Road, Petersfield, GU32 3BH. Tel: (0730) 67244.

---

**NORTH LINCOLNSHIRE HEALTH AUTHORITY**

**ST GEORGE'S HOSPITAL**

**MEDICAL EQUIPMENT UNIT MANAGER**

Due to the retirement of the existing postholder a vacancy has arisen for this senior position in the Medical Physics Service in North Lincolnshire. The Medical Equipment Unit provides a comprehensive equipment service throughout the District.

The successful candidate will need to have had extensive experience in equipment support. He/she will be responsible for seven other technical staff in the Unit and will be accountable to the Head of Medical Electronics.

Salary: Medical Physics Technician I - £10,830 per annum rising to £12,650 per annum.

For further information please contact Dr N. Gravill on (0522) 512512, ext 2738.

Application forms and job descriptions are available from and should be returned to:
**The Personnel Department,**
St George's Hospital, Long Leys Road, Lincoln LN1 1EF. Tel: (0522) 512512, ext 7001.
Wanted urgently
Practical people for the
Third World.

Many people want to help the Third World.
But relatively few can offer the kind of help
wanted most: the handing on of skills and
professions which lead to self-reliance.

You could make this priceless contribution
by working with VSO.

Current requests include:

- Electronics
  - Instructors
  - Studio
  - Electronic
    Engineer

- Hospital
  - Electronics
  - Engineers

- Lecturers in
  - Power and
    Communication

For more details, please complete and return
this advertisement to: Enquiries Unit, VSO,
9 Belgrave Square, London SW1X 8PW.

Conditions of work:
- Pay based on local rates
- Posts are for a minimum of 2 years
- You should be without dependants
- Many employers will grant leave of absence.

I'm interested. I have the following training/experience:

Name
Address

VSO
Helping the Third World help itself.
24p S.A.E. appreciated
Charity No 313757

CLIVEDEN
Technical Recruitment

SERVICE ENGINEER
Berks
Repair and service IBM pc., XT, AT
systems
£12,000

TEST ENGINEER
Middx
Fault find and repair digital video and
broadcast equipment
£10,000

FIELD SERVICE
ENGINEER
Berks
Data/telecomms equipment
£9,000 + car

REPAIR TECHNICIAN
N. London
Service and maintenance UHF/VHF
comms systems
£10,000 + bonus

BRANCH TECHNICIAN
Middx
Component level repair of radio
telephones
£12,000

PROJECT ENGINEER
Berks
Manage the development of process
control and telemetry systems, contracts
experience useful
£12,000 +

Hundreds of other Electronic vacancies
CLIVEDEN TECHNICAL RECRUITMENT
82 The Broadway, Bracknell, Berks RG12 1AR
Tel: 0344 498489 (24 hour)

FIELD SERVICE ENGINEER
£10,500 + Car
To cover London area for repair/
service of U.P.S. Previous
experience essential.

FIELD SERVICE ENGINEER
up to £12,000 + Car
For South West London. To
service a range of micro’s IBM/
Phillips/Epson/Fujitsu.

SUPPORT ENGINEER
up to £14,000
To provide support by phone/site
visits on micro based equipment.
Support background required.
Herts.

FIELD SERVICE ENGINEER
up to £14,000 + Car
To install/commission a range of
data comms equipment.
Experience with models/
multiplexers/Lan essential. Herts.

For further information please
contact Terry Broom on (0462)
37111 or after 6.30pm on (0767)
317379 alternatively please send
a CV to:
SOUTHERN RECRUITMENT
33 Bancroft, Hitchin, Herts SG5 1LA.

Professional Career Opportunities
£8,000 – £22,000 p.a.
The Effective Way to Find Your Next Job
We have many clients throughout the UK
Seeking Engineers at all levels
- Systems Engineering
- Analogue Design
- Real-Time Software
- Project Management
- Digital Design
- Test Engineering
Simply return the coupon for one of our
application forms or, alternatively, send us your
C.V. today using our FREEPOST address.

Name
Address

J O H N  P R O D G E R
Recruitment
Freepost 499 St. Albans
Herts AL3 5BR Tel: 0727 41101
After hours and weekends
0727 30602

ARTICLES FOR SALE

TEST EQUIPMENT
GOOD USED EQUIPMENT ALWAYS AVAILABLE & WANTED
SIGNAL SOURCES/SCOPES/ANALYSERS/BRIDGES/POWER SUPPLIES
HP 614A UHF signal source 800Mhz-2Ghz excellent order £450.00
HP 1715A 200Mhz/. D/T with delay, time, immaculate £1,250.00
HP 1714A 100Mhz, Van persist. storage, mint condition £1250.00

LOTS OF BARGAINS TO CALLERS.
Hours of business Monday-Friday, 9.30am-5.00pm.
Saturday by arrangement.
BUYING OR DISPOSING you should contact:
COOKE INTERNATIONAL
Unit 4, Fordingbridge Site, Main Road, Barnham, Bognor Regis,
West Sussex PO22 9ER. Tel: 0243 88 5111/2
TO MANUFACTURERS, WHOLESALERS, BULK BUYERS, ETC.

LARGE QUANTITIES OF RADIO, TV AND ELECTRONIC COMPONENTS FOR DISPOSAL

SEMICONDUCTORS, all types, INTEGRATED CIRCUITS, TRANSISTORS, DIODES, RECTIFIER, THYRISTORS,etc. RESISTORS, C/F, M/F, W/W, etc. CAPACITORS, SILICON, POLYSTYRENE, C200, C266, DISC CERAMICS, PLATE CERAMICS, etc. ELECTROLYTIC, CONDENSERS, SPEAKERS, CONNECTING WIRE, CABLES, SCREENED WIRE, SCREWS, NUTS, CHOKES, TRANSFORMERS, etc.

ALL AT KNOCKOUT PRICES — Come and pay us a visit ALADDIN’S CAVE

TELEPHONE: 445 0749/445 2713

R. HENSON LTD
(5 minutes from Fulham Road)

6/13

ARTICLES FOR SALE

FOR SALE
Motorola Escort 167 6809 Development System
In excellent condition and fully working order and supplied complete including relevant manuals. £6850.00. (01) 661 6063 (Lloyd I/O Cross-Assembler)

Newcom Communications Software
Stylograph Word Processor
Full documentation

For further details please contact:
Mr. P. B. Patel at Prestone Ltd on 01-871 3046

GOLLEDGE

ELECTRONICS

QUARTZ CRYSTALS OSCILLATORS AND FILTERS of all types. Large stock of standard items. Specials supplied to order. Personal and commercial reference supplied to order. Please telephone 01-376236.

01-376236.

10/13

ARTICLES WANTED

WANTED
Test equipment, receivers, transmitters, components, cable and electronic scrap and quantity. Prompt service and cash. M & B RADIO
86 Bishopsgate Street
Leeds LS1 4BB
0532 435649

09/02

STEWART OF READING
110 WYKEHAM ROAD
READING RG6 1PL.

TOP PRICES PAID FOR ALL TYPES OF SURPLUS TEST EQUIPMENT, COMPUTER EQUIPMENT, COMPONENTS etc. ANY QUANTITY

S. E. Labs, Tektronix 0460 73718.

BILLINGTON VALVES
20 Highlnd Road, Handsworth, West S_SUSSEX BN4 5LA.
Tel: 0243/46878 Fax: 0243/46878 (day)

BILLINGTON VALVES

FOR QUOTATIONS contact Martin Billington

01-270-7070 ext. 202 609

WANTED TRANSISTORS 1Cs

WANTED also IC sockets, plugs, connectors, factory clearance etc. Valves types PX4 PX20 KT96 especially wanted. Billington Valves See above

FOR SALE

G.W. RADIO LTD
40-42 Portland Road, Worthing, Sussex BN11 2AD

Communications Receivers — Racial RA 17 £175
Edystede 7304 £110 plus carriage s.a.e. for details. Many bargains for callers

10/13

CIRCOLEC
THE COMPLETE ELECTRONIC SERVICE

Please telephone 01-646 5989 for advice or further details.

TAMWORTH MANOR
302-310 COMMSCOPE EAST, M ritcham

11/01

AUCTIONS

John Russell & Co
Auctioneers & Valuers of Computer Hardware, Electronic Measurement and Test Equipment

Auctions every 3 weeks throughout the South of England.

For forthcoming sales:
Friday 27th May: The West Pavilion Suite, Twickenham Rugby Football Club, Middlesex. Test & measurement equipment, microcomputers, etc.
Saturday 11th June: The Pavilion, Lingfield Park, Racecourse, Lingfield, Surrey. 1,000 lots of microcomputer, peripherals add-ons, software and accessories. Telford Spot Welding Heats £95.
Saturday 9th July: Dacorum College, Hemel Hempstead, Herts Microcomputers & Peripherals.
Saturday 30th July: The Cannons Leasure Centre, Madeira Road, Mitcham, Surrey. Microcomputers & Peripherals

Phone: 01-681 5413 for details of the above auctions or write to:

Heathrow, Middlesex.

11/01

COURSES

UNIVERSITY OF WALES

CARDIFF COLLEGE OF ENGINEERING

MSc in Electronic Engineering

Analogu and Digital Signal Processing, Communication Systems, Information Technology, Control and Instrumentation, Medical Electronics, Integrated Circuits, Power Systems

Diploma in Electronic Engineering

(Approved by the Council of Higher Education in Technology to meet the MSc scheme)

Further details and application forms may be obtained from the

Assistant Registrar, UWIST, PO Box 68, Cardiff CF1 3XA.

10/02

631
MATMOS LTD, 1 Church Street, Cuckfield, West Sussex RH17 5JZ.
Tel: (0444) 414484/454377.
COMPUTER APPRECIATION, 30/31 Northgate, Canterbury, Kent CT1 1BL.
Tel: (0227) 470512.

TRIUMPH ADLER ROYAL OFFICE MASTER 200 DAISY WHEEL PRINTERS, 20 cps. FULL MANUFACTURERS' SUPPORT AND SERVICES INTERFACE, housing, underframe, lid, subscripts, superscripts, etc. Complete with typewriter and ribbon, manufactured to highest standards in Germany by Europe's largest typewriter manufacturer and offered elsewhere at over £350.00...£119.50 (carr. £5.00).

VICTOR SPEEDPAK 296, 0296 based speed up card for IBM PC. Features cache memory and runs 8 to 7 times faster...£139.00 (carr. £3.00).

DEC PDP 11/73 SYSTEM with DZV11 asynchronous multiplexer, DLV11 serial interface, BA11-S 9 x 4 backplane, TANDON 8 floppy disc drive with DILOG MODEL RXV-21 controller. 2 x AMPEX PYRIS 27.5" Winchester disc drives with DILOG DO 614 controller. All controllers NOFAC and power control, 5.25" disc memory, Fast 170, 3M Winchester device...£1245.00 (carr. £15.00).

PANASONIC MODEL JU-363 3" floppy disc drives. Double Sided Double Density 80 track, 1 megabyte capacity unformatted. Lasered low component 1/2 height design. SHUGART compatible interface using 34 way DIL plug. Will interface to just about anything. BRAND NEW! (We can offer at least 20% discount for quantities of 5). Current Model...£99.00 (carr. £5.00).

DATA GENERAL MODEL 6220 8" Winchester drive, 10mbyte. Apparently suitable for above. Condition as seen...£175.00 (carr. £5.00).

Please note: 'VAT & carriage (also - VAT) must be added to all prices. 

INDEX TO ADVERTISERS

Apointments Vacant Advertisements appear on pages 628-631

START 39 ON REPLY CARD
19" RACK MOUNT CRYSTAL CONTROLLED
VESTIGIAL SIDEBAND TELEVISION MODULATOR

PRICES FROM £203.93 (excluding VAT & carriage)

Prices
CCIR/5-1 Modulator £104.53
CCIR/5-2 Modulators £159.99
CCIR/5-3 Modulators £226.28
CCIR/5-4 Modulators £292.56
CCIR/5-5 Modulators £358.85

19" RACK MOUNT VHFI/UHF
TELEVISION DEMODULATOR

PRICE AT ONLY £189.00 (excluding VAT & carriage)

WALLMOUNT DOUBLE SIDEBAND
TELEVISION MODULATOR

PRICES FROM ONLY £104.53 (excluding VAT & carriage)

TAYLOR BROS (OLDHAM) LTD.
BISLEY STREET WORKS, LEE STREET,
OLDHAM, ENGLAND.
TEL: 061-652 3221
TELEX: 669911
FAX: 061-626 1736
2955 The multi-
function civil and
military mobile radio
test set that is easy to
use and makes others
seem slow and
overpriced.

The first name
to call for
mobile radio test

Who else could offer you a
comprehensive range of innovative
instruments offering more features
and simpler operation, for less money?

To test the performance of these
dedicated radio systems plus our
outstanding range including
Spectrum Analyzers, Frequency
Counters and Datacomms Analyzers
call us first on 0727 59232.
Marconi Instruments Limited, Longacres,
St. Albans, Herts. AL4 0JN, England.

2957 The first choice
for AMPS cellular
testing, now with
EAMPS software.

2306 MISATT
Programmable semi
automated radio test
system with fast
2019A Signal
Generator and
accurate 2305
Modulation Meter now
with comprehensive
IBM PC test software.

2963 TACS abbreviated
cellular radio testing
in 30 seconds.

2968 Now with
Domestic and
Worldwide NMT
variants capability.

Marconi
Instruments

1967