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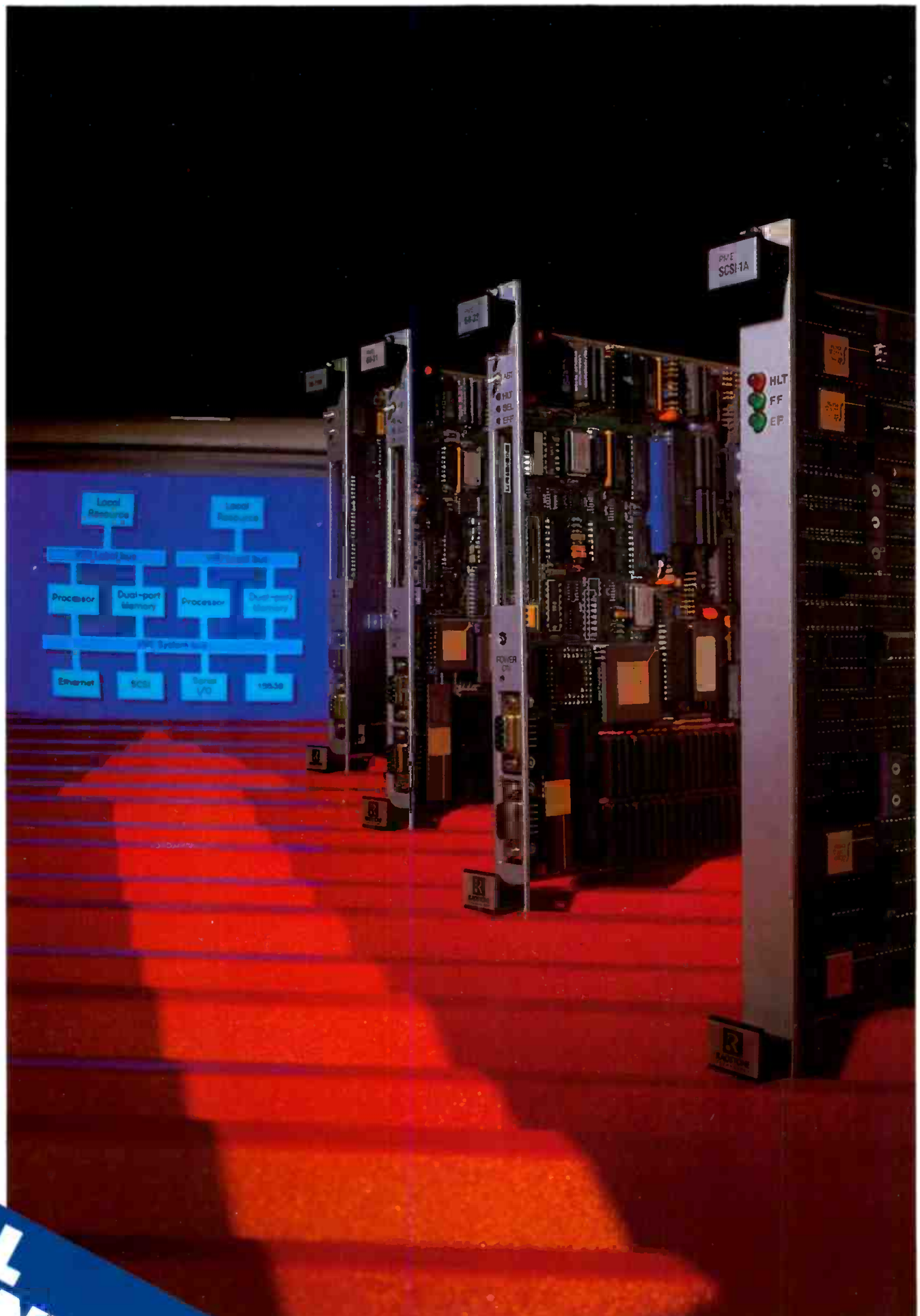

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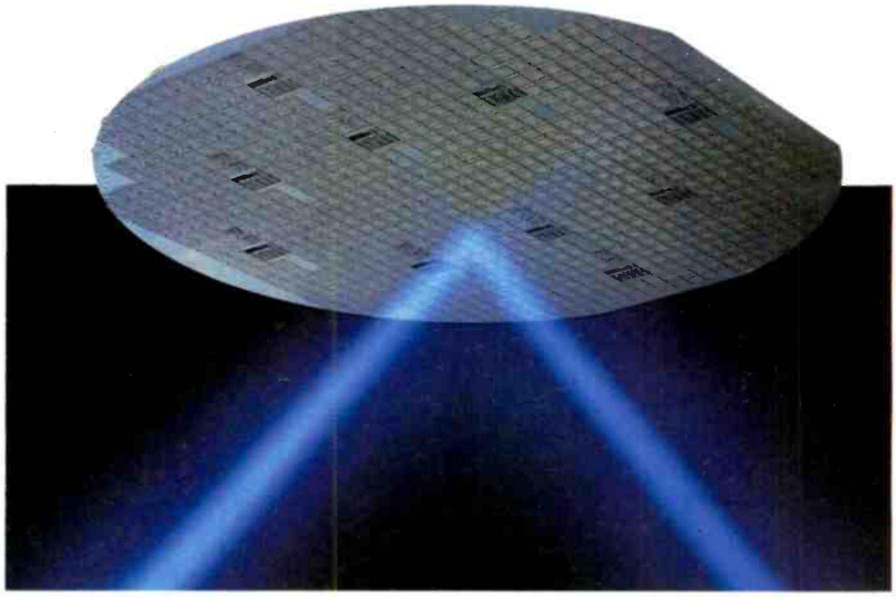

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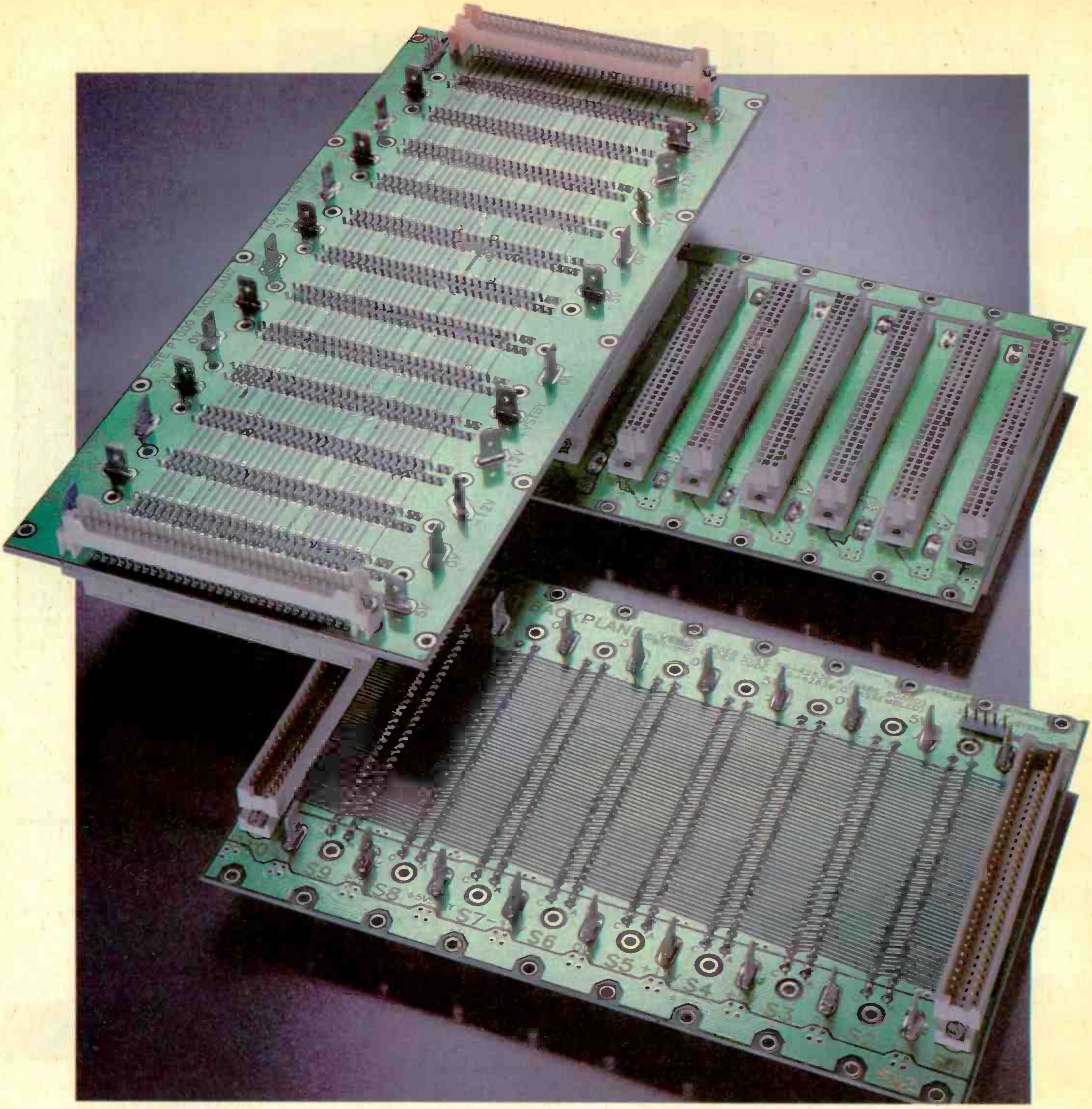

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COMMENT

Long-term R&D – who cares?

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REED BUSINESS PUBLISHING

When the Government abolishes the IBA, as now seems imminent, one result could be another loss to sustained engineering research and development in the UK.

Earlier this year the IBA was told it would no longer be regulating commercial radio. In July the Parliamentary Select Committee on Home Affairs published a report on the future of broadcasting which recommended that all commercial television – terrestrial broadcasting, cable and satellite – should be regulated by a single commercial tv authority. Douglas Hurd, the Home Secretary, is apparently in favour of this idea and will include it in a White Paper on broadcasting due out in November. This could result in a Bill during 1989 and an Act of Parliament the following year.

Although the new commercial tv authority would carry on many of the IBA's present engineering functions there is some doubt on whether these would include long-term R&D projects. The IBA's experimental and development department has made world-renowned contributions to broadcast engineering. Best known are probably its projects in teletext, the MAC system, digital video recording and standards conversion, adaptive antennas, satellite uplinks and extended-definition tv. It has also published a steady stream of advanced analytical studies and research findings in the electronics literature. Over the years the UK commercial programme companies have greatly benefitted from this backing, but now, because they don't have the resources to do such work themselves, are alarmed at the prospect of losing it. They could become totally dependent on foreign technology.

The change is being made by a government with a philistine attitude to intellectual achievement, that is turning over university research to the military-industrial complex and allowing academic research assistants to work unpaid except by the DHSS. In spite of the Japanese example, it doesn't seem to understand the need for research not tied to the immediate market and how this functions to the good of the economy. Developments like those mentioned above are seen as clever ideas or gadgets thrown off in moments of inspiration by brilliant scientists or inventors. Such notions go well with the opportunistic, casino-like attitudes that now hold sway in Britains's deregulated financial services. We saw an example of this blinkered outlook recently when the Government's plans for privatizing the electricity supply industry completely forgot to include anything about R&D in this field.

It can be argued that R&D in broadcast engineering should be done by the manufacturers of broadcast equipment themselves. This would be fine if we had a few British owned companies of the calibre of Sony, NEC, Matsushita and the like. But most of the UK electronics industry, recently criticised in a NEDO report, is too preoccupied with mergers, takeovers, rationalizations and other measures for survival in the financial jungle to be bothered with such details as R&D – the lack of which has been mainly responsible for its relative decline in the first place.

One idea being considered for the proposed commercial television authority is that the newly broadened engineering side might be split off from the regulatory function and be turned into an autonomous commercial company. If this could be done successfully, with reliable funding and perhaps collaborative links with other European organizations through the EEC, it might possibly provide a suitable environment to support the life and growth of long-term R&D. Certainly the IBA technicians, engineers and scientists caught up in the present changes have a right to expect reasonable conditions of stability and security for their work. If they don't get this they will take their talents and experience elsewhere, and the new tv authority will be the poorer.

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Interfacing and signal processing with C

This article is aimed at engineers who have heard of the advantages of programming in C, and would like to see how this powerful language can be exploited when interfacing a microcomputer to the real world.

HOWARD J. HUTCHINGS

If you require the advantages of assembly language programming without the frustration of learning yet another idiosyncratic instruction set – then C may be the language you have been looking for. The versatility of C allows it to run on personal eight-bit computers or on Cray-1, the world's fastest computer. Designed to make programs fast and compact, this portable assembly language was used to program the remarkable computer-animated sequences in *Return of the Jedi* and the *Star Trek* series. In many cases, programs written in assembly language for 'efficiency' have been outperformed by comparable programs written in C. Despite being a medium-level language, it embodies advanced structured programming features normally associated with high-level languages such as Pascal. C is a small language and small can be beautiful when programming.

The C language is compiled. Program statements are not executed directly but written to a file called the source program. This file converts program statements into machine instructions – the object code. Finally the object code is processed into executable code by a link program prior to running in the computer.

Before you can interface successfully with C it is first necessary to access data from specific memory locations. Basic provides this facility with the familiar Peek and Poke commands (in BBC Basic, through the ? and ! indirection operators). C provides an analogous read, write structure – although the construction is a little more complicated, involving the use of pointers. As an illustration, consider the problem of accessing data from the user port (located at address 65120 in the BBC model B). Two possible constructions are shown in Fig.1.

Repetition figures prominently in many programming applications; C provides a number of particularly attractive and elegant constructions. In Fig.2, we require the main body of the program (which is largely made up of the previous program fragments) to be repeated indefinitely. One possible construction which avoids using the infamous Goto is

```
for ( ; ; )
{
/* C CODE TO BE EXECUTED
INSIDE INFINITE LOOP */
}
```

```
/**********
* READING *
**********/
#include<h.stdio
main()
{
int *portb;
int *ddrb;
unsigned char contents;
/*---------------------
*portb AND *ddrb ARE
POINTERS DECLARED AS
INTEGERS.THE VARIABLE
contents IS AN UNSIGN
ED CHARACTER
---------------------*/
portb = (int*)65120;
ddrb = (int*)65122;
/*----------------------
THIS CONSTRUCTION ESTABL
ISHES THE ADDRESS OF THE
POINTERS
----------------------*/
*ddrb = 0;
contents = *portb;
/*----------------------
MAKE PORT B AN INPUT.'*'
BEHAVES AS AN INDIRECTION
OPERATOR.WHEN THE * IS US
ED AS A PREFIX TO AN INTE
GER VARIABLE NAME WE RECO
VER THE VALUE AT THAT ADD
RESS -------------------*/
printf("%d\n",contents);
/*-----------------------
PRINT THE DENARY CONTENTS
OF PORT B ON THE SCREEN
----------------------*/
}
```

```
/**********
* WRITING *
**********/
#include<h.stdio>
main()
{
int *porta;
int *ddra;
int x;
portb = (int*)65121;
ddrb = (int*)65123;
*ddra = 255;
/*-------------------
MAKE PORT A AN OUTPUT
-------------------*/
scanf("%d",&x);
/*-------------------
INPUT A NUMBER FROM
THE KEYBOARD
-------------------*/
*porta = x;
/*-------------------
USE INDIRECTION OPER
ATOR TO WRITE X INTO
PORT A
-------------------*/
}
```

Fig.1. Accessing absolute addresses with C.

The program in Fig.2 is designed to read a number from the keyboard, to output the binary value to leds on port A and read/display the contents of port A.

DATA TYPES

To illustrate how C deals with data types consider Fig.2 again. Suppose in our haste to program we had inadvertently declared – **int contents**. C interprets the variable *contents* as a signed binary integer, with potentially disastrous consequences when reading the contents of the user port. Fortunately C includes a construction called a cast which persuades the compiler that an object of one type should be treated as if it had a different type. A cast gives the language flexibility, permitting eleventh hour fixes. The modification is:

```
printf("%d\n",(unsigned char)contents);
```

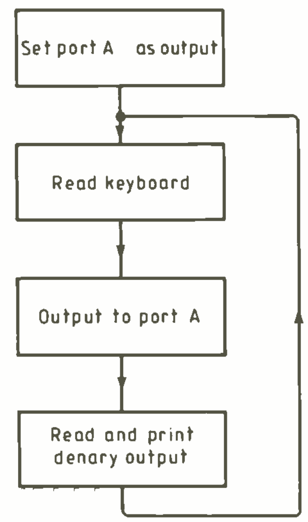
Square-wave generator. This simple example, Fig.3, generates a square-wave of appro-

COMPUTER AND COMPILER

Program examples presented in this article have all been tested on a BBC model B microcomputer using a Beebug C compiler. The emphasis is on effective interfacing rather than elegant programming. Where possible I have included alternative program constructions in an attempt to demonstrate the flexibility of this remarkable language. Most programs exist to be re-written; and if after working through the examples you cannot do better, I'll be disappointed.

I have tried to organize the programs in a progression of complexity such that each program presents a new feature of C or an alternative program construction. All of the examples are concerned with interfacing a microcomputer to the predominantly analogue outside world, and each program is littered with comments to aid comprehension. Comments – which are preceded by a slash-star/* and terminated by a star-slash */ – are similar to Basic REM statements and are ignored by the compiler.

Certain constructions are fundamental and where possible the fine detail of the program is presented separately as an aid to understanding.




```
/**********************
*                     *
*  REPETITIVE READ-   *
* WRITE-DISPLAY LOOP  *
*                     *
**********************/
#include<h.stdio>
main()
{
int *porta;
int *ddra;
int x;
unsigned char contents;
porta = (int*)65121;
ddra = (int*)65123;
/*-----------------
 DECLARE POINTERS
-----------------*/
ddra = 255;
for(;;)
{
/*-------------
 INFINITE LOOP
 . -----------*/
printf("Enter a no.\n");
scanf("%d",&x);
/*-----------------
  I/P NO. FROM KEY
      BOARD
-----------------*/
*porta = x;
/*------------------
  WRITE TO O/P PORT
------------------*/
contents = *porta;
printf("%d\n",contents);
/*------------------
  READ O/P & DISPLAY
------------------*/
}
}
```

Fig.2. Simple program to monitor keyboard continuously and to write to port A.

Table 1: data types in C.

Type	Size (bytes)	Value/range
char	1	−127 to +128
unsigned char	2	0 to 255
int	2	−32768 to +32767
unsigned int	2	0 to 65535
float	4	single-precision floating point to E38
double	8	double-precision floating point to E308

ximately 1000Hz, by causing PA_0 to go repeatedly high then low. As a programming exercise it demonstrates how we can replace names for constants, improving the readability of the program. Most C programmers use upper-case letters when naming a **#define constant** – this helps to distinguish variables from defined constants. Notice that the constants are defined outside the main program.

```
/****************
*                *
* SQUAREWAVE     *
* GENERATOR      *
*                *
****************/
#include<h.stdio>
#define ON 1
#define OFF 0
main()
{
int *porta;
int *ddra;
porta = (int*)65121;
ddra = (int*)65123;
*ddra = 255;
for(;;)
{
*porta = ON;
*porta = OFF;
/*-------------------
 DEFINED CONSTANTS
 -------------------*/
}
}
```

Fig.3. Square wave generator.

```
/*********************
*                    *
* BINARY COUNTER     *
*                    *
*********************/
main()
{
int *porta;
int *ddra;
int i;
int k;
porta = 65121;
ddra = 65123;
*ddra = 255;
for(;;)
{
int i = 0;
while(i++ <= 255)
/*---------------
 TEST "I" THEN
    ADD ONE
 ---------------*/
{
*porta = i;
printf("%d\n",i);
for(k = 0;k <= 800;k++)
{
/*-------------------------
    3 PARTS OF LOOP
INITIALISE:TEST:INCREMENT
-------------------------*/
}
}
}
}
```

Fig.4. Building a binary counter on the leds of port A and displaying the status of the count on the screen.

A binary counter. Educationally the program of Fig.4 is particularly rewarding because it demonstrates a number of different loop constructions in a single program.

The program structure is made up of a number of loops; the outer loop,

```
for ( ; ; )
{
}
```

ensures that the count is continued indefinitely. The actual count is controlled using the

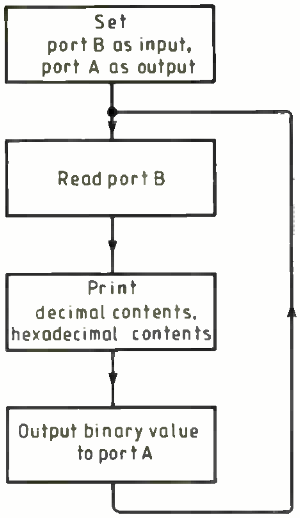
```
while (expression)
{
}
```

construction. In this case the expression is made up of the post-increment operator **i++ <=255** which means, test the value of i and then add one to it. C includes a pre-increment operator **++i** which, not surprisingly, means add one and then test. I chose not to include this latter construction since the counter would start from one, rather than zero. To produce an observable display it was necessary to introduce a significant time delay into the loop. This is exploited to demonstrate the for construction in greater detail.

CONTROLLING PRINTF

By modifying the format of the **printf** statement we are able to display a variety of different data types. The format specification begins with the % and ends with the desired data type. In this example, Fig.5, the **d** ensures the argument is output is signed decimal notation, whilst the **x** ensures unsigned hexadecimal output. This format is by no means exhaustive, although adequate for our present purposes.

Light-chaser effect: this program, Fig.6, is designed to produce the effect of a light running repeatedly across the leds connected to port A. It works by taking powers of two and writing the byte to the output port, and demonstrates how to write your own functions in C[1]. Notice that the program is composed of a main function that controls the flow of the program, together with a function **power(x,n)** that can be called and executed from the main function.



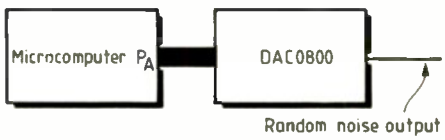

```
/************************
*                        *
* READ I/P SWITCHES      *
* DISPLAY IN DECIMAL     *
* AND HEX O/P TO LEDS    *
*      ON PORT A         *
*                        *
************************/
#include<h.stdio>
main()
{
int *portb;
int *ddrb;
int *porta;
int *ddra;
unsigned char contents;
portb = (int*)65120;
ddrb = (int*)65122;
porta = (int*)65121;
ddra = (int*)65123;
/*-----------------
 DECLARE POINTERS
 -----------------*/
*ddrb = 0;
*ddra = 255;
/*-----------------------
 MAKE:PORTB I/P PORTA O/P
 -----------------------*/
for(;;)
{
/*-------------
 INFINITE LOOP
 -------------*/
contents = *portb;
printf("Decimal No.:%d\n",contents);
printf("Hex No.:%x\n",contents);
/*---------------------------
  READ AND DISPLAY I/P PORT
      DENARY AND HEX
 ---------------------------*/
*porta = contents;
/*------------------
  WRITE TO O/P PORT
 ------------------*/
}
}
```

Fig.5. Program to read the switches on Port B, display their decimal and hexadecimal values on the screen and output their values to leds on port A.

```
/*****************/
/*               */
/* LIGHT CHASER  */
/* WRITE YOUR    */
/* OWN FUNCTIONS */
/*               */
/*****************/
main()
{
int *porta;
int *ddra;
int i;
int k;
unsigned char contents;
porta = (int*)65121;
ddra = (int*)65123;
ddra = 255;
for(;;)
{
for(i = 0;i <= 7;i++)
{
contents = power(2,i);
*porta =contents;
for(k = 0;k <= 100;k++)
{
/*--------------------
 TIME DELAY IMPROVES
    VISUAL EFFECT
--------------------*/
}
}
}
}
/*-----------------------------
 RAISE X TO N-TH POWER:N > 0
-----------------------------*/
power(x,n)
int x;
int n;
{
int i;
int p;
p = 1;
for(i = 1;i <= n;i++)
p = p*x;
return(p);
}
```

Fig.6. Write your own functions: this example shows a light-chaser.

A random noise generator. Configuring a port as an output and connecting an eight-bit d-to-a is the basis of this example, Fig.7. The program generates random combinations of integers in the range 0 to 255 using the **rand()** function. Notice that the macro **#define RANDMAX 255** is placed outside the main body of the program, which restricts the maximum value returned.




```
/*****************
*                 *
* RANDOM NOISE    *
*   GENERATOR     *
*                 *
*****************/
#include<h.stdio>
#include<h.stdlib>
#define RANDMAX 255
/*-----------------
 LIMIT RANDOM NO.
-----------------*/
main()
{
int *porta;
int *ddra;
porta = (int*)65121;
*ddra = (int*)65123;
*ddra = 255;
for(;;)
{
*porta = rand();
/*----------
 O/P TO DAC
 ----------*/
}
}
```

Fig.7. Creating a random noise generator.

Synchronized a-to-d conversion: this program, Fig.9, synchronizes the operation of the a-to-d with the data capture and display routine. This approach is particularly rewarding when modelling sampled data systems or writing software-based signal processing algorithms.

Pin 4 of the bipolar a-to-d ZN449 (Fig.8) is supplied with a low-going start conversion pulse generated on CB_2. The end-of-conversion signal generated on pin 1 is connected to CB_1 which raises IF_4 in the interrupt flag register of the 6522 v.i.a. The flag is Anded with a mask (denary 16), so that

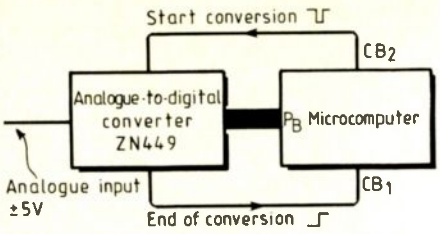
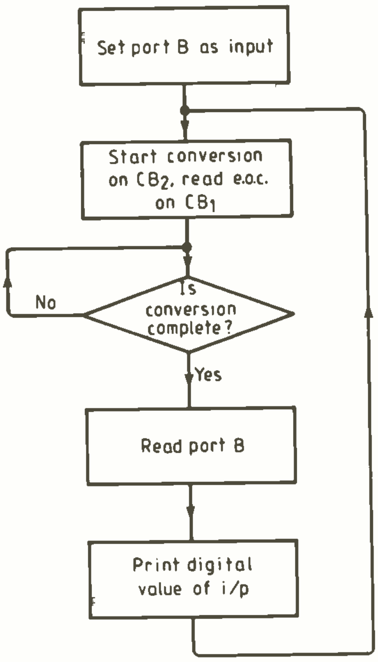


Fig.8. Interfacing an analogue-to-digital converter to the computer via the 6522 versatile interface adapter.

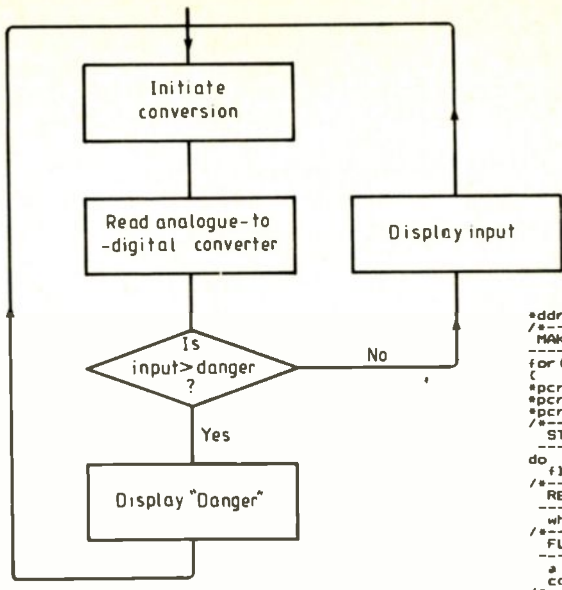
when the flag is set, the current contents of the a-to-d are read on the input port B.

The conversion time of the software-controlled a-to-d can easily be monitored by connecting an oscilloscope to pin 4 of the a-to-d. Some increase in speed can be achieved by deleting the flag-testing software, since the conversion time is guaranteed as 9µs.




```
/*******************
*                  *
* SYNCHRONIZE ADC  *
*   PRINT DECIMAL  *
* VALUE OF INPUT   *
*                  *
*******************/
#include<h.stdio>
main()
{
int *portb;
int *ddrb;
int *pcr;
int *ifr;
double a;
char flag;
double contents;
portb = (int*)65120;
ddrb = (int*)65122;
pcr = (int*)65132;
ifr = (int*)65133;
/*---------------
 DECLARE POINTERS
-----------------*
*ddrb = 0;
/*---------------
 MAKE PORT B I/P
-----------------*/
for(;;)
{
*pcr = 240;
*pcr = 208;
*pcr = 240;
/*---------
  START ADC
 ---------*/
do
  flag = *ifr;
/*--------
  READ IFR
 --------*/
  while(!(flag & 16));
/*-------------
  FLAG RAISED ?
 -------------*/
  a = *portb;
  contents = 0.039 * (a - 128);
/*----------------------------------
  READ I/P PORT: WEIGHT & OFFSET
 ---------------------------------*/
  printf("Digital i/p:%f\n",contents);
 }
 }
```

Fig.9. Program to synchronize a-to-d and print decimal value of input signal.



A more satisfactory approach would be to write the software to control the operation of the a-to-d in assembly language. Standard C permits this with the compiler directives **#asm** followed by the required assembler code and terminated with **#endasm**[2]. Unfortunately Beebug C does not yet include these directives.

A software-based comparator. An interesting modification to the a-to-d program is to add a warning displayed on the screen when the input exceeds a pre-determined threshold, Fig.10. In this example we have set the threshold at +2.0V, **#define DANGER 2.0**

The conditional jump structure is simply achieved by the construction

```
if (contents >= DANGER)
{
printf("Danger \n");
}
else
{
printf ("Digital i/p: %f\n", contents);
}
```

Data capture with graphics. The superb graphics associated with the BBC computers are readily accessible using Beebug C, which retains the familiar mode(), draw() and plot() functions. Figure 11 shows how real-time graphics can be incorporated into the data logging example and paves the way for the more sophisticated signal processing applications to be presented later[3].

In this example, repetition is achieved by the goto command, which returns control to the statements that begin at the label *start* (which must be terminated with a colon).

SIGNAL PROCESSING WITH C

Relatively advanced signal processing techniques are routinely available using personal computers programmed in C. Consider the problem of calculating and displaying the autocorrelation function of the data captured and displayed previously. The required signal processing algorithm for continuous signals is given by

$$r_{xx}(\tau)=\lim_{T\to\infty}\left[\frac{1}{T}\int_{-T/2}^{T/2}x(t)x(t+\tau)dt\right]$$

```
/**************
*             *
*  SOFTWARE   *
* COMPARATOR  *
*             *
**************/
#include<h.stdio>
#define DANGER 2.0
main()
{
int *portb;
int *ddrb;
int *pcr;
int *ifr;
double a;
char flag;
double contents;
portb = (int*)65120;
ddrb = (int*)65122;
pcr = (int*)65132;
ifr = (int*)65133;
/*---------------
 DECLARE POINTERS
-----------------*
*ddrb = 0;
/*---------------
 MAKE PORT B I/P
-----------------*/
for(;;)
{
*pcr = 240;
*pcr = 208;
*pcr = 240;
/*---------
  START ADC
 ---------*/
do
  flag = *ifr;
/*--------
  READ IFR
 --------*/
  while(!(flag & 16));
/*-------------
  FLAG RAISED ?
 -------------*/
  a = *portb;
  contents = 0.039 * (a - 128);
/*----------------------------------
  READ I/P PORT: WEIGHT & OFFSET
 ---------------------------------*/
if(contents >= DANGER)
/*-----------------------
 TEST IF I/P EXCEEDS 2.0V
 -----------------------*/
{
printf("Danger\n");
}
else
{
 printf("Digital i/p:%f\n",contents);
}
}
}
```

Fig.10. Software comparator.

which may be re-written in sampled data form[4]

$$r_{xx}(k)=\frac{1}{N}\sum_{n=0}^{N-1}x(n)x(n+k)$$

The sampled data system organized around a ZN449 a-to-d is designed to capture 512 bytes of data in real time and store the data sequentially in an array Fig.12. The program then evaluates the autocorrelation coefficients and plots them on the screen.

The a.c.f. construction is made up essentially of a pair of nested loops, to provide the necessary multiply-summate and shift structure.

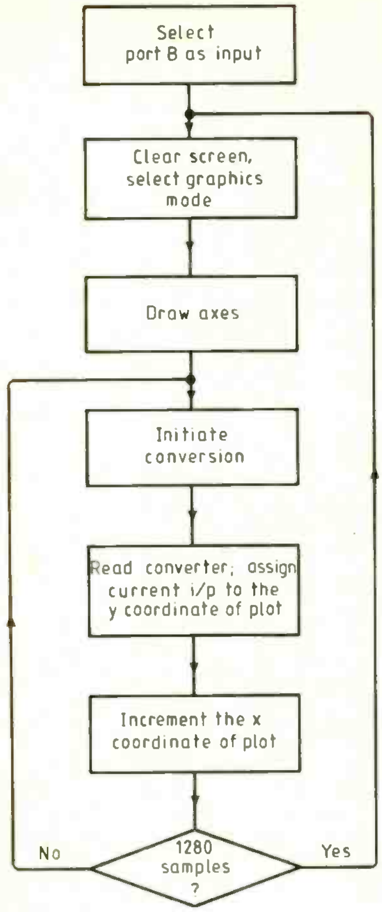
```
for (k=0; k<=255 ++k)
{
sum=0; /* RESET TO ZERO */
for (i=0; i<=255; ++i)
{
sum += contents[i]*contents[i+k];
...
```

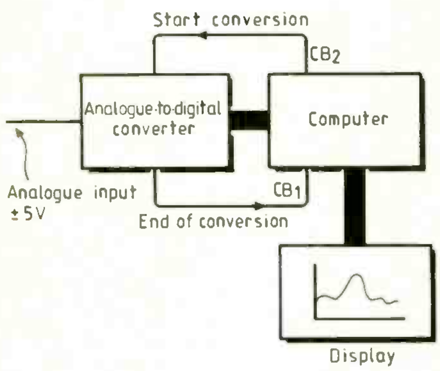
Notice the captured data is stored in an array identified by the squared brackets. The shifted and multiplied data array is summated by the addition assignment operator **sum +=**, which is then divided by N to give each autocorrelation coefficient. This is then plotted on the screen to display the autocorrelation function.

To avoid an excessively long processing time I have restricted the value of k. The x coordinate of Plot() is multiplied by four to exploit the horizontal range of the graphics routine.

Spectrum analysis. The data capture with graphics routine provide a useful time-domain record of the captured signal. In certain applications it may be advantageous to present this in a complementary form, as a frequency-domain record.

For example, let us use the impressive computational power of the personal com-

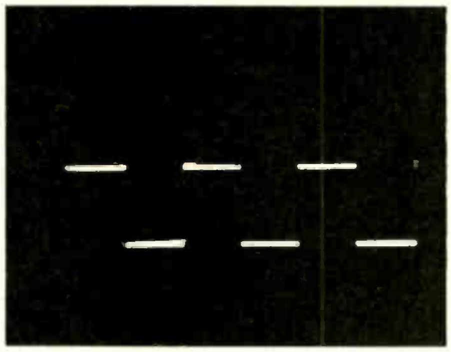




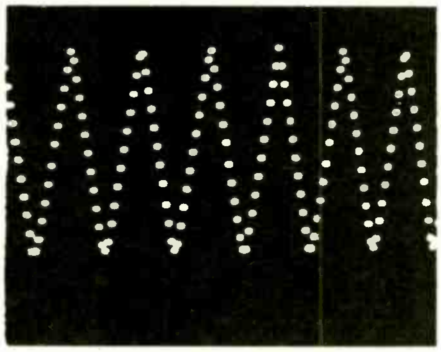

```
/*********************
 *                   *
 * CAPTURE 1280 BYTES *
 *    AND DISPLAY    *
 *                   *
 *********************/

#include<h.stdio>
#include<h.stdlib>
main()
{
int *portb;
int *ddrb;
int *pcr;
int *ifr;
int i;
int y;
unsigned char contents;
char flag;
portb = (int*)65120;
ddrb = (int*)65122;
pcr = (int*)65132;
ifr = (int*)65133;
*ddrb = 0;
start:clg();
mode(4);
draw(0,0);
draw(1279,0);
draw(0,0);
draw(0,1023);
/*----------------
SET UP X & Y AXES
-----------------*/
for(i =0;i <= 1279;i++)
{
*pcr = 240;/*START ADC*/
*pcr = 208;
*pcr = 240;
do
  flag = *ifr;/*POLL IFR*/
  while(!(flag & 16));
  contents = *portb;
  y = 4 * contents;
  plot(69,i,y);
/*----------------------
 X-COORD. IS INCREMENTED
 ON EACH PASS:ASSIGN CUR
  -RENT I/P TO Y-COORD.
 ----------------------*/
}
goto start;
}
```

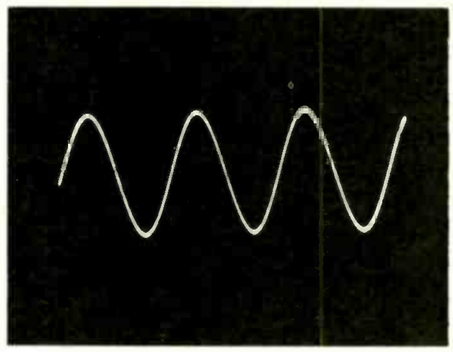
Fig.11. Data capture with graphics.



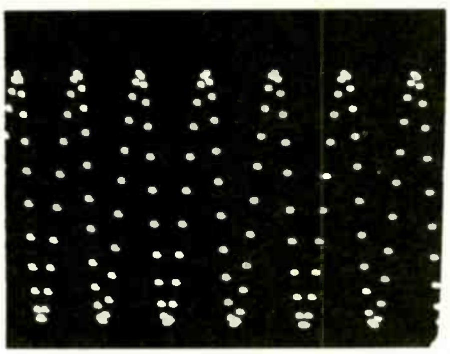
Oscilloscope display, 2V pk-pk, 10Hz (for comparison with a.c.f. display).



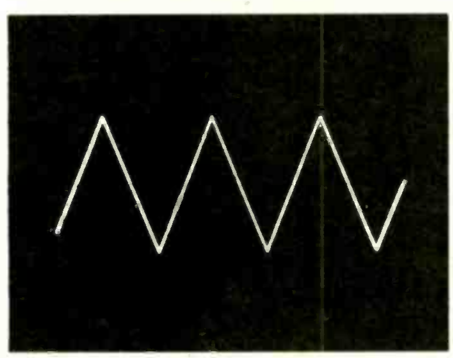
Monitor display, autocorrelation function.



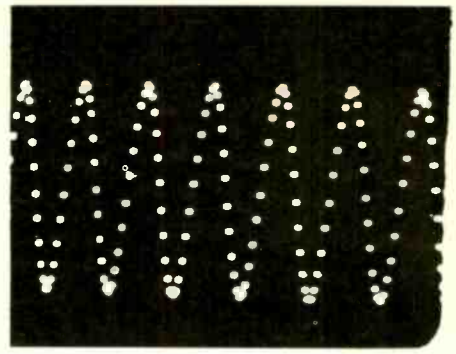
Oscilloscope display, 2V pk-pk, 10Hz.



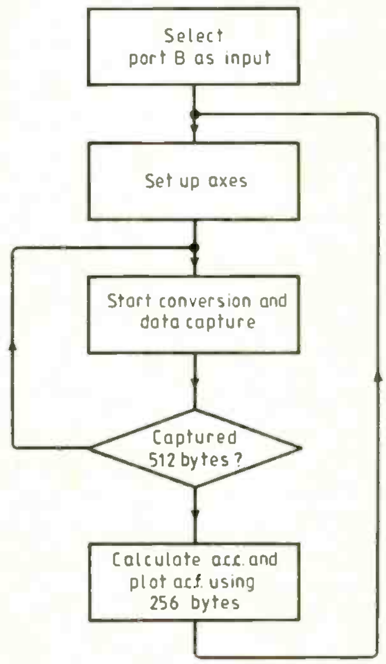
Monitor display, autocorrelation function.



Oscilloscope display, 2V pk-pk, 10Hz.



Monitor display, autocorrelation function.




```
/*******************************
 *                             *
 * CAPTURE 512 BYTES CALCULATE *
 *  AUTOCORRELATION FUNCTION   *
 *                             *
 *******************************/
#include<h.stdio>
#include<h.stdlib>
main()
{
int *portb;
int *ddrb;
int *pcr;
int *ifr;
int i;
int k;
long int sum;
float y;
int a;
unsigned char contents[512];
char flag;
portb = (int*)65120;
ddrb = (int*)65122;
pcr = (int*)65132;
ifr = (int*)65133;
*ddrb = 0;
start:clg();
mode(1);
vdu(19,3,2);
draw(0,0);
draw(1279,0);
draw(0,0);
draw(0,1023);
/*----------------
 CAPTURE 512 BYTES
 ----------------*/
for(i =0;i <= 511;++i)
{
*pcr = 240;
*pcr = 208;
*pcr = 240;
do
  flag = *ifr;
  while(!(flag & 16));
a = *portb;
  contents[i] = a - 128;
}
/*---------------
   ACF ALGORITHM
  --------------*/
for(k = 0;k <= 255;++k)
{
sum = 0;
/*-----------------
  RESET SUM TO ZERO
 -----------------*/
for(i = 0;i <= 255;++i)
{
sum += contents[i] * contents[i + k];
}
y = 102.4 * 0.00153 / 256 * sum;
/*----------------------------
 WEIGHT & SCALE AUTOCORRELATION
          COEFFICIENT
 ----------------------------*/
gcol(0,2);
plot(69,4 * k,y);
}
goto start;
}
```

Fig.12. Program to calculate and plot the autocorrelation function.

puter to evaluate the Fourier transform of the captured time-domain signal. I have purposely chosen the relatively straightforward discrete Fourier transform, DFT, as an initial example, since it may be programmed directly and conceptually it underpins the fast Fourier transform, FFT, which is presented later.

The process of continuous Fourier transformation is represented by the expression

$$X(\omega)=\int_{-\infty}^{\infty}x(t)e^{-j\omega t}dt$$

The mathematical scaffolding indicates how the energy of x(t) is distributed throughout the frequency range. Since the digital computer only processes samples or snapshots of the signal x(t), we modify the continuous transform into the discrete transform DFT, where integration is replaced by summation. The DFT of x(i) is described by the finite weighted summation

$$X(k)=\frac{1}{N}\sum_{i=0}^{N-1}x(i).\exp\left(-j\frac{2\pi}{N}ki\right)$$

of N samples of x(i) over the range 0 to N−1.

Expanding the exponential term we can express X(k) as the sum of the real and imaginary coefficients ar(k) and ai(k) respectively.

$$ar[k]=\frac{1}{N}\sum_{i=0}^{N-1}x[i]\cos\left(\frac{2\pi ki}{N}\right)$$

$$ai[k]=-\frac{1}{N}\sum_{i=0}^{N-1}x[i]\sin\left(\frac{2\pi ki}{N}\right)$$

For many applications the mean squared power is the quantity of most significance. This is simply

$$|X(k)|^2=(ar[k])^2+(ai[k])^2$$

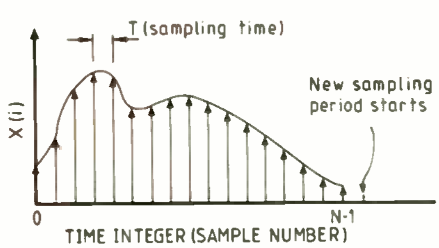


Fig. 13a. Sampled data signal.

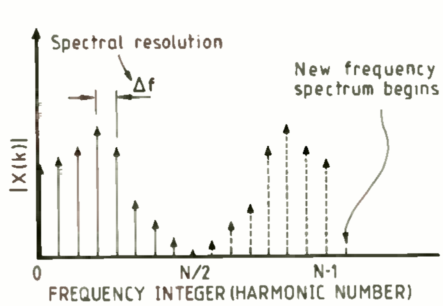


Fig.13b. Discrete Fourier transform. The spectral resolution Δf equals 1/N.T hertz, where N is the number of samples and T the time increment between samples. For example, if the time between samples is 6.5ms and we decide to process 16 points, then the spectral resolution will be 10Hz. Therefore a digitized 50Hz sinewave would ideally be observed as a single ordinate at the sixth sample point.

The program, Fig.16, requests you to enter the number of samples, up to 32 this case. If you wish to process more then it will be necessary to modify the size of the declared array: in the example it has been restricted to avoid a prohibitively long processing time. The capture data x[i]=0.039* (a−128) is offset and weighted prior to being stored in an array. Some increase in sampling rate can be achieved by performing these calculations later, rather than in real time.

To reduce the spectral spreading (leakage) due to the input waveform being truncated during data capture, I have elected to process the data through a Hanning window prior to DFT processing[5,6]. The structure of the program is somewhat unconventional at this point because of the idiosyncratic Beebug cos() function, which becomes badly behaved for large values of argument. We can avoid this by employing degrees and then converting to radians using the rad() function prior to trigonometric evaluation.

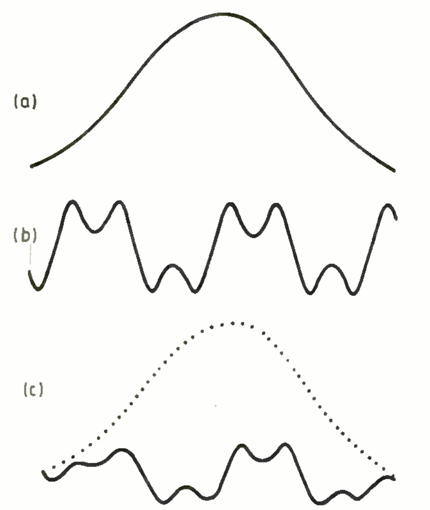


Fig.14. The Hanning function. At (a), the Hanning data window. W[i]=0.5(1−cos(2πi/N)), where i is the sample point number and N the total number of samples. At (b), truncated data to be transformed; and at (c), the effect of multiplying by the Hanning data window.

The captured data multiplied by the window function is stored back in array x[i] prior to processing by the DFT. In the program the real and imaginary coefficients ar[k] and ai[k] are called 'realsum' and 'imagsum' respectively. The final part of the program is made up of the DFT algorithm which is best described by the flow-chart (Fig.15). The mean squared power, called 'modulus' in the program, is plotted on the screen using the draw() macro.

FAST FOURIER TRANSFORM

Inspection of the DFT algorithm and the relevant C program reveals that approximately n complex multiplications and about the same number of additions are required to compute the frequency coefficient for a particular value of k. Since there are n/2 unique spectral components, the total number of multiplications required to compute the complete spectrum is approximately n^2. The FFT recognizes that many of the terms

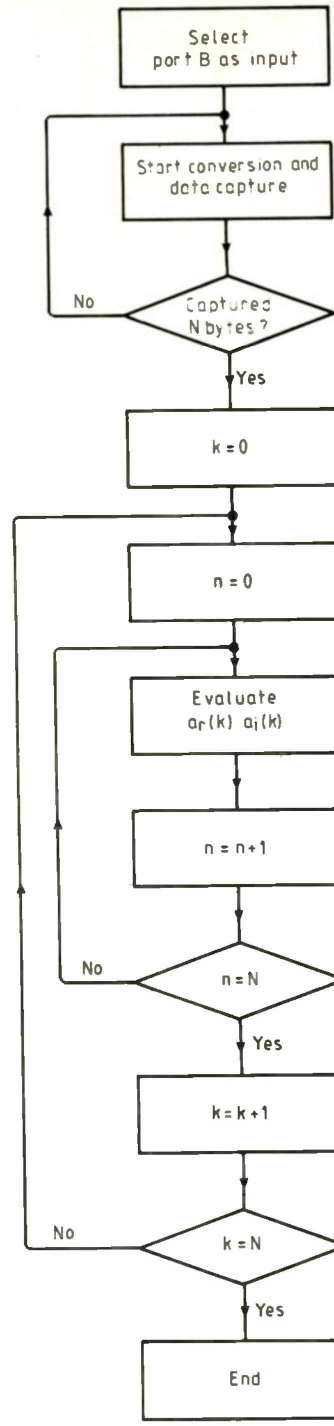


Fig.15. DFT and Hanning window: flow-chart for the program of Fig.16.

are redundant and can be factored out. This results in a complete transformation with approximately $n\log_2(n)$ computations, a considerable saving of computational time. To understand the mathematics, consider the behaviour of the complex coefficient W_N, for eight sampled values – i.e. N=8. W_N is raised to the power ki, where k and i are integers in the range 0 to 7. The repetitive nature of the algorithm results in the calculation of W_8^{ki} being carried out 64 times. Inspection of the calculated coefficients reveals only eight unique products, the result of the integer product ki, over the range 0 to 7. The FFT recognizes that many of the calculations are redundant and uses a decimation process to bisect the data array until only two-point transforms remain.

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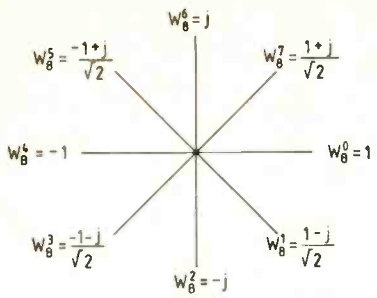


Fig.17. The development which follows provides an intuitive insight into the FFT algorithm, expressing the discrete Fourier transform

$$X(k) = \frac{1}{N}\sum_{i=0}^{N-1} x(i).\exp\left(-j\frac{2\pi}{N}ki\right)$$

in the form

$$X(k) = \frac{1}{N}\sum_{i=0}^{N-1} x(i)W_N^{ki}$$

$$\text{where } W_N = \exp\left(-j\frac{2\pi}{N}\right)$$

where $W_N = \exp(-j2\pi/N)$.

The unique complex coefficients of W_8^{ki} ($0 \leq ki \leq 7$) are displayed above on an Argand diagram.

Fig.16. DFT and Hanning window software.

```
/*************************
 *                       *
 * DFT AND HANNING WINDOW *
 *                       *
 *************************/
#include<h.stdio>
#include<h.stdlib>
#include<h.math>
main()
{
int *portb;
int *ddrb;
int *pcr;
int *ifr;
int i;
int k;
int n;
int y;
int z;
double realsum;
double imagsum;
double modulus;
double angle;
double angle1;
double a;
double x[32];
double ar[32];
double ai[32];
double window[32];
char flag;
portb = (int*)65120;
ddrb = (int*)65122;
pcr = (int*)65132;
ifr = (int*)65133;
ddrb = 0;
printf("Enter no. of samples");
scanf("%d",&n);
/*--------------------------
  INPUT NO. OF SAMPLES 32 MAX
 --------------------------*/
start:clg();/*CLEAR GRAPHICS*/
mode(1);
draw(0,0);     /* SET UP */
draw(1279,0);/* X-AXES */
draw(0,0);     /* SET UP */
draw(0,1023);/* Y-AXES */
for(i = 0;i <= (n - 1);i++)
{
*pcr = 240;/*START ADC*/
*pcr = 208;
*pcr = 240;
do
flag = *ifr;/*READ FLAG*/
while(!(flag & 16));
a = *portb;
x[i] = 0.039 * (a - 128);
/*-----------------
 STORE CAPTURED DATA
    IN AN ARRAY
 -----------------*/
}
for(i = 0;i <= (n - 1);i++)
{
angle1 = 360 * i / (n - 1);
window[i] = 0.5 * (1 - cos(rad(angle1)));
x[i] = x[i] * window[i];/*HANNING WINDOW*/
printf("%f\t",x[i]);
}
/*--------------
   DFT ALGORITHM
 --------------*/
for(k = 0;k <= (n - 1);k++)
{
realsum = 0;/*RESET*/
imagsum = 0;
modulus = 0;
for(i = 0;i <= (n - 1);i++)
{
angle = 360 * i * k / n;
realsum += x[i] * cos(rad(angle)) / n;
imagsum += x[i] * sin(rad(angle)) / n;
}
modulus = realsum * realsum + imagsum
* imagsum;
y = 1000 * modulus;
draw(1023 * k / (n - 1),0);/*DFT ORDINATES*/
draw(1023 * k / (n - 1),y);
draw(1023 * k / (n - 1),0);
}
goto start;
}
```

Table 2. Determination of complex coefficient W_8^{ki} (from Electronic signals and systems, see text).

VALUES OF k \ VALUES OF i	0	1	2	3	4	5	6	7
0	1	1	1	1	1	1	1	1
1	1	$(\frac{1-j}{\sqrt{2}})$	$-j$	$-(\frac{1+j}{\sqrt{2}})$	-1	$-(\frac{1-j}{\sqrt{2}})$	j	$(\frac{1+j}{\sqrt{2}})$
2	1	$-j$	-1	j	1	$-j$	-1	j
3	1	$-(\frac{1+j}{\sqrt{2}})$	j	$(\frac{1-j}{\sqrt{2}})$	-1	$(\frac{1+j}{\sqrt{2}})$	$-j$	$-(\frac{1-j}{\sqrt{2}})$
4	1	-1	1	-1	1	-1	1	-1
5	1	$-(\frac{1-j}{\sqrt{2}})$	$-j$	$(\frac{1+j}{\sqrt{2}})$	-1	$(\frac{1-j}{\sqrt{2}})$	j	$-(\frac{1+j}{\sqrt{2}})$
6	1	j	-1	$-j$	1	j	-1	$-j$
7	1	$(\frac{1+j}{\sqrt{2}})$	j	$-(\frac{1-j}{\sqrt{2}})$	-1	$-(\frac{1+j}{\sqrt{2}})$	$-j$	$(\frac{1-j}{\sqrt{2}})$

Table 3: Comparing the number of computations required for DFT and FFT.

Number of samples N	DFT N^2	FFT $N\log_2(N)$
8	64	24
16	256	64
32	1024	160
64	4096	384
128	16384	896
256	65536	2048
512	262144	4608
1024	1048576	10240

Referring to the signal flow diagram, Fig.18, notice that the effect of the algorithm has been to scramble the order of the output data. Writing both the input and processed output in binary form, it will be apparent that the scrambling is not random, but a mirror image of the input – where the results are placed in bit-reversed order[7].

The FFT program, Fig.20, is a translation into C of a Basic program found in Electronic signals and systems, by P.A. Lynn, page 207 (published by Macmillan). The C program evaluates the FFT of 128 samples, the data being generated synthetically within the program, making it ideal for demonstration purposes. Changing the sign of the sine function allows the inverse Fourier transform to be calculated by applying the FFT algorithm to its own output, thus regenerating the original input data – a useful check.

When transforms are displayed graphically it is customary to display the mean square power (details in Fig.19).

Below are several examples which demonstrate a few of the limitations of digital signal processing. The various functions are software-generated and the pseudo-sampled data stored in the array ar[w] prior to processing.

The first example generates a sinewave of 200Hz, which is digitized into 128 samples over a total sampling period of 100ms. Careful choice of numerical values ensures that exactly 20 cycles of data are synthetical-

Fig.18. Butterfly diagram for the fast Fourier transform of an eight-element data array. The signal path is interpreted as follows: two paths entering a node are combined by forming the sum

dotted line + (node coefficient). (solid line).

The integer in the circle is the power of W. Hence the output of the second row; second column is $X(1)+W.^0X(5)$. The procedure is repeated until the processed output appears in the final column.

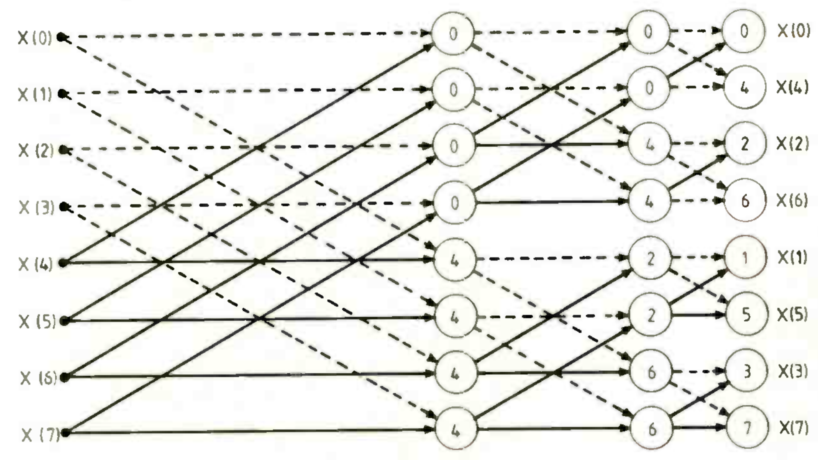
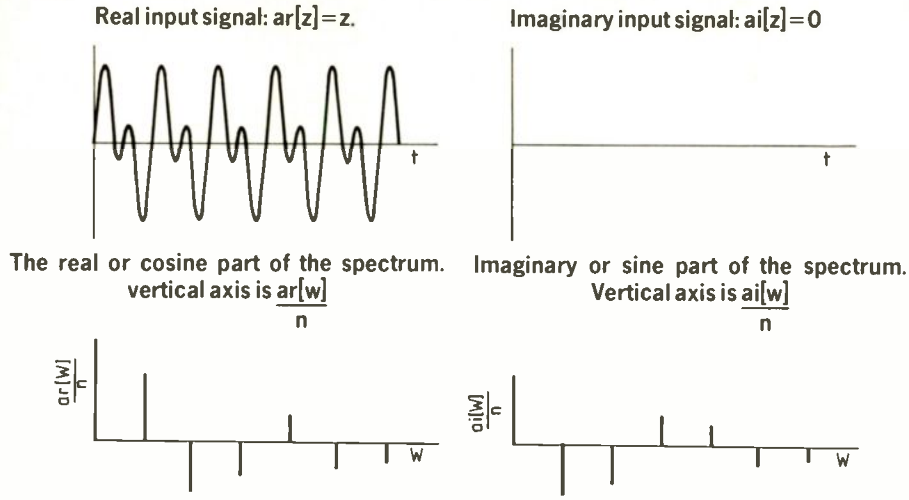
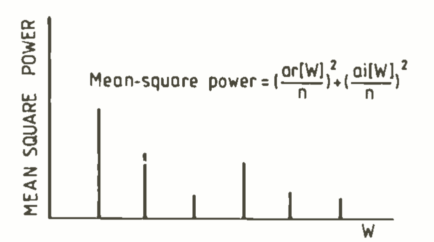


Fig.19. Graphical description of Fourier transform. The a-to-d samples the input signal, loading the real array ar[z] with data. The imaginary array ai[z] is filled with zeros.



Squaring and adding the real and imaginary parts of the spectrum gives the power spectrum.



ly captured without truncation. Modifying the data to make the sinewave 201Hz illustrates the effects of leakage and the "picket fence effect", where the principal component lies between two of the discrete transform lines (see also Introduction to d.s.p., by Alan Sewards, August issue, pages 741-746).

Increasing the frequency of the synthetic data above the Nyquist frequency, in this example 640Hz, demonstrates the effects of aliasing in the frequency domain. Experiment with your system to observe the frequency translation of the aliased component[8].

The following listing (Fig.22) can be used with the FFT program to generate and display the frequency spectra shown in Fig.21.

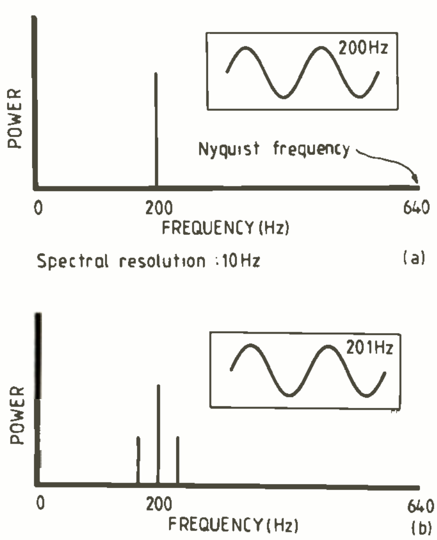


Fig.21. Results of processing synthetic data through FFT program to demonstrate the effects of spectral spreading due to signal truncation. At (a), no signal truncation results in the displayed spectrum agreeing with the anticipated result. At (b), effects of spectral spreading (leakage); 128 samples captured in 100ms.

Fig.20. This bidirectional FFT program generates data synthetically.

```
/****************************/
/*                          */
/* FAST FOURIER TRANSFORM   */
/* AND INVERSE 128 POINTS   */
/*                          */
/****************************/
#include<h.stdio>
#include<h.math>
#include<h.stdlib>
main()
{
double ar[128];
double ai[128];
int n;
int n1;
int n2;
int a;
double b;
int c;
int d;
double e;
int f;
int g;
int h;
int j;
double k;
double l;
double co;
double si;
int m;
int p;
int q;
int r;
int s;
int t;
int u;
int w;
int z;
n = 128;
n1 = 7;
for( z = 1;z <= n;z++)
{
ar[z] = z; /* SYNTHETIC DATA */
ai[z] = 0;
}
start:printf("Choose transform or inverse
(+1/-1)\n");
scanf("%d",&n2);
a = n;
b = 360 / n;
for( c = 1;c <= n1;c++)
{
d = a;
a = a / 2;
e = 0;
for(f = 1;f <= a;f++)
{
co = cos(rad(e));
si = sin(rad(e)) * n2;
e = e + b;
u = 1;
for(g = d;g <= n;g = u * d)
{
u = u + 1;
h = g - d + f;
j = h + a;
k = ar[h] - ar[j];
l = ai[h] - ai[j];
ar[h] = ar[h] + ar[j];
ai[h] = ai[h] + ai[j];
ar[j] = co * k + si * l;
ai[j] = co * l - si * k;
}
}
b = 2 * b;
}
/*-----------------------
 RE-ORDER SCRAMBLED O/P
 -----------------------*/
m = 1;
p = n / 2;
g = n - 1;
for(r = 1;r <= q;r++)
{
if(r > (m - 0.1)) goto label1;
k = ar[m];
l = ai[m];
ar[m] = ar[r];
ai[m] = ai[r];
ar[r] = k;
ai[r] = l;
label1:s = p;
label3:if(s > (m - 0.1)) goto label2;
m = m - s;
s = s / 2;
goto label3;
label2:m = m + s;
}
for(w = 1;w <= n;w++)
{
/*---------------------------------
 SAMPLE NO.:REAL COEFF.:IMAG COEFF
 ---------------------------------*/
printf("%d\t%f\t%f\n",w - 1,ar[w] /
n,ai[w] / n);
}
goto start;
}
```

```
/*----------------
  SYNTHETIC DATA
 ----------------*/
for( z = 1;z <= n;z++)
{
omega = 360 * hz * t;
ar[z] = sin(rad(omega));
t = t + 7.874e-4;
ai[z] = 0:
}


/*----------------
 GRAPHICS ROUTINE
 ----------------*/
clg();
mode(4);
draw(0,0);
draw(1279,0);
draw(0,0);
draw(0,1023);
for(w = 1;w <= 64;w++)
{
y = (ar[w] * ar[w] + ai[w] * ai[w]) * 6.1e-5:
y = 1200 * y;
draw(16 * (w - 1),0);
draw(16 * (w - 1),y);
draw(16 * (w - 1),0);
}
}
```

Fig.22. Frequency spectra such as those shown in Fig.21 are produced from the FFT program using these routines.

References

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2. Hogan T., The C programmer's handbook. Prentice-Hall 1984.
3. Ferguson J.D., Stewart J. and Williams P., Interfacing microprocessors. *Wireless World*, December 1981.
4. Hutchings H.J., Linear systems and random inputs. *Electronics & Wireless World*, April 1988.
5. Omer W., Faster Fourier transforms. *Electronics & Wireless World*, June 1986.
6. Finch P. and Tayler D., Data capture for Fourier analysis. *Electronics & Wireless World*, August 1987.
7. Oran, Brigham E., The Fast Fourier transform. Prentice-Hall 1970.
8. Stanley W., Dougherty G. and Dougherty R., Digital signal processing. Prentice-Hall 1984.

A simple introduction to C programming may be found in The illustrated C programming book, by J.E. Beam, Wordware Publishing Inc., 1985.

Introduction to d.s.p.

Two typographical errors crept into this article in the August issue: the list of signal frequencies on the ninth line of the shaded box on page 741 should begin with 131Hz, not 131kHz; and the expression in the second paragraph of page 745 should end with plain dB, not dBm.

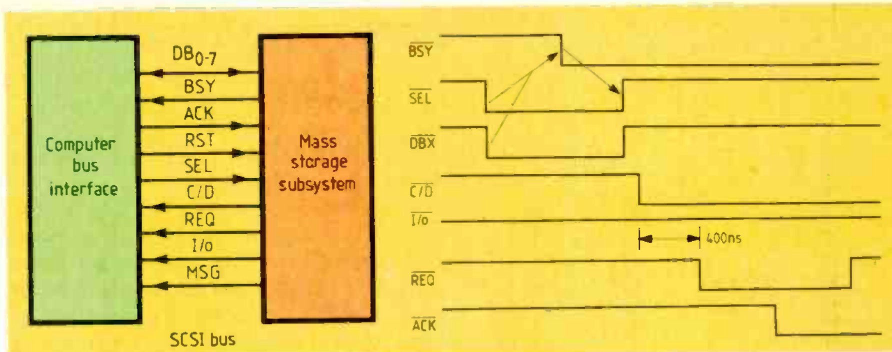
A copy of the Turbo Pascal source code mentioned on page 746 is available from the *Electronics & Wireless World* editorial office in return for a stamped, self-addressed envelope or two international reply coupons. Please mark your covering envelope "Digproc".

Piezoelectric coaxial cable

At the end of this article in the September issue, we said incorrectly that Quantelec was in Henley on Thames. It is in fact in Witney, Oxon (telephone 0933 776488).

APPLICATIONS SUMMARY

Minimal but fast SCSI control using a p.l.d.



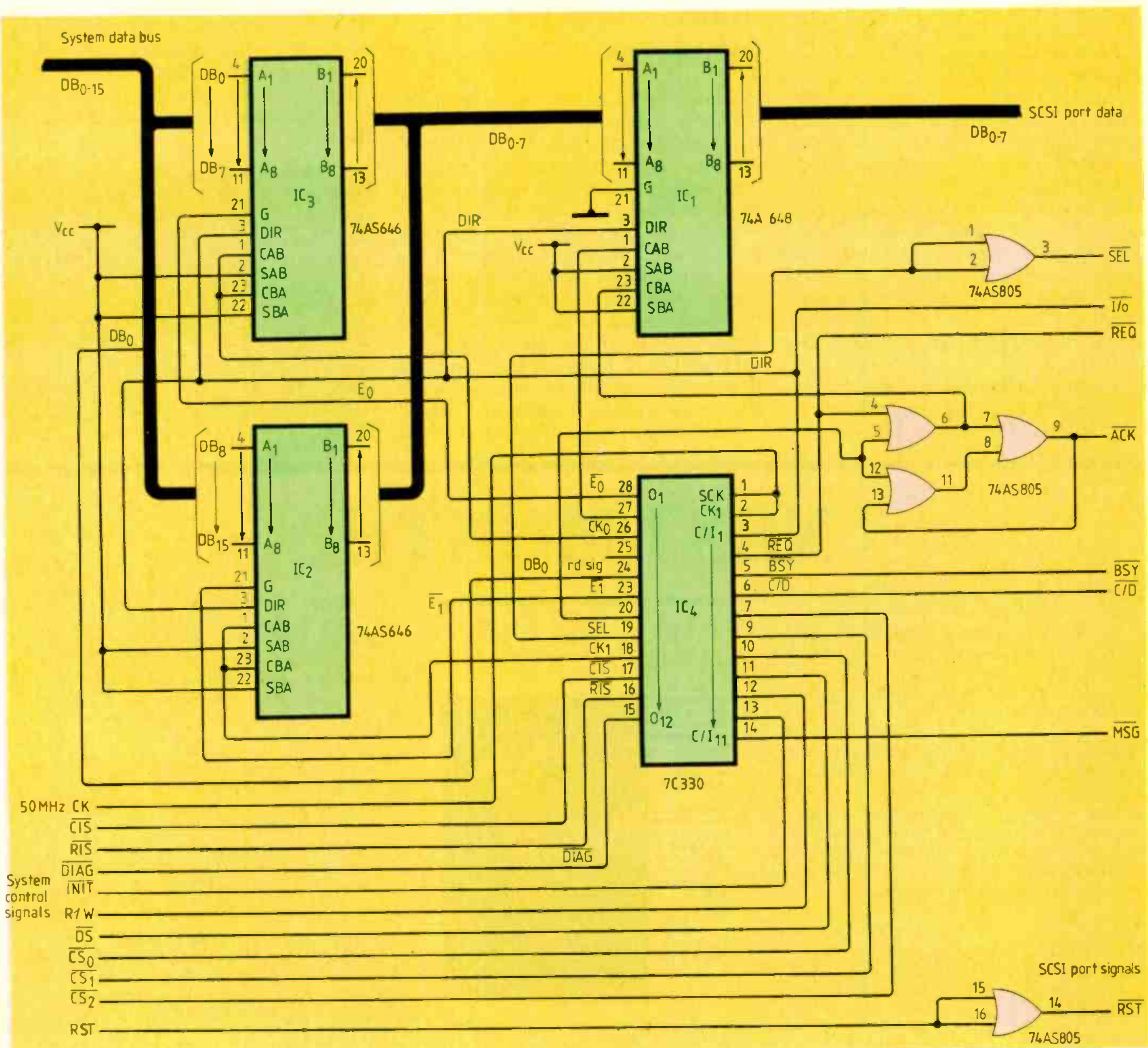
For communication with some hard-disc drives, a full small computer systems interface implementation is unnecessary. This minimal host interface for asynchronous transfers is fast – 12MHz using a 50MHz clock – and it needs only five i.cs.

Besides describing how the CY7C330 p.l.d. is turned into an s.c.s.i. host, the Cypress application note 'High-speed asynchronous s.c.s.i. controller' presents a useful simplification of an s.c.s.i. data access, part of which is the timing diagram shown.

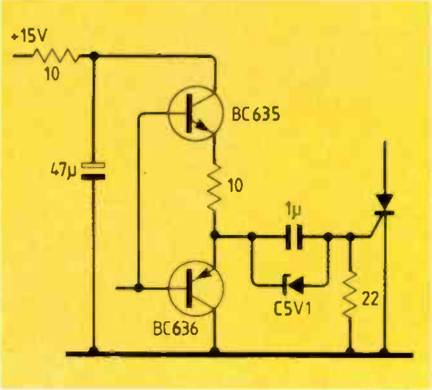
In an s.c.s.i. data-access, a control transfer is followed by a data transfer. Initially, the host waits for BSY to go high, then asserts one of the eight data bits to select one of eight controllers. When this combination is detected by the controller, it asserts BSY, upon which the host releases SEL and the selection data bit.

Next, in a cycle that is normally repeated six times for six data bytes, the controller asserts C/D and REQ to read a command byte from the host. After the host has presented the data byte, it asserts ACK, causing the controller to accept the data byte and remove REQ; finally, the host removes ACK.

There are further details of data accesses in the note, and similar coverage for transfers between the controller and host. Timing considerations for the controller are also discussed.



APPLICATIONS SUMMARY



Resonant converters

As power and frequency increase, losses in conventional switching converters increase to a point where inefficiency makes them no longer worthwhile. Technical Publication 262 from Mullard says that many of the loss problems can be overcome by using resonant power-conversion circuits incorporating gate turn-off thyristors.

Natural LC resonance produces sinusoidal current and voltage waveforms in a resonant converter, making it possible to switch at zero current, and at a point where the rate of current change is low.

The gate turn-off thyristor handles large peak currents and high voltages while its drive requirements are relatively simple, as shown. Advantages of the g.t.o. thyristor circuit compared with conventional converters are said to be reduced switching losses, increased frequency/power capabilities and reduced e.m.i.

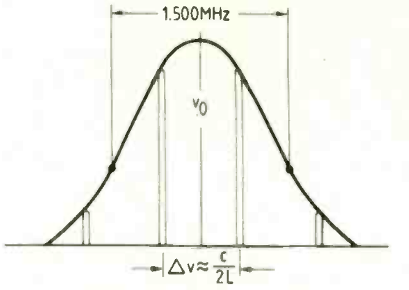
The three-page booklet describes the resonant switch, drive requirements and resonant flyback-converter calculations.

Laser considerations

As the writers of the background information in Polytec's HeNe laser catalogue admit, the work is no replacement for a course in laser physics, but it is useful as a refresher course or as an introduction.

In the section including this diagram for example, properties of a HeNe laser beam are discussed. As you will probably know, twice the laser's cavity length, 2L, needs to be an exact integer multiple, m, of wavelengths in order to set up standing waves. Because m is usually large, there are many other frequencies at which the cavity is resonant, and if the laser light source contains other frequencies, the output will consist of a series of frequencies separated from each other by a small fraction.

$$\Delta v = \frac{c}{2L}$$



Δv Longitudinal mode spacing c Velocity of light
L Cavity length v_0 ≙ 632.8nm

where c is the velocity of light. These are the laser's longitudinal modes.

The catalogue goes on to discuss transverse electric and magnetic modes, polarization, beam collimation and expanding/focussing beams. It includes tips for choosing a HeNe laser.

Mains-supply problems

Practical tips for curing mains-borne interference problems are presented in Seaward's leaflet, QA test data library No 2. Most of the tips will be obvious to you but since they might also save some readers a lot of money in filtering equipment, here goes.

Firstly, the note advises you to connect all items of equipment in an installation to the same earth. Next, you should avoid connecting equipment that might cause surges to the same circuit as sensitive electronic equipment, using an alternative phase where possible. Suppressors should be fitted in the equipment rather than at the supply point and mains leads should be kept short.

Finally, you should consider the electrical wiring. While the wiring might comply with the 15th edition of the wiring regulations, it might not have been installed with sensitive electronic equipment in mind.

Types of mains fault and the company's mains-monitoring unit are also described in the leaflet.

Addresses

Cypress
Ambar Cascom
Rabans Close
Aylesbury
Buckinghamshire HP19 3RS
0296 434141

Polytec
Lambda Photometrics
Lambda House
Batford Mill
Harpenden
Hertfordshire AL5 5BZ
05827 64334

Seaward Electronic
Bracken Hill
South West Industrial Est
Peterlee
County Durham SR8 2JJ
091 586 3511

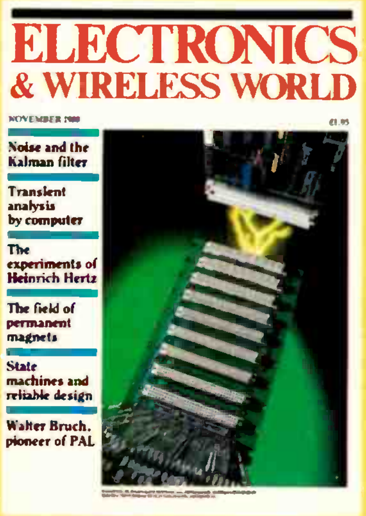
Philips
Mullard House
Torrington Place
London WC1E 7HD
01-580 6633

NEXT MONTH

Pioneers – Bruch. Walter Bruch, German pioneer of the PAL tv colour system, is 80 this year. He was present at the 1936 Berlin Olympics operating a live-broadcast tv camera and he was sent to Peenemünde to photograph the V1 and V2s. W.A. Atherton tells of these and other events in Bruch's life.

Transient analyser. A computer with a transient-capture interface is more flexible than a digital-storage oscilloscope since it permits the writing of capture-control and waveform analysis software to suit the application. J.F. Van der Walle's hardware and software design discussion is illustrated by a 50ns sampling interface with its own memory.

Notes on Hertz. It is now a hundred years since Heinrich Hertz carried out many of his experiments leading to the discovery of electromagnetic waves. Ken Smith writes about his remarkable work.



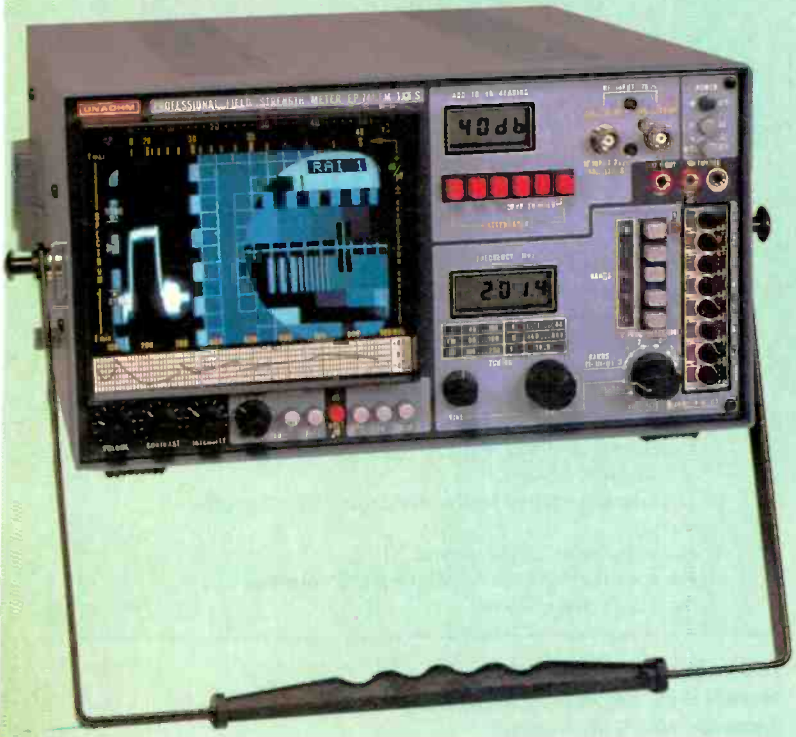
Magnets. Joules Watt discusses in depth the principles and properties of the widely used but often taken for granted permanent magnet. Starting from basics, he leads up to magnet design requirements, taking in topics such as Bohr magnetrons and bulk magnetization along the way.

Kalman filtering. The Kalman noise filter is now 25 years old but it has only recently become popular due to the availability of cheaper and faster computer processing. G.F. Steven has brought together the concepts relating to Kalman filters and set them down in a readily assimilable form.

State machines and reliable design. Unhappy with commercial designs, Jeremy Stevens set about designing his own vehicle burglar alarm. His description of it is an illustration of sound logic-design procedure.

TAYLOR RF/VIDEO MEASUREMENT INSTRUMENTS

MEASUREMENTS MADE EASY



UNAOHM EP741FMS FIELD STRENGTH METER/SPECTRUM ANALYZER

Frequency Range:	Continuously adjustable via a geared-down vernier as follows: IF 38.9MHz Band I 46 to 106MHz FM Band 88 to 108MHz Band III 106 to 290MHz Band H 290 to 460MHz Band U 460 to 860MHz
Frequency Reading:	TV Bands — 4 digit counter with 100KHz resolution FM Band — 5 digit counter with 10KHz resolution Reading Accuracy: reference Xtal +/−1 digit.
Function: TV Monitor	NORMAL: picture only ZOOM : 2 to 1 horizontal magnification of picture ⎍ : picture + line sync pulse (with chromaburst if TV signal is coded for colour)
Panorama:	panoramic display of the frequency spectrum within the selected band and of tuning marker.
Panorama Expansion:	Adjustable expansion of a portion of the spectrum around the tuned frequency.
Analogue Measurement:	20 to 40dB. Static measurement of received signal. Scale calibrated in dBuV (at top of picture tube) to rms value of signal level.
DC/AC Voltmeter:	5 to 50V.
Measurement Range:	20 to 130dBuV in ten 10dB attenuation steps for all bands; −60 to 130dBuV in nine 10dB steps for IF.
Measurement Indication:	ANALOGUE: brightness stripe against calibrated scale superimposed on picture tube. The stripe length is proportional to the sync peak of the video signal.
Video Output:	BNC connector. 1Vpp max on 75 ohm.
DC Output:	+12V/50mA max. Power supply source for boosters & converter.
TV Receiver:	tunes in and displays CCIR system I TV signals. Other standards upon request.
Additional Features:	(1) Video input 75 Ohm. (2) 12V input for external car battery. (3) Output connector for stereo earphones.
Price:	**£1344.00** exc. VAT and Carriage.

UNAOHM FSM5987 T.V. FIELD STRENGTH METER

INPUT

Sensitivity:	from 20dBuV to 110dBuV (−40dBmV to 50dBmV) or 10uV to 0.3V, in eight 10dB steps.
Reading:	dB reading proportional to peak value for video signals; proportional to mean value for AM or FM sound signals. For both signals scale calibrated to rms value and expressed in dBuV. Two more scales are available: volt from 0 to 50, and ohm from 0 to 2000 ohm. Battery status is also provided.
Accuracy:	+/− 3dB for bands I & III +/− 6dB for bands H & IV/V
Impedance:	75 ohm unbalanced; DC component blocked up to 100V.

FREQUENCY

Range:	46 to 860 MHz as follows: Band I 46 to 106MHz; III 106 to 206MHz; H 206 to 460MHz; IV/V 460 to 860 MHz
Reading:	4 digit LCD readout. 100KHz resolution.
Price:	**£378.00** exc. VAT and Carriage.

UNAOHM EH 1000 TELETEXT AND VIDEO ANALYZER

Function:	Eye Pattern: display of RF and video-frequency teletext signals by means of eye pattern diagrams both in linear representation and lissajous figures (O and X). Line selection: display of video signals and line by line selection. Measurement of modulation depth. Teletext: monitoring of teletext pages.
RF Input:	Freq. Range: 45 to 860MHz. Frequency synthesis, 99 channel recall facility, 50KHz resolution, 30 channel digital memory. Level: 40 to 120dBuV; attenuator continuously adjustable. Indication of the minimum level for a correct operation of the instrument. Impedance: 75 ohm. Connector type: BNC.
Video Frequency Input:	Minimum Voltage: 1Vpp. Impedance: 75 ohm or 10K ohm in case of a through-signal. Connector type: BNC.
Teletext Input:	Voltage: 1Vpp/75 ohm.
Teletext Clock Input:	Voltage: 1Vpp/75 ohm. Measurement: Aperture of eye pattern: linear or Lissajous figures, selectable. Indication: directly on the picture tube. A calibrated scale shows percentage of eye pattern aperture. Error: the instrument introduces an error of ⩽5% with video input and 20% with RF input. Jitter on regen'd clock: ⩽25ns. Line selector: Selection of any TV line between the 2nd and the 625th scanning cycle by means of a 3 digit thumbwheel switch.
Oscilloscope:	VERTICAL CHANNEL: Sensitivity: 0.5 to 2Vpp/cm. Frequency Response: DC to 10MHz. Rise time: pre & overshoot ⩽2%. Input Coupling: AC. Input Impedance: 75 ohm/50pF. TIME BASE: Sweep Range: 20 to 10ms (1.1/2 frames); 32; 64/192us (1/2; 1; 3 lines). Linearity: +/−3%. Horizontal Width: 10 divisions; x5 magnification.
Price:	**£1670.20** exc. VAT and Carriage.

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VISA Access

ENTER 27 ON REPLY CARD

Two-way opto-coupled link

This communications circuit, designed for use in an a.t.e. system, made it possible to earth the unit under test independently of the controlling computer.

R.A. BECK

For automatic test equipment, opto-coupling is preferable to linking the equipment directly, both for safety reasons and for avoiding noise injected by the computer. Communication in one direction is very easy to achieve with opto-couplers, but bidirectional communication is more complicated. The problem comes when you want to hand control of the equipment back to the computer after receiving a d.v.m. reading. What happens is that the equipment and the computer will want to read at the same time, or write at the same time; and the latter possibility could lead to damage.

But with the circuit described here, a 12-bit a-to-d can be read and digital latches and d-to-a converters can be written to, using a single eight-bit parallel port and one handshake line. The circuit works directly with a BBC microcomputer and connects to the user port. To give an idea of its speed, it can return an average of 255 12-bit samples (giving ±2mV accuracy over a 0-10V range) in less than half a second.

SYSTEM OPERATION

System bytes and data bytes are sent alternately*. The first byte is a system byte. Each bit of the system byte is able to set a function, such as whether a latch or a d-to-a converter is to be addressed. The circuit as drawn will cope with nine eight-bit latches and ten eight-bit d-to-a converters, but it is easy to cope with many more by reconfiguring the control lines in the system byte or by making small changes in the circuit.

The system byte is latched into IC_{18}. Bits 0-3 specify which device (numbered 0-9) is to be addressed; bit 4 resets the system and is used only at the start of a narrative sequence; bit 5 resets all the system latches; bit 6 is unused; and bit 7 specifies whether a latch or a d-to-a converter is to be addressed. Bit 7 is used to differentiate between the two because in my case the number of latches and d-to-a converters amounted to more than 10 and less than 20, and this proved a very convenient way of doing it.

Addressing the a-to-d is a special case, since the device must be addressed a number of times successively to make it carry out a conversion and return the two data bytes. To prevent excessive time-wasting by continually having to select the a-to-d on alternate system bytes, a special bit in the a-to-d address latch IC_{16} is set to "short-circuit" the alternation system when a d.v.m. reading is required. Bit 0 of IC_{16}, once set, prevents further access to the system latch IC_{18}.

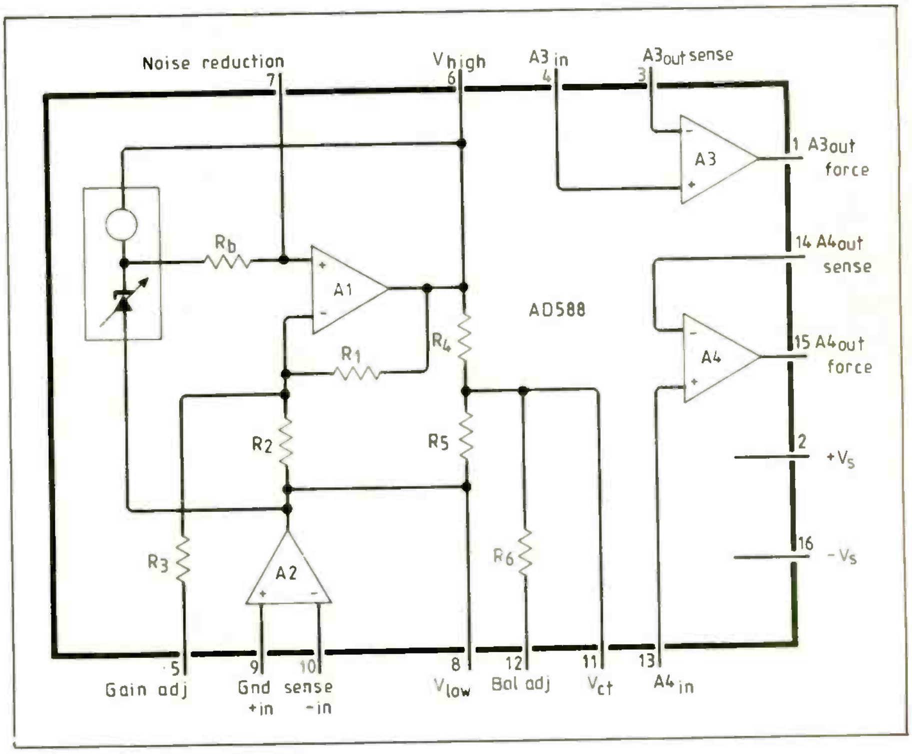
The d.v.m. section is drawn as a low-impedance differential input. For a high-impedance input, simply introduce two OP07 op-amps connected in voltage-follower mode to each input. Transistor Tr_3 and IC_{13} are recommended in the data sheet for the AD574A to reduce the amount of voltage flutter at pin 13 caused by the AD574A changing its input bias as it digitizes the voltage.

To get the a-to-d converter to measure a variety of different points, I built a two-channel multiplexer board with 30 inputs. The computer sets which input it wants to read by addressing latches before calling the a-to-d routine.

Switch S_1 can be used to make the whole circuit static in operation. This means that if a single-step machine-code monitor is used to step through the software, d.v.m. readings can be taken to verify correct operation of the board. For normal operation the "dynamic" setting should be used, since if the high-level software crashed, or if you pressed the Escape key half-way through accessing the a-to-d, you would otherwise be unable to regain control of the system except by turning the power off. It works in the following manner. During normal operation the control line voltage is low and thus the reset pin of IC_{18} (pin 1) is held high. When data is transferred by toggling the control line, its average voltage never rises above about one-third of the supply rail. The voltage required to flip the output of Inverter 4, and therefore gain access to IC_{18} by resetting all its outputs, is two-thirds of the rail voltage, and so this never normally happens. When a new narrative is started between the computer and the equipment, the first thing that happens is that the control line is held high long enough to allow the 10μF capacitor to charge. The output of Inverter 4 goes low and resets all the data latches in the equipment. Then the control line is held low again long enough for a complete discharge of the capacitor before the narrative starts.

Since the a-to-d completes a conversion in less than 35μs, it did not seem worthwhile to enable the computer to respond to interrupts polled by the converter. Instead, the software waits in a loop for the conversion to be completed and then it interrogates the device. The BBC microcomputer takes about 50μs to discover the cause of an interrupt, and so it is in fact quicker to make the computer wait in a loop.

AD 588 voltage reference, consisting of zener, amplifiers for programming output range and thin-film resistors. Temperature coefficient is less than 1.5p.p.m./°C.



* *For another protocol of this type, see Minimal eprom programmer, by B.J. Sokol, Electronics & Wireless World*, June and July 1987

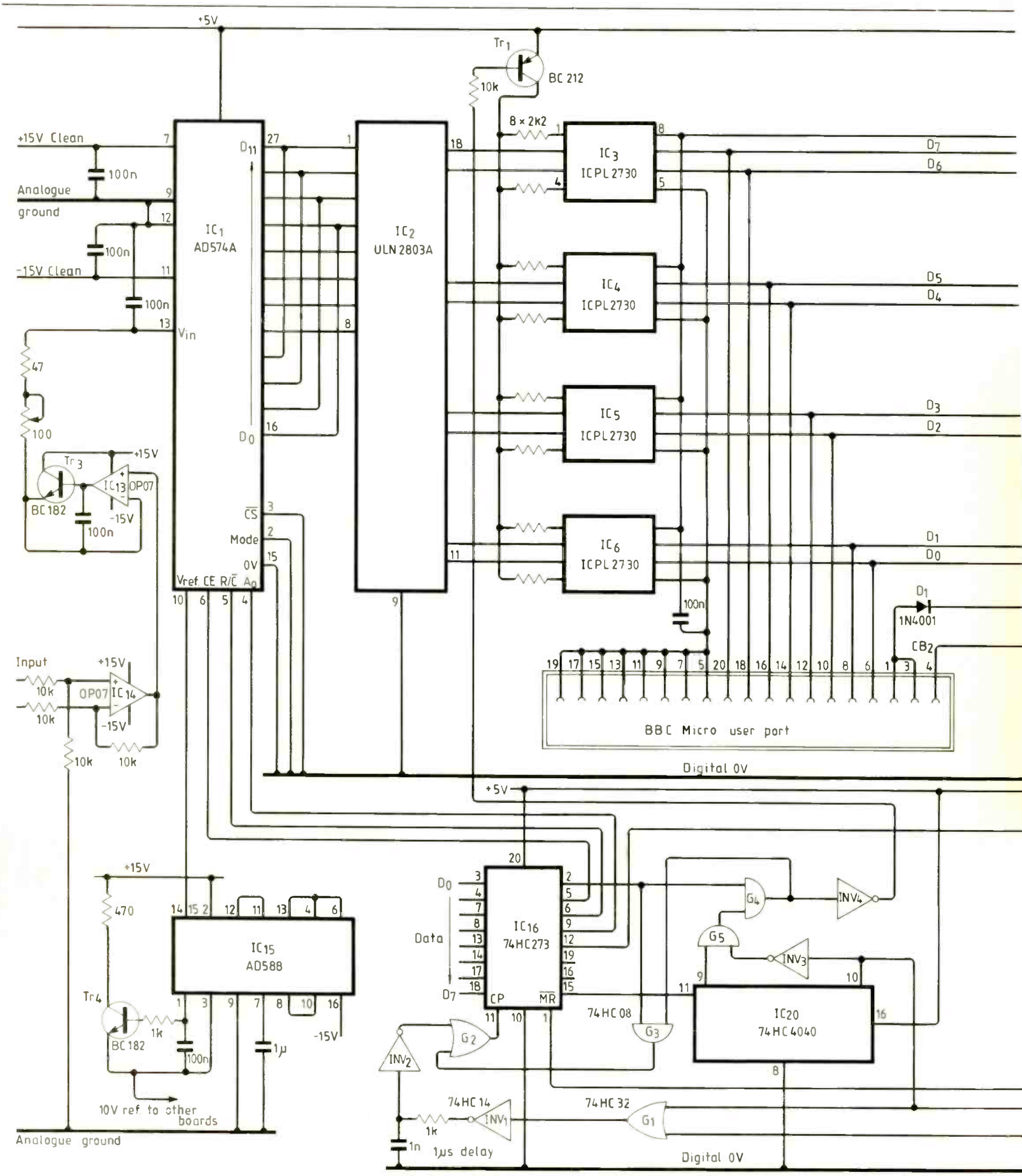
CIRCUIT DESCRIPTION

The eight-bit parallel opto-couplers IC_{7-10} link the computer to the card, and IC_{3-6} are the coupler from the card to the computer. The opto-coupler for the control or handshake line is IC_{11}. Diode D_1 protects IC_{3-6} if a reverse voltage is inadvertently applied to the computer connections.

In front of Inverter I1 is a low-pass filter to prevent noise on the control line during a level transition from causing multiple clock pulses for IC_{17}.

Two delay circuits, giving about 1μs delay, are included to allow time for the 74HC4040s to change their outputs after a clock pulse before they are combined with the signals by the gates. Without the delay multiple clocking occurs, corrupting data in the latches.

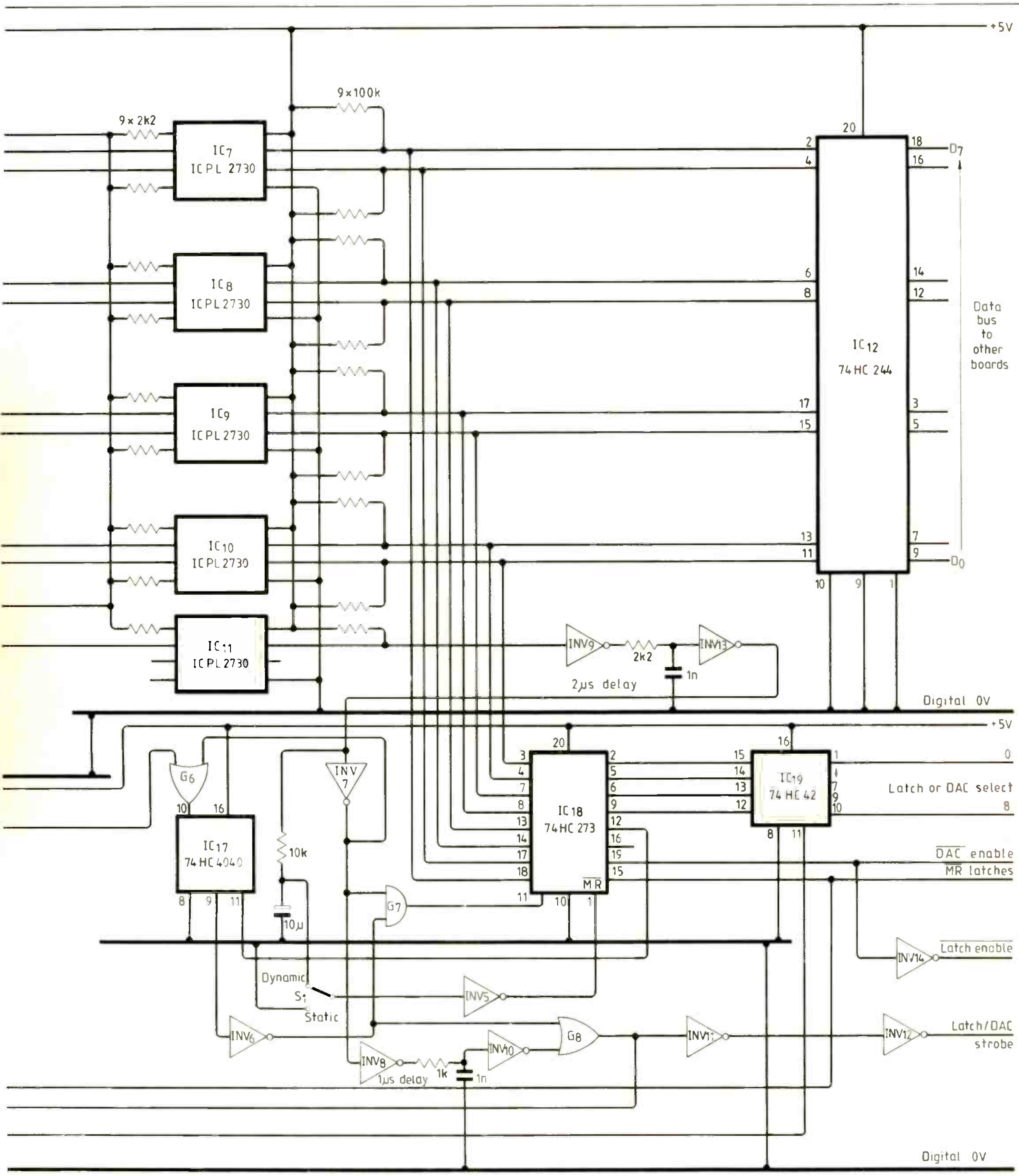
Data from the a-to-d converter is put on the bus by the following method. First a series of commands is sent to the a-to-d to initiate a conversion. The last byte addressed



Complete circuit of the a.t.e. interface. The author's source code is for the BBC microcomputer but could easily be adapted for other eight-bit machines.

to IC_{16} sets bit 0 high. Then the user port of the computer is set up to read rather than write. At this point the a-to-d's output is feeding an open-collector buffer. The data is put on the bus by setting the control line high. Then IC_{20} clocks, the output at pin 9 goes high. Inverter 4 goes low and provides power for any bits for the opto-couplers IC_{3-6} which are zero. Next the computer reads the data, exclusive-Ors it (it is inverted) and sets the control line low to take the data off the bus. The computer sets the port to write mode and writes the next byte to IC_{16}. The data is not re-applied to the bus because IC_{20} clocks when the control line goes high and so the output at pin 9 of IC_{20} goes low, disabling in turn Tr_1. In the first byte which is loaded into IC_{16}, bit 5 is set to reset the IC_{20} and bit 0 is cleared to ensure that no data is output on the bus at the wrong time.

● A copy of the source-code and an example high-level language program to run with it can be obtained for £5 from the author at 11 Lynwood Gardens, Hook, Basingstoke, Hampshire RG27 9DT. Please send a 5¼ inch disc and a self-addressed envelope in which to return it. The source code is about 10kbytes long (with many comments in it) and is written in a structured, easily-maintainable way.



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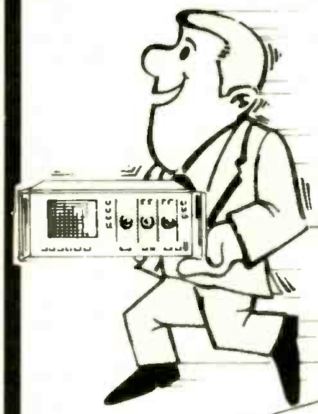

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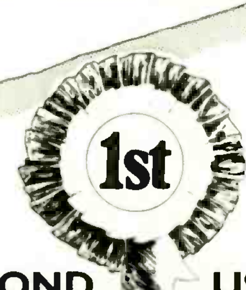

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SATELLITE SYSTEMS

Space invaders

Satellites may be blissfully remote from the atmospheric pollution that plagues us earthlings but they do suffer from the environmental hazards of outer space. Up there, various nasties are whizzing about that do not get very far into our atmosphere. Some are dust particles or micrometeoroids with diameters up to 0.1mm. Others are subatomic particles like electronics and protons. Unattached to atoms, these rush about unhindered in the high vacuum of space. At the altitudes of low Earth orbits there is also monatomic oxygen to contend with.

The solar arrays of satellites (see item elsewhere) are particularly vulnerable to bombardment by these particles because of their necessarily large areas. For protection the solar cells are normally covered with extremely thin sheets of borosilicate glass (0.5mm down to 0.05mm) with optical characteristics – wavelength, absorptance, non-reflection etc. – designed to transmit maximum radiant energy to the cells.

But glass also happens to be a dielectric, so this and other similar surfaces tend to build up static charges as a result of the electron and proton bombardment. Potential gradients are formed – at the edges of individual solar cells among other places – and when the p.ds are high enough discharges can occur. These discharges can damage the spacecraft by eroding surface coatings or puncturing or degrading electrical insulation.

ERA Technology, the independent r&d organization, has been investigating these discharges in the laboratory, particularly their threshold conditions, by charging up small portions of solar arrays by electron bombardment in a vacuum. They have found that the current pulses resulting from the discharges are of short duration with sub-nanosecond risetimes but with amplitudes of several amperes. According to ERA these pulses can directly invade a satellite's electrical system and cause disruption of normal operation or even catastrophic failure. The ultimate purpose of the investigations, of course, is to find ways of minimizing or eliminating the static charges collected by the spacecraft.

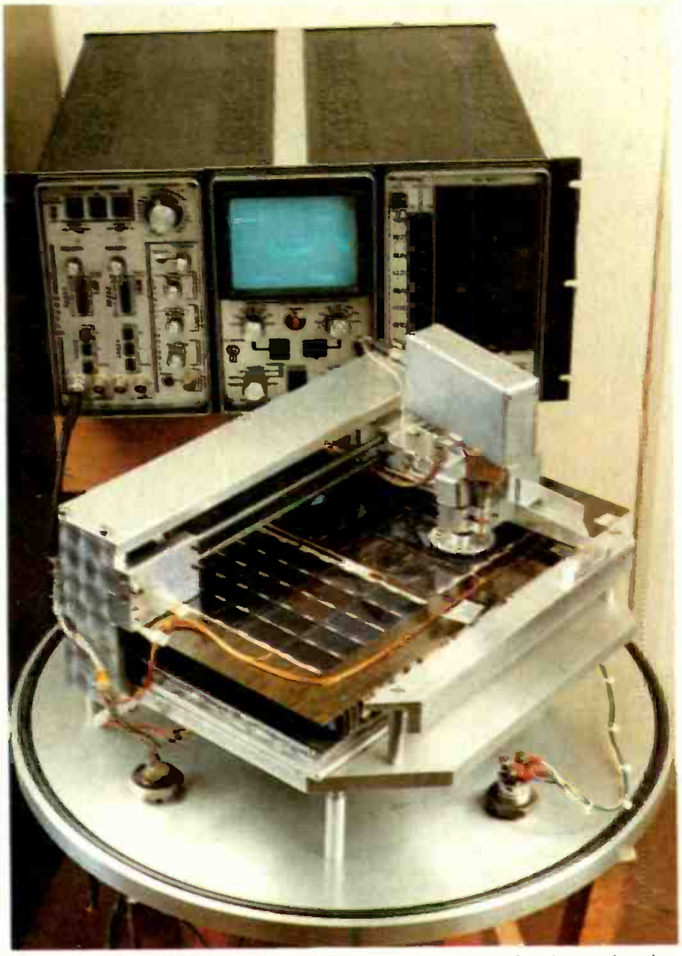


Fig.2. ERA Technology's laboratory equipoment for investigating discharges in solar arrays. The portion of an array is charged up by electron bombardment in a vacuum. Circular table is the base of the vacuum chamber.

British Aerospace is tackling the problem of corrosion of solar arrays by monatomic oxygen that afflicts spacecraft travellng in low Earth orbits. They are building replacement solar arrays for the Hubble Space Telescopic (not yet launched). These structures will be fitted in orbit by astronauts after about three years' operation with the original solar arrays. The replacement arrays will use back surface field reflector silicon solar cells which are more resistant to the effects of monatomic oxygen.

Solar power systems

If the photovoltaic effect had not been discovered, by Adams and Day in 1876, the communications, d.b.s., meteorological and other satellites we know today would not have been possible. Certainly the first few spacecraft launched in the late 1950s used batteries to operate their radio equipment, but of course the power soon ran out. It's difficult to imagine any electrical generator other than solar cells that could be used in satellites and keep going with only about 30% reduction in power output over ten years or more.

Solar cell generators are absolutely crucial to the entire design and performance of satellite communication systems because they set a limit on the total r.f. power than can be transmitted. This controls the number of transponders, of given r.f. power outputs, that can be provided in a single spacecraft. In turn it therefore determines the total downlink bandwidth available, the carrier-to-noise ratio of transponders and the design of antenna feeds and reflectors.

However, with gradual increases in the efficiency of solar cells and in the total number of cells that can be carried on solar panels (allowed by bigger and more powerful launchers), the power generated has been steadily creeping up over the years. Starting from a few tens of watts twenty years ago, solar generator outputs are now well above 1kW in many operational satellites. Larger spacecraft soon to be launched, such as Intelsat VI and the Franco-German d.b. satellites, will generate d.c. powers in the 2-4kW range. Olympus, the ESA multi-purpose satellite which is likely to go into orbit next year, will provide up to 7.5kW.

The ECS-5 comsat launched by Arianespace in July is one current example of solar generator practice. Fig.1 is a block diagram of the power system carried in this spacecraft. Each of the two solar arrays measures 5.2m×1.25m. When fully unfolded and extended in space their total span is 13.8m. Each array is made up of three panels covered in silicon solar cells.

When the satellite is on station the two arrays are aligned north-south, panels facing the sun. The solar constant in space is about 1.4kW/m^2, and so the radiant power falling on the total array area of 13m^2 is approximately 18kW. But, of course, nothing like this figure is converted into electrical power because there are spaces between the individual solar cells on the panels and the conversion efficiency of the cells is somewhere below 15%. In fact the actual power available at the beginning of the comsat's life is 1.26kW.

Each of the three-panel solar arrays is mounted on a frame which is pivoted at a bearing on the side of the box-shaped spacecraft. By this means the array can be gradually rotated, as the spacecraft orbits the Earth, so that it is always facing the sun. Automatic positioning is achieved by a closed-loop control system in which optical sensors mounted on the arrays are kept locked on to the sun.

The bearing and power transfer assemblies shown in Fig.1 contain electric motors which drive the pivoted arrays through bearings. Relative to the sun, the spacecraft's body rotates through 360° about its north-south axis once per day in its 24-hour geostationary orbit (the antennas always pointing at the

SATELLITE SYSTEMS

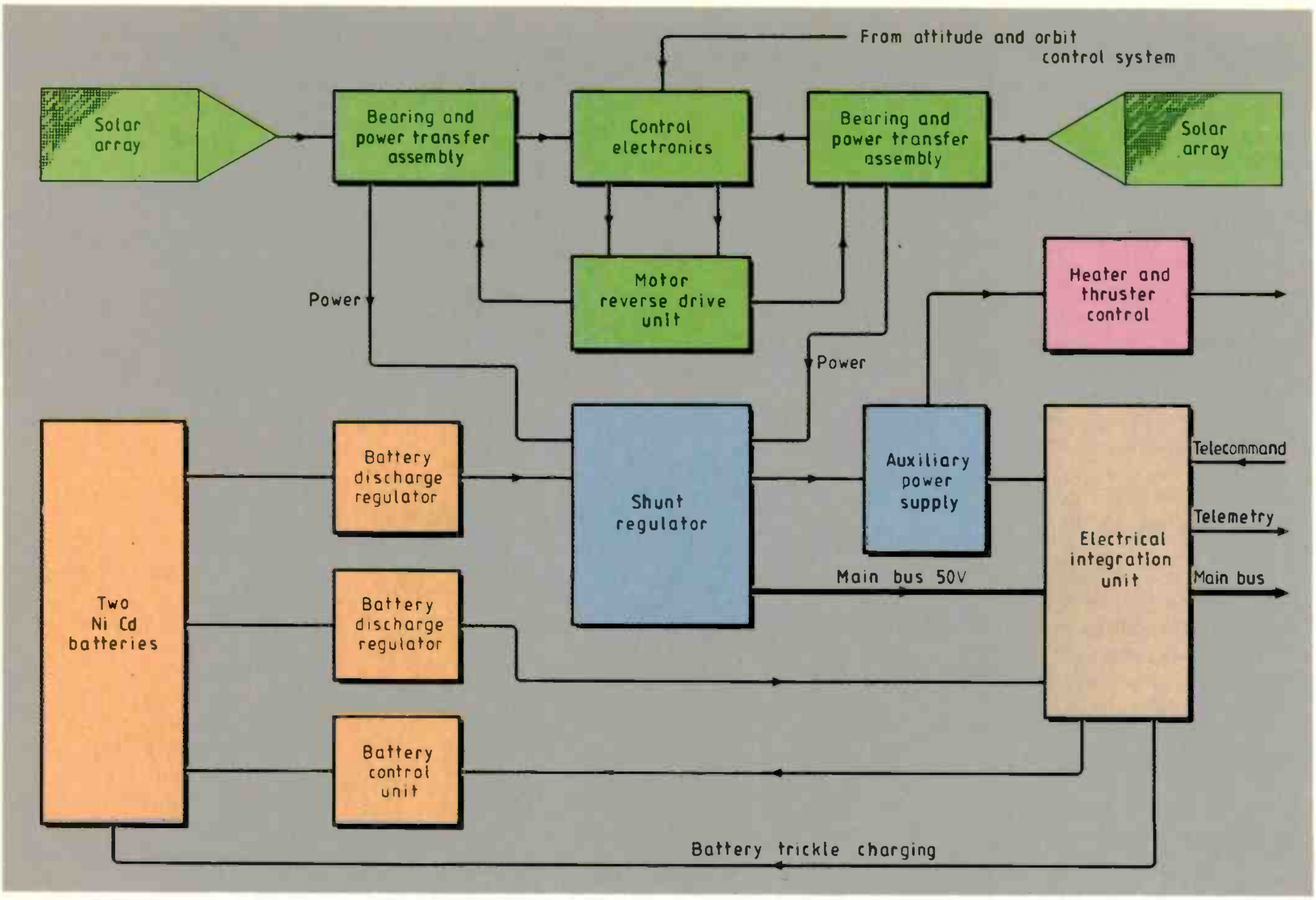


Fig.1. Solar power generator system in the ECS-5 communications satellite.

Earth). So the control system has to turn the solar arrays in the opposite direction at the same speed in order to keep them facing the sun. Apart from this automatic control, the positioning system can also be controlled by telecommand signals from the ground.

Electrical power from the solar arrays passes into the spacecraft body through multiple slip-rings on the array bearings. It goes without saying that these bearings and slip-rings must be extremely reliable mechanical components to maintain the rotation and power transfer without failure for ten years or more. Once brought inside the spacecraft body, the power is voltage regulated and then emerges on a main bus at 50V±2%.

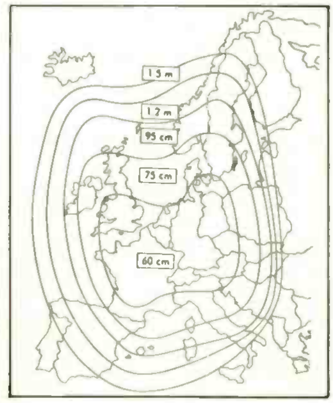
Because the Earth's equatorial plane lies at an angle of about 23° to the plane of the solar system (the ecliptic) the satellite's geostationary orbital plane is also tilted at this angle. For most of the year the comsat can 'see' the sun, either directly or looking 'above' or 'below' the Earth when the planet is interposed between them. But twice a year, at the spring and autumn equinox, the spacecraft encounters the Earth's shadow and so experiences an eclipse of the sun.

It starts to move through the edge of the shadow for a few minutes each day about three weeks before the equinox. But by the actual date of the equinox (21 March or 21 September) the spacecraft is in full shadow for well over an hour per day. The actual time of day at which this occurs depends on the east-west position of the satellite in the geostationary orbit. After another three weeks the comsat is completely clear of the shadow.

During these eclipse periods of up to an hour or more each day, the solar arrays obviously receive no solar radiation and generate no electrical power. To cope with this daily eclipse occurring twice a year, the satellite also carries secondary batteries as shown in Fig.1. These are kept trickle-charged from the solar generators during sunlight periods. They are normally light-weight NiCd or NiH batteries providing up to 2Ah per kilogram of weight. The ECS-5 power system has two NiCd batteries, each containing 32 cells of 24Ah capacity. The trickle-charging rate is set by telecommand from the ground.

Broadcasting satellites

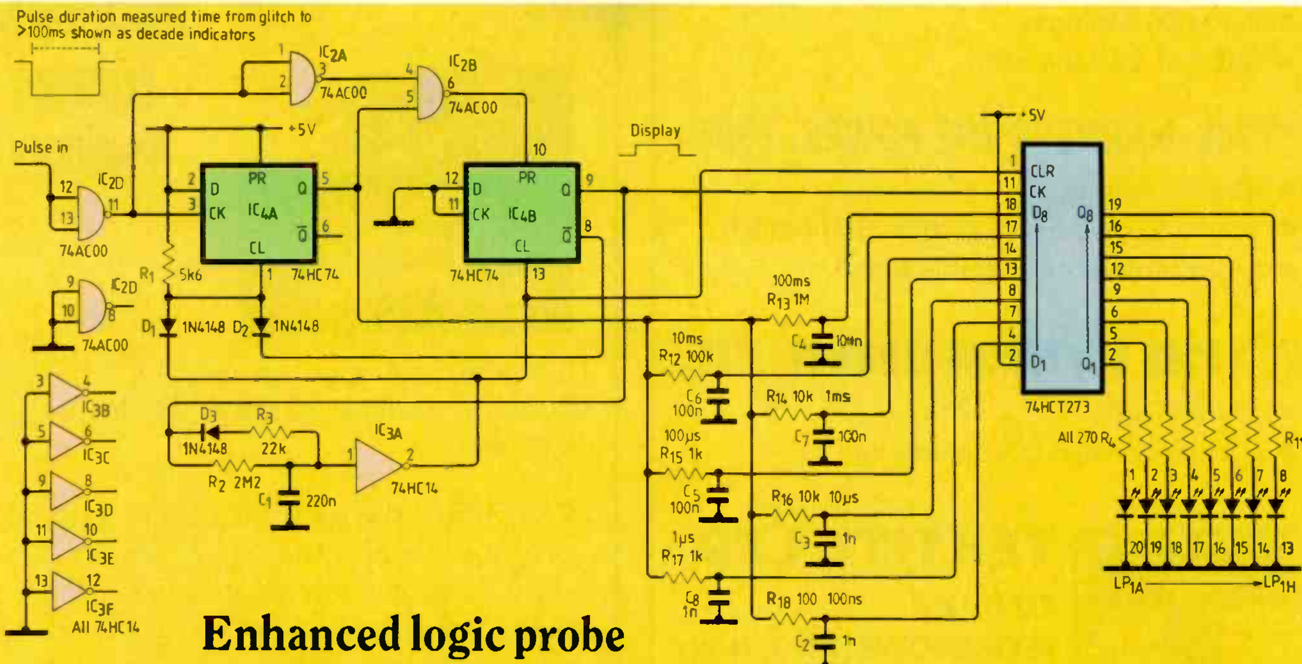
Europe will have two television broadcasting satellites in orbit before the end of the year if the launches go ahead as planned.



First to go up, in October, will be the French high-power d.b. satellite TDF-1, which will have an e.i.r.p. of 63.5dBW (see April 1987 issue. p.377, for details). Its tv signals are likely to be encoded in D2-MAC. Orbital position will be 19°W.

About a month later it will be followed by the medium-power Astra satellite, owned and operated by SES of Luxembourg and due to be positioned at 19°E. As described in the June and August 1987 issues, Astra would have transmitted an e.i.r.p. of 50dBW over its primary coverage area. Now, SES thinks this power is more likely to be 52dBW over the area. The accompanying map has contours showing the receiving dish sizes which are expected to be adequate in different parts of Europe and Scandinavia. First channels in operation will be PAL encoded, though others to follow are likely to use D2-MAC (see leader in August issue, p.739, for details and comment).

Satellite Systems is written by Tom Ivall.



Enhanced logic probe

Most existing logic-probe designs indicate that a pulse has occurred, but this one also indicates the duration of the pulse. Having an idea of the pulse width greatly simplifies fault finding. In a microprocessor system for example healthy strobe pulses are typically from 200ns to 1µs wide. Any strobe of less than 100ns or greater than 10µs therefore requires further investigation. Without the probe, a fast oscilloscope would be needed.

Eight leds indicate pulse durations ranging from a 'glitch' to greater than 100ms in decade steps. Edge triggering is used throughout and the circuit is tolerant of variations in pulse repetition rate.

The negative-going input pulse passed through IC_{2d} and its leading edge causes IC_{4a}, to be set, initiating charging of the bank of seven time-constant networks. With IC_{4a} set, the trailing edge presets IC_{4b}, clocking octal latch IC_1 whose data inputs are outputs from the seven time-constant networks plus one pin tied high. While the input pulse is low, the time-constant networks switch sequentially up to 100ms, when all seven are set; the eighth bit is always set during a pulse to indicate a glitch.

Once the pattern is latched and displayed, IC_{3a} and its CR network hold the value for about a half second, after which the latches are cleared and the circuit rearmed. Since IC_{4a} only needs a negative-going edge to initiate the entire sequence, glitches will always be indicated provided that they return high for more than 20ns. This applies even for glitches that are too fast for the subsequent logic.

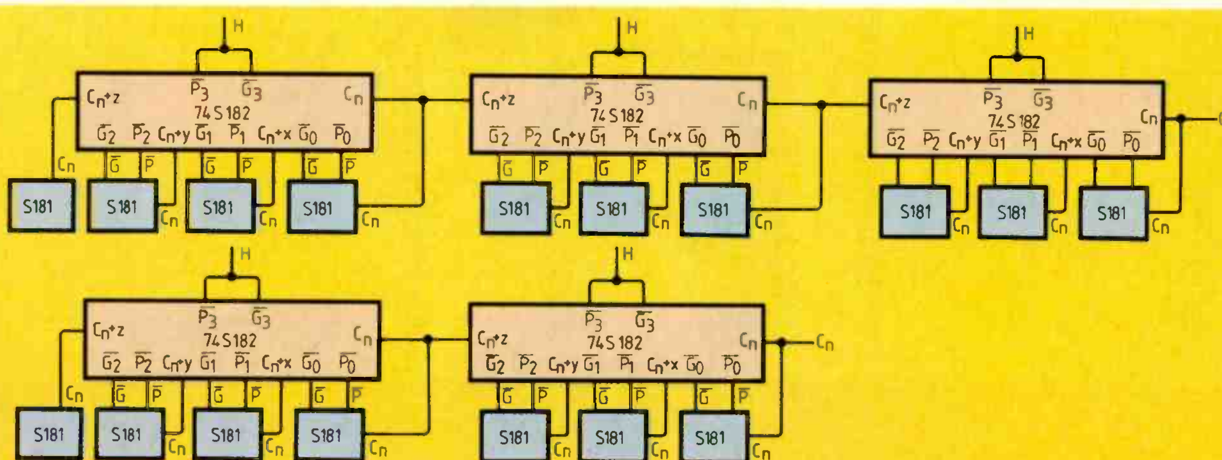
Accuracy of my prototype was not excellent, mainly due to the use of HCT logic rather than HC for the latch (HCT has a lower threshold), but it was within a factor of two. Attention to component values would improve accuracy. It is not essential to use a 74AC00; a 74HCT132 instead would also make the 74HC14 redundant. Only negative-going pulses are monitored, but it would be a simple matter to either duplicate the circuit for positive-going pulses, or include an exclusive-Or gate and switch at the input.

B.J. Frost
Dorset Design and Developments

More efficient a.l.us

It is rather inefficient to use full look-ahead carry when a 24, 28, 32, 36 or 40bit a.l.u. is constructed from 74S181 a.l.us and 74S182 look-ahead carry generators. From a TI data book, I found that the circuit shown first provides the same speed as a 40bit full look-ahead a.l.u. In the second circuit, the 28bit a.l.u. has typically 7ns shorter addition and subtraction times. Maximum times are reduced by 10.5ns. In both cases, the board space needed is smaller and supply current, input loading and the price are all reduced.

Marcel van de Gevel
Harlem
The Netherlands



NEW PRODUCTS

Polypropylene capacitors

A range of axial type metallized polypropylene film capacitors with a tolerance of 1% has been introduced by Steatite Roederstein.

The MKP 1839 series is available with capacitance values ranging from 1000pF to 6.8μF, and voltage ratings from 160 to 630V d.c. The devices have a dielectric absorption figure of only 0.03% and are suitable for use in pulse circuits, deflection circuits in tv sets and snubber circuits for power semiconductors. Steatite Insulations Ltd, Ceramic Products Division, 2 The Square, Birmingham B15 1AP. Tel:

Read/write interface

A high-speed, low-noise head interface device for hard disc drives marketed in the UK by Microlog performs both read and write functions.

A variety of surface mounts and dual-in-line packaging options make the XR-501 suited to applications requiring six or eight centre-tapped read/write heads. For drives with more heads, multiple devices can be cascaded. The pinout for the device places all head ports on one side of the circuit, eliminating crossovers and simplifying flex cable or board layout. Microlog Ltd, The Cornerstone, The Broadway, Woking, Surrey GU21 5EZ. Tel: 04862 29551.

Screen cleaning to recover metals

Screens used for accurate placing of solder paste on surface mount p.c.bs can be thoroughly cleaned and the metals recovered using a Screenklene stand-alone cleaning unit.

ICI has designed the plant with an integral, removable settling tank. Once the solvent, either ICI's Genklene or Arklone, has been sprayed onto the workpiece it drains into a tank which traps the insoluble heavy metal residue for disposal or reclamation. A totally enclosed, illuminated cabinet protects the operator from inhaling solvent vapour and the screens are sprayed manually using solvent resistant gloves firmly attached to hand access holes in the front of the cabinet. The unit can be operated either by single phase electricity or compressed air and is designed to take screens up to 800 × 500mm in size. Chlor-Chemicals, ICI Chemicals and Polymers Ltd, PO Box 14, The Heath, Runcorn, Cheshire WA7 4QF. Tel: 0928 514444.

All-in-one outside broadcast equipment

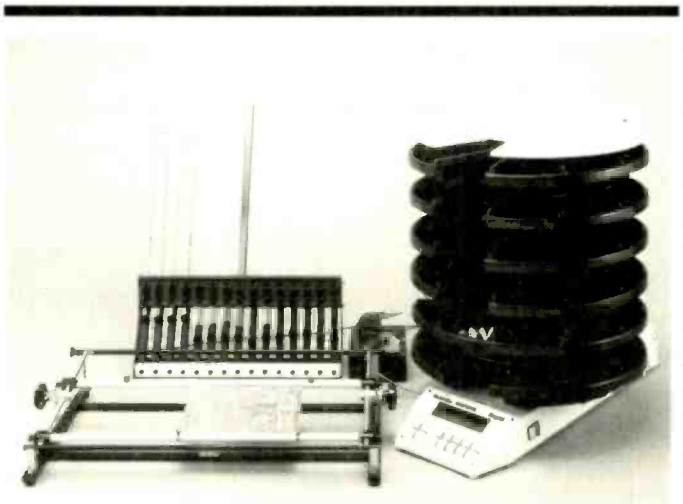
As the result of consultation with the broadcast industry worldwide an all-in-one portable Reporter Radio Link unit integrates an extended audio u.h.f. transmitter link with a v.h.f. cueing receiver and off-air station monitor.

Wood & Douglas has designed the equipment to be easy to operate; the preset controls are located behind the engineer's panel rather than on the front panel. Other features include microphone or line-level output, common receiver volume control, auto off-air/cueing electronic audio switch, internal power source for electret microphones, two or three-antenna operation and low-battery indicator. Power comes from a sealed lead/acid battery with the option of an external d.c. feed to power the unit and charge the internal battery. Wood & Douglas, Unit 12-13, Youngs Industrial Estate, Aldermaston, Reading RG7 4PQ. Tel: 07356 71444.

Fast monolithic log amplifier

The AD9521 monolithic logarithmic amplifier from Analog Devices offers a 7 to 250MHz bandwidth and low 4.7dB noise figure.

It is useful in radar signal receivers, electronic countermeasures, sonar equipment, miniaturized log strips and nuclear instrumentation. With better gain flatness and output matching than the SL521 and SL1521 log. amplifiers the voltage gain range is essentially flat, varying only 1.2dB from 30 to 160MHz. The amplifier operates from a single 6V supply and dissipates 90mW of power. Analog Devices, Station Avenue, Walton on Thames, Surrey KT12 1PF. Tel: 01-



Low volume assembly automation

P.c.b. assembly can be semi-automated at a low cost with Blakell Systems' new Minisert workstation.

It delivers components and i.cs to an operator in a programmable sequence for insertion into the p.c.b., and is suitable for low-volume p.c.b. production, particularly the small batch environment. The system combines the company's existing motorized rotary component dispenser with a new universal i.c. dispenser. An interface module extends the capability of the integral programmer to control the complete workstation. Up to 10 different assembly programs can be stored locally for instant recall at the push of a button. Blakell Systems Ltd, Blandford Heights, Blandford Forum, Dorset DT11 7TE. Tel: 0258 51353.

Fast s-rams

A range of hc-mos s-rams with access memory times of 25 and 34ns has members with 4K × 4, 64K × 1 and 16K × 4 organizations.

Motorola claims that these are the first production s-rams to use double metal, double polysilicon c-mos process with 1.5μ design features. The chip-select access time from the powered-down state is as fast as the address access time and fast entry into the low-power standby mode provides a standby current of 20mA at t.t.l. levels without degrading access time performance. These chips are suitable for highly pipelined digital signal processing systems, real time measurement and test equipment and speech recognition and synthesis systems. Motorola Ltd, 88 Tanners Drive, Blakelands, Milton Keynes MK14 5BP. Tel 631 1044.

Miniature counter/displays

Small six and eight digit counter/display modules which can be mounted on a p.c.b. like an integrated circuit are available from Red Lion Controls.

The units can be supplied with a bezel kit for front panel mounting. They are ideal for internal on-board use where a readout of count frequency or time is needed within a circuit enclosure. Sub-Cub component counters are based on a custom c-mos monolithic counter/driver chip and operate up to 500Hz. Construction features solderless elastomeric connectors to provide corrosion-proof, gas-tight contacts. Red Lion Controls, Cranford Lane, Heston, Hounslow, Middlesex TW5 9NQ. Tel: 01-759 0694.

Thermal analysis of p.c.b. designs

Designers can analyse p.c.b. designs for operating temperatures, reliability rates and noise susceptibility during board layout, using the Thermostats software package from Valid Logic Systems.

The company believes that excessive temperature is the leading cause of board failure and that controlling thermal output is key to designing reliable boards. The package includes thermal, reliability and noise-margin analysis software, and a thermal model library of 1200 devices. Valid's Allegro p.c.b. design system is a prerequisite for Thermostats – designs created on other cad systems can be imported into the Allegro system and then used. Valid UK Ltd, Valid House, 39 Windsor Road, Slough SL1 2EE. Tel: 0753 820101.

NEW PRODUCTS

Waveform generator

The memory of the Prisma VR 1000 video waveform generator has been revised to ensure greater portability between the IBM PC range of computers.

Millipede believes this unit to be the first IBM PC/XT/AT plug-in board capable of producing high-definition one-dimensional video waveforms (gratings) to an accuracy of 12 bits. The VR1000 is completely programmable and can easily support 4000 line displays. It can also drive monitors with refresh rates in excess of 200Hz. The board is available in single or synchronized dual-channel versions. Millipede Electronic Graphics, 12 Pryor Close, Milton, Cambridge CB4 4BU. Tel: 0223 862066.

Accurate spectrum analysis

Automatic amplitude calibration is achieved by Anritsu's MS2601A spectrum analyser, which has a frequency resolution of 1Hz over its entire 10kHz to 2.2GHz range.

Each time the cal. operation is selected, the internally routed calibration signal is measured, compared and signal processed at high speed using the 16 bit microprocessor. The corrected measured value is then displayed. For e.m.c/r.f.i. applications amplitude measurements can be performed in accordance with CCIPR recommendations. Anritsu Europe Ltd, Thistle Road, Windmill Trading Estate, Luton, Beds LU1 3XJ. Tel: 0582 418853.

Signal distribution system

A remote-control crossbar distribution system for audio, video and data switching applications, manufactured by Ghielmetti of Switzerland, is available from Data Precision.

The GMS crossbar distributor is suitable for use wherever a number of electrical signal inputs have to be switched to a number of outputs. It is designed to replace mechanical matrix programming boards, where easy operation and speed of switching are important considerations. The unit may be programmed from the 8×8 matrix keypad front panel. Remote control is available via an RS232/V24 serial interface. Data Precision Ltd, Fromson Building No. 1, Canada Road, Byfleet, Surrey KT14 7JL. Tel: 09323 53879.

Domestic users get gas sensors

Quantelec's range of hot-wire flammable gas sensors for domestic use are of the type previously only available for industrial applications.

The NAP-7A sensors have a matched sensor and compensator pair, both mounted in coils of fine platinum heaters covered with high-temperature oxides and a catalyst. The platinum heaters are part of a balanced Wheatstone bridge circuit and when combustible gases are present, the catalyst causes a temperature rise of the heaters and a change in their electrical resistance which unbalances the bridge and can be detected electronically. Quantelec Ltd, 46 Market Square, Witney, Oxon OX8 6AL. Tel: 0903 76488.

Panel-mounting neon indicators

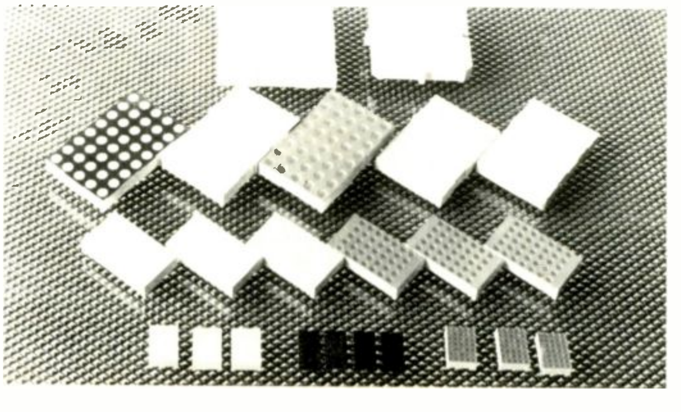
Easily installed panel-mounting neon indicators are available from Appeltech.

Fitting only requires a 9mm space behind the panel; the lens is inserted through a hole in the panel and clips onto the neon tube by two projecting legs which firmly secure both parts of the indicator. There are 15 indicator styles and shapes in the range and non-standard indicators can be made to order from customers' specifications. Appeltech Ltd, Unit 5, Meadowbank Road Industrial Estate, Harrison Street, Rotherham S61 1EE. Tel: 0709 550524.

Interlocking display modules

New members of a family of bi-colour dot matrix led display modules from Selectronic have interlocking keyways for end-stacking applications.

All feature high brightness and matched conversion efficiencies between individual elements and between the two colours on the same display module. The elements are individually accessible for drive purposes. Colours are orange-red, produced by a gallium arsenide phosphide diode, and green from a GaP chip. Sizes vary from a 4×4 to an 8×8 dot matrix. The various versions carry a code letter so that large arrays of matched brightness can be built up. Selectronic Ltd, 46 Market Square, Whitney, Oxon OX8 6AL. Tel: 0993 73888.



Pressure transmitters

An accuracy of 0.5% is achieved by the Sensym range of stainless steel pressure transmitters from Hi-Tek Electronics.

The series is both temperature compensated and signal conditioned to provide a high level output. Devices are available from 0-15psig up to 0-300psig, with output options of 1-6V d.c., 2.5-12.5V d.c., or 4-20mA for each pressure range. A diaphragm which is plasma welded to the body minimizes the amount of oil needed for optimal performance and provides a reliable bond able to handle extreme burst pressures without leakage or media contamination. Hi-Tek Electronics, Ditton Walk, Cambridge CB5 8QD. Tel: 0223 213333.

High resolution oscillator

A high-resolution numerically controlled oscillator which generates digitized sine and cosine functions of a precise frequency is available through Chiptech.

The STEL-1172B offers 32 bit frequency resolution and operates up to 50MHz. It has applications in high speed frequency synthesis, single sideband converters, baseband receivers and digital signal processors, and incorporates an eight-bit microprocessor interface for simple integration into digital systems. In conjunction with a d/a converter the oscillator can be used in analogue signal generation applications. Chiptech Ltd, Alban Park, Hatfield Road, St Albans, Herts AL4 0JJ. Tel: 0720 40476.

Thin film v.c.o. module

Stable frequency outputs from 7 to 10GHz are produced by the Sivers IMA PM7621 wideband thin film v.c.o. modules.

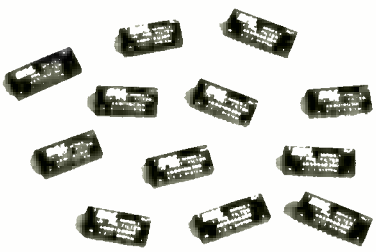
The module, available from Anglia Microwaves, is designed to give a clean output, based on a bipolar transistor and fundamental hyper-abrupt varactor-tuned oscillator package. Tuning is linear, with a 3:1 variation for a 0 to 20V tuning voltage range. The oscillator and buffer stages are sited on a ceramic substrate with integral resistors and removable SMA connectors to allow integration into microstrip and stripline circuits. Anglia Microwaves Ltd, Radford Business Centre, Radford Way, Billericay, Essex CM12 0BZ. Tel: 0277 630000.

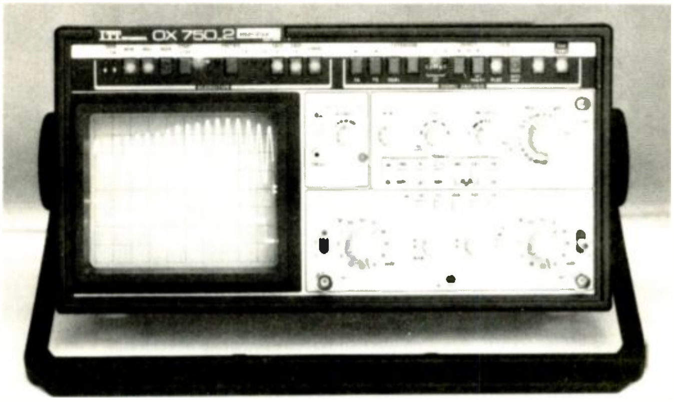
NEW PRODUCTS

Video filters

A set of video filters has been developed by BAL Components for component signal processing using the 4:2:2 system.

The Series 5 filters have been designed to give good transparency in the video passband and provide a soft transition and reduce ringing in the time domain. All filters have input and output impedances of 75ohm and are available with sin x/x correction for post filtering after digital-to-analogue conversion of the video signals. The luminance filters are packaged in 28 pin dual in-line packages and the colour difference circuits are housed in 24 pin integrated circuits. BAL Components, Bermuda Road, Nuneaton, Warks. Tel: 0203 375827.





External control for oscilloscope

The RS232 serial interface on the OX 750 digital storage oscilloscope allows external start/stop control of the digital signal acquisition, and output of the stored data for external storage, comparison and analysis. The data transmission rate is adjustable from 300 to 9600 Baud in six steps.

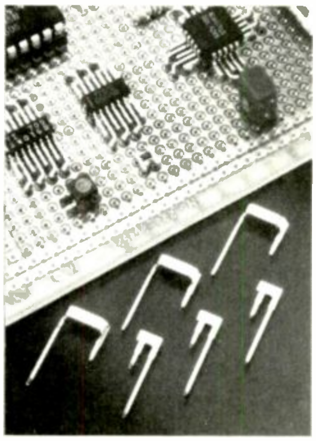
Two eight bit, 2MHz a-to-d converters provide the digital performance of ITT Instrument's oscilloscope. The memory stores 2000 samples per channel, plus 48 samples for the reference position. Microprocessor controlled, single shot, roll and refresh modes are included with pre-trigger available in all modes.

Post-storage analysis featurs include a horizontal expansion in six steps up to 32 times and an interactive cursor which allows the user to select the required portion of the stored signal for further study. ITT Instruments, 346 Edinburgh Avenue, Slough, Berks SL1 4TU. Tel: 0753 824131.

Surface mount pins

A range of Vero surface mount pins for prototyping SM devices on to conventional p.c.bs has been designed to allow for conventional hot gas, vapour phase and infra-red reflow soldering processes.

The pins are suitable for both gull-wing and J leaded devices in dual in-line and quad packages of any size. They are supplied in kits which contain 200 pins and include an insertion and removal tool, a Eurocard square pad board, design layout sheet and full instructions. BICC-Vero Electronics Ltd, Flanders Road, Hedge End, Southampton SO3 3GL. Tel: 0703 266300.



C-mos chip for mobile radios

Car telephones (C network) and cordless telephones are the main areas of application for Siemens' TBB 200 p.l.l. chip for processor-controlled frequency synthesis. The circuit is intended for the r.f. section of two-way mobile radios operating in the frequency bands upwards of 900MHz. Siemens Ltd, Siemens House, Windmill Road, Sunbury-on-Thames, Middlesex TW16 7HS. Tel: 0932 752323.

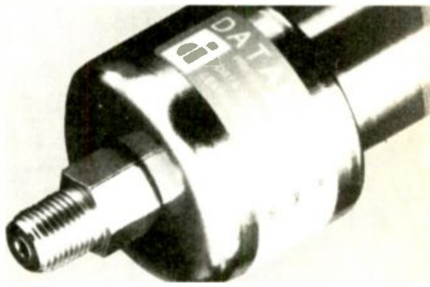
Four-way video amplifier

The four-way output from one input in Labgear's video distribution amplifier is designed to distribute signals from t.v. camera installations, satellite receivers, video recorders and waveform generators.

In addition a loop-through facility enables the input signal to continue on to other equipment where required. The bandwidth is adequate for MAC and other high-definition systems. Labgear Cablevision Ltd, PO Box 182, Abbey Walk, Cambridge CB1 2QN. Tel: 0223 66521.

Pressure transducer for harsh environments

The stainless steel pressure port and diaphragm of the Model DM pressure transducer means it can be used in a variety of corrosive media.



Pressure ranges of 1 to 34bars with 1% accuracy are offered by the device from Control Transducers. The standard 4 to 20mA output on two wires makes it ideal for monitoring both primary and secondary process variables. The electrical connections may be made through conduit for extra protection. Overpressure can rise to twice the rated pressure without damage to the transducer and ten times the rated pressure can be reached without bursting. Control Transducers, North Lodge, 25 Kimbolton Road, Bedford MK40 2NY. Tel: 0234 217704.

Power plant monitor and controller

A cost-effective system for remote monitoring control of power plants has been introduced by Harmer & Simmons.

The Remote Access Monitor can monitor plant voltages and currents as well as other analogue and binary inputs, and will provide relay output control of plant equipment. It stores 32 days of plant operation data, which can be automatically down loaded to a central reporting system. Up to 5000 R.A.Ms can be controlled through the power network manager central reporting software package which features auto-polling, remote direct access and remote strip chart recording. Harmer & Simmons Ltd, Peregrine Road, Hainault, Ilford, Essex IG6 3XJ. Tel: 01-500 1211.

On-the-spot print-out of sound test data

On-site documentation of sound level measurements is possible using Bruel & Kjaer's portable, battery-powered printer.

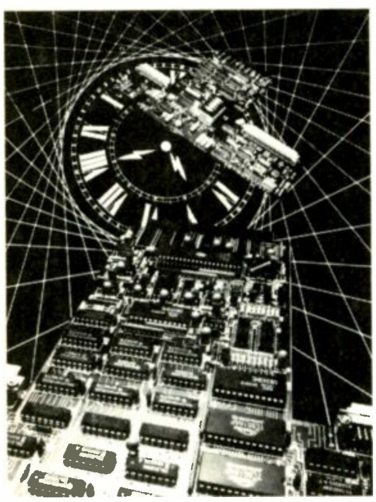
The 2318 graphic documentation printer is designed for use with the 2231 modular sound level meter, but can also be used with B & K's intensity analysers and most instruments with an RS232C serial interface. The printer provides on-the-spot print-out of fully annotated bar charts, tables and graphs. Each paper roll has space for about 4000 lines. Bruel & Kjaer (UK) Ltd, Harrow Weald Lodge, 92 Uxbridge Road, Harrow, Middlesex HA3 6BZ. Tel: 01-954 2366.

NEW PRODUCTS

Timing abilities on voltage card

A voltage measurement card for DCA Technology's TS3000 test system incorporates a precision timing facility to allow evaluation of complex waveforms without the need for additional equipment.

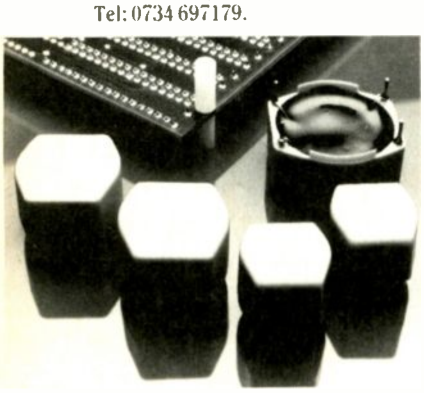
The card provides d.c., a.c. r.m.s. and a.c. peak voltage measurements. All inputs are isolated, allowing differential or singled-ended measurements. The programmable timer on the card provides delays between 85μs and 10s, selectable in 5μs steps. DCA Technology Ltd, 5 Grove Park, Mill Lane, Alton, Hants GU34 2QG. Tel: 0420 84088.

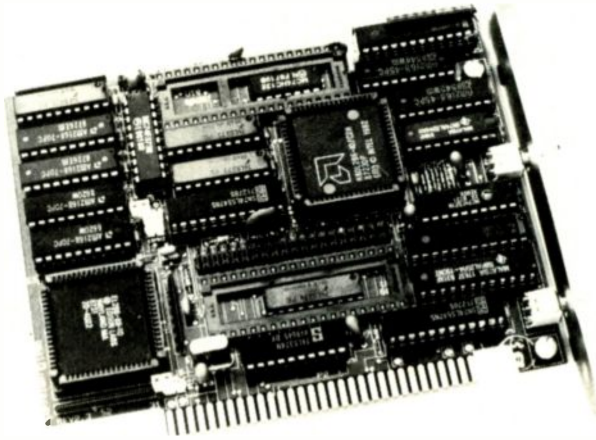


Current compensated chokes

The compensated toroidal core winding on a new range of current-compensated chokes presents a high inductance to r.f.i. while remaining transparent to the supply current.

The chokes from Schaffner EMC are designed for p.c.b. mounting and use in r.f. filters and similar components. They have a full 250V r.m.s. working voltage rating. Over the range the supply current ratings cover 0.3 to 4A. Schaffner EMC Ltd, Headley Park Area 10, Headley Road East, Woodley, Reading RG5 4SW. Tel: 0734 697179.





Faster performance using speed card

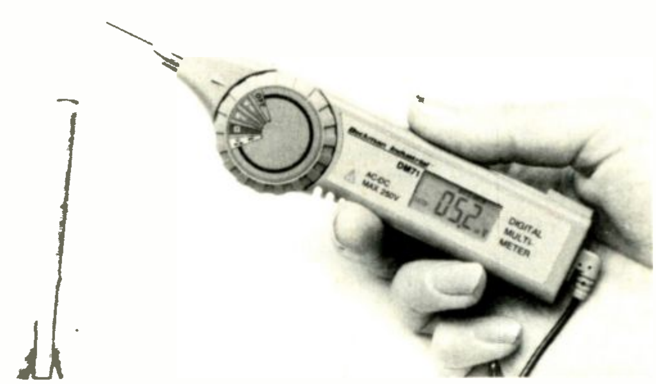
The XT-268 speed card is an internal half length board designed to enhance the performance of the IBM PX/AT and compatible computers.

It gives the 8088 c.p.u. computer faster performance than the IBM AT in computation-intensive programs. Many software applications can run up to seven times faster using the card from Roalan International. The card replaces the 8088 processor with a 80286 16-bit processor that resides on the add-on board. The 80286 runs at 10MHz compared to 4.77MHz on the 8088. Included is 8K of cache memory from which data is fed directly to the 80286 at 10MHz with zero wait states. Roalan International, Gleneagles House, 31 Riverside Road, West Moors, Wimborne, Dorset BH22 0LG. Tel: 0202 861512.

Small incremental encoder

Murata claims its new miniature rotary encoder with a diameter of 30mm is the world's smallest incremental encoder.

A permanent magnet on the rotating shaft causes changes in the values of magnestoresistors, and two outputs permit detection of the direction of rotation. The encoder can be used for angle, position and speed measurement in photocopiers, motors, robots and printers. Murata Electronics (UK) Ltd, 5 Armstrong Mall, Southwood, Farnborough, Hants GU14 0NR. Tel: 0252 523232.



Hand-held multi-meter

A hand-held, pen-type, autoranging digital multi-meter with 17 ranges/functions measures d.c. and a.c. voltages, resistance, and includes a continuity and diode test function.

The DM71 from Beckman Industrial incorporates a rotary function selector, a touch hold function which freezes the display and an audible indication of continuity and range changing. The l.c.d. display indicates value, polarity, measurement unit, over-range, data hold and low battery. The DM71 is supplied complete with batteries, test leads, operator's manual and a rigid plastics case. Beckman Industrial Ltd, Temple House, 43-48 New Street, Birmingham B2 4LJ. 021-643 8899.

Rigid, composite laminate for p.c.bs

Savings in material, tooling, time and costs in p.c.b. production and assembly should be made using a presensitized, rigid, composite laminate available from Mega.

The FPC-16 laminate consists of a paper-based core impregnated with epoxy resin, sandwiched between two thin layers of glass cloth resin-impregnated, copper-clad laminate. It offers all the operational characterstics of the conventional p.c.b. material but is lower in cost, lighter and easier to use. It may be drilled using conventional steel bits and is supplied in sheet sizes up to 1060 × 1280mm. Mega Electronics Ltd, 9 Radwinter Road, Saffron Walden, Essex CB11 3HU. Tel: 0799 21918.

Bandpass filters

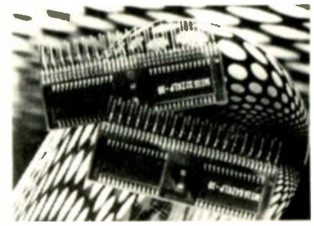
A range of metal insert filters which cover the frequencies from 17 to 110GHz has been developed by GEC-Marconi in waveguide sizes R220 to R900.

The designs are etched from copper foil and clamped in a waveguide housing split at the E-plane to form the filter cavities. The filters have a typical passband v.s.w.r. better than 1.1:1 with bandwidths of up to 15% available. Insertion losses of three, five-section filters, each with 1GHz bandwidths centred at 36, 60 and 94GHz are 0.6, 1.8 and 2.3dB respectively. GEC-Marconi Research Centre, West Hanningfield Road, Great Baddow, Chelmsford, Essex CM2 8HN. Tel: 0245 73331.

S-rams for transputers

To save board space, Hybrid Memory Products has developed two s-rams in 40 pin zig-zag packages suitable for use with transputers.

The devices are 50.9mm long and are configured as 64K × 16 and 32K



× 16. On-board decoupling capacitors save space, and common datat inputs and outputs simplify board layout. Hybrid Memory Products Ltd, Elm Road, West Chirton Industrial Estate, North Shields, Tyne and Wear NE29 8SE. 091-258 0690.

NEW PRODUCTS

Differential amplifier

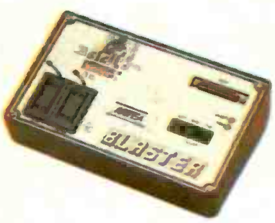
Current mode feedback is used to achieve more bandwidth at a given gain than in a conventional amplifier by the EL2020 differential amplifer.

The fast settling, wide bandwidth amplifier is optimized for gains of between −10 and +10 and is available from Microelectronics Technology. The bandwidth and slew rate are relatively independent of the closed loop gain setting, so that the unity gain bandwidth of 50MHz only reduces to 30MHz at a gain of 10. In most applications where a conventional op-amp is used an improvement in speed power product is obtained with this device. Microelectronics Technology Ltd, Unit 2, Great Haseley Trading Estate, Great Haseley, Oxfordshire OX9 7PF. Tel: 08446 8781.

Self-contained eprom programmer

The Artea Blaster is a low cost easy-to-use eprom programmer which works with any development system equipped with a standard RS232 port.

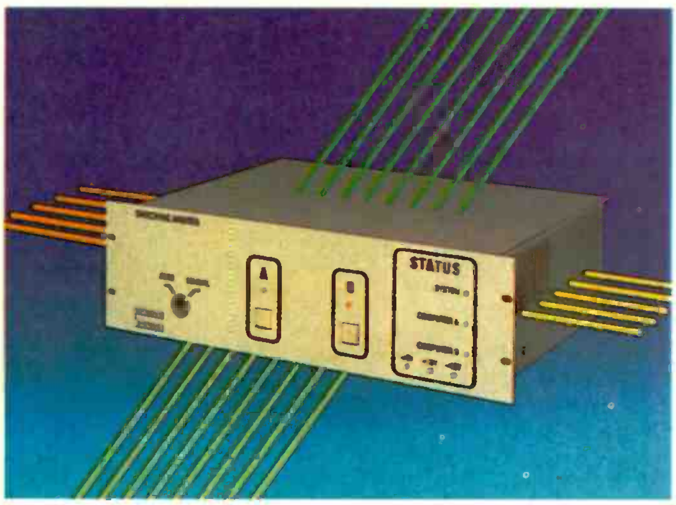
It contains a standard 25-way D-type family connector which allows it to replace printers directly. The data is transmitted using the host's print command. Operation is by front panel buttons and device status is shown by two leds. The Blaster can program all devices with the normal 50ms program pulse or it can use a VCC algorithm to reduce programming time. The instrument has a built-in power supply capable of operating from 240 or 100V and comes with a manual that includes a quick reference operating guide. A.R.T. Engineering Associates, Storrs House, Cavendish Avenue, Harrowgate, North Yorks HG2 8HX. Tel: 0423 60593.



Four-wire sensor and changeover switch

A range of four-wire d.c. sensors proof to IP67 and suitable for inductive or infra-red sensing in severe industrial environments has been introduced by Electromatic of Aldershot.

The device operates as a changeover switch so while it is not sensing the output can be used to light a display or control another circuit. Both p-n-p and n-p-n outputs are available which work on any voltage between 10 and 40V d.c. and can switch up to 200mA per output. Both plug and socket connectors and potted cable types are included in the range. The units can also be fitted with optical fibre cables. Electromatic Components Ltd. Unit 3, Eastern Road, Aldershot, Hants GU12 4TD. Tel: 0252 29324.



Switching for computer back-up

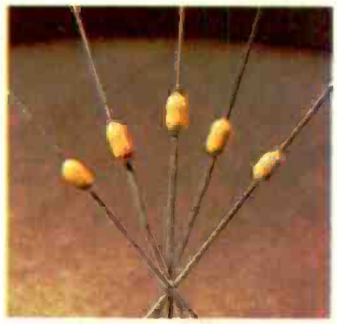
To create total integrity and fail-safe back-up, two computer systems can be connected to a common set of input and output peripherals with the Switching Arbiter from Softronic.

In the event that one system fails the unit automatically transfers control of all peripherals to the remaining computer. This link can then be maintained, without power, while the failed component is replaced. The Switching Arbiter is compatible with most computer systems, has a manual over-ride and can switch up to 16 peripherals per system. If a larger number of peripherals is required, then switching units can be added in multiples of 16. Softronic Systems Ltd, 2 & 3 Enterprise Estate, Station Road West, Ash Vale, Aldershot, Hants GU12 5QJ. Tel: 0252 513884.

Multilayer capacitors

The Aximax series of dipped, axial, conformally-coated, multilayer ceramic capacitors has a capacitance range of 10pF to 0.47μF.

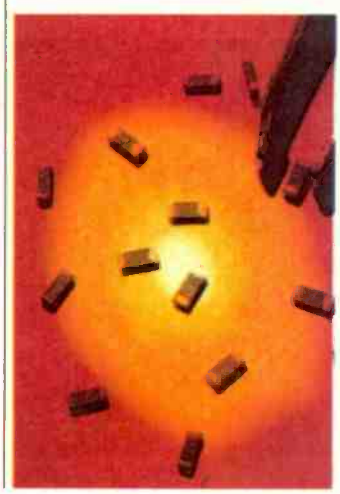
These devices are encapsulated in a shock and moisture resistant epoxy coating. STC Electronic Services supplies the series in three dielectrics – COG, X7R and Z5U – at 100 and 50V. The capacitors are designed for automatic insertion. The Capacitors Group, STC Electronic Services, Edinburgh Way, Harlow, Essex CM20 2DF. Tel: 0279 626777.



Thermistors can be wave soldered

High temperature wave and vapour phase soldering techniques can be used on the platinum palladium silver terminations of Dale-ACI's range of surface mounting chip thermistors.

The J-style thermistors feature wrap around terminations, simplifying direct mounting to the bonding pads of a hybrid substrate. They have an overall size of up to 2.54 × 1.47 × 0.94mm and values available range from 5 to 500kohm at 25°C. Also available is a 1Mohm (at 70°C) value, for high-temperature applications. Dale-ACI Components Ltd, River Park Industrial Estate, Berkhamsted, Herts HP4 1HL. Tel: 04427 72391.

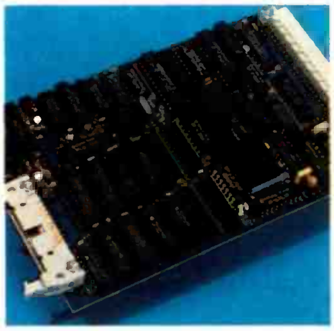


NEW PRODUCTS

Colour graphics

Single-board layout, smooth hardware scroll, flash facility, 2MHz operation and a Centronics printer port are among the advantages claimed for the CU-Graph II colour graphics controller.

Compatible with its predecessor, it is designed by Control Universal for use with EuroBEEB, the BBC Basic-based single-board computer. Three versions of the controller are available: colour and monochrome each with a Centronics printer port; and a low-cost monochrome without the printer port. Control Universal Ltd, 137 Ditton Walk, Cambridge CB5 8QF. Tel: 0223 244448.



Backplane simplifies AT-bus designs

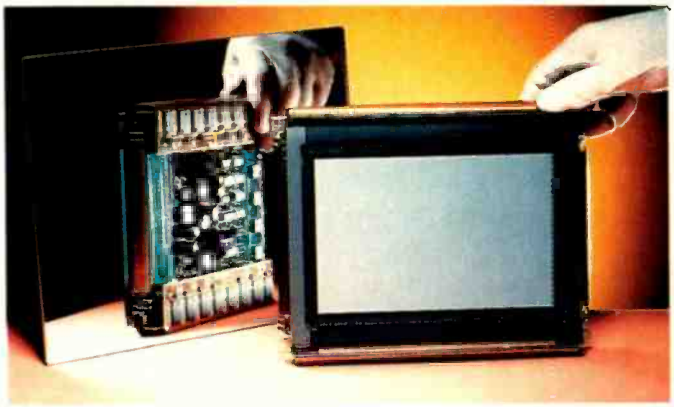
Systems based on AT-bus boards can be integrated simply using the Cheater backplane from Chiptech.

It provides eight 16-bit locations which can be socketed for PC or AT bus boards. Mounting holes are provided to allow the backplane to be fitted into a standard XT or baby AT enclosure. Power can be brought to the backplane via IBM-style connectors. A standard keyboard connector and a user patch area with printed-through holes are included on the board. Chiptech Ltd, Alban Park, Hatfield Road, St. Albans, Herts AL4 0JJ. Tel: 0727 40476.

Thin graphic module

A front luminous vacuum fluorescent display with 320×240 pixels, high-voltage driver control circuit and power circuit are all packaged together in Futaba's thin graphic module from Regisbrook.

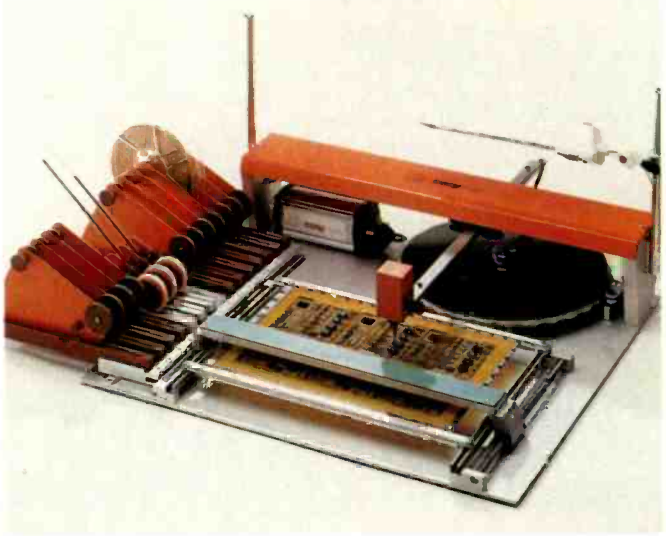
The display area is 120×90mm and has a dual-wire grid scanning system which enables a vertical or horizontal line to be displayed in a continuous line. It is available in 505nm green but the shade can be altered using simple wavelength filters. The Regisbrook Group, Units 1 and 2, Suffolk Way, Drayton Road, Abingdon, Oxon OX14 7JY. Tel: 0235 554433.



I.c. and component tester

The Beckman Scopemate-2 i.c. and component tester available from STC Instruments is designed for rapid testing of in- or out-of circuit components.

It generates simple patterns which are displayed and compared on any external x-y mode oscilloscope. The device can be used by non-technical personnel for direct comparison testing on microprocessors, d.t.l., t.t.l., c-mos i.c.s, op-amps, comparators, regulators, opto-isolators, diodes, transistors, capacitors, inductors and resistors. STC Instrument Services, Edinburgh Way, Harlow, Essex CM20 2DF. Tel: 0279 641641.



Manual pick-and-place machine

A vacuum pick-up tool for the assembly of devices such as flat packs and chip carriers is built in to Sohlberg-Surtech's Cosy BP-01-03.

The assembly station accepts p.c.bs up to 12 × 16in and is capable of placing approximately 500 components per hour. The machine is supplied complete with a bulk carousel for 60 component types and can also accommodate up to 15 extra tape or stick feeders. An optional magnifier and light source are available and a solder/glue dispensing head can be used in conjunction with the placement head. Sohlberg-Surtech Ltd, Unit 4, INTEC 2, Wade Road, Basingstoke, Hants RG24 470848. Tel: 0256 470848.

Tough p.c.b. spacers

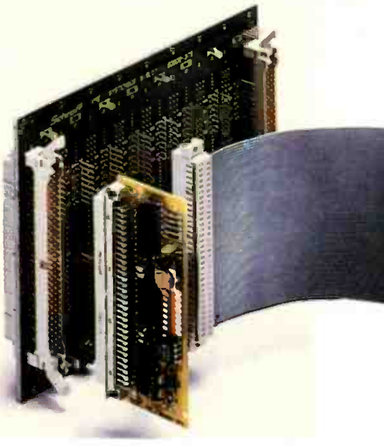
Tough nylon spacers for mounting p.c.bs have been introduced in the UK by Salterfix. The spacers are part of the Skiffy range of small nylon parts and come in two types.

One version has simple click-in mountings at both top and bottom, while the other can be used with a securing nut on the bottom mounting. The spacers offer vibration damping and full electrical insulation, the sizes allowing for distances from 4.8 to 22mm between boards. Salterfix, Salter Springs & Pressings Ltd, Spring Road, Smethwick, Warley, West Midlands B66 1PF. Tel: 021-553 2929.

Transfer connector

Built-in lock/eject levers give greater security and ease of use in Schroff's new DIN 41612 transfer connector.

It is designed to provide a wiring interface to VME backplanes and consists of a female moulding that slides directly on to the backplane's wire-wrap pins. The mounting is screwed into position from the opposite side of the backplane. Spacers are available so that the transfer connector can be used with different length wire-wrap pins. Schroff UK Ltd, Maylands Avenue, Hemel Hempstead, Herts HP2 4SG. Tel: 0442 40471.



COMMERCIAL QUALITY SCANNING RECEIVER

The IC-R7000, advanced technology, continous 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 pushing the digit keys in sequence of the frequency or by turning the main tuning knob. FM wide/FM narrow/AM upper and lower SSB modes with 6 tuning speeds: 0.1, 1.0, 5, 10, 12.5 and 25kHz. 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 infra-red remote controller, voice synthesizer and HP-1 headphones.

ICOM

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4116 (Pulls)	1.00	.90	.85
4164	Please call for best prices		
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41464	Please call for best prices		
2114 200ns Low Power	1.75	1.60	1.55
6116 150ns Low Power	5.50	★	★
6264 150ns Low Power	7.75	★	★
62256 120ns Low Power	10.50	9.75	9.00
2716 450ns 5 volt	3.20	3.05	2.95
2532 450ns	5.40	4.85	4.50
2732 450ns	3.20	3.05	2.95
2732A 250ns	3.95	3.70	3.50
2764 250ns	2.85	2.65	2.50
27128 250ns	4.90	4.65	4.45
27256 250ns	3.95	3.65	3.50
27C256 250ns	4.55	4.25	3.95
27512 250ns	8.45	7.95	7.65
27C512	8.95	8.40	7.95

Second-hand chips available for many of the above devices, 'phone for availability and pricing.

Low profile IC sockets:								
Pins	8	14	16	18	20	24	28	40
Pence	5	9	10	11	12	15	17	24

Please ask for quote on higher quantities or items not shown.
Data free on memories purchased, enquire cost for other.

Please add 50p post & packing to orders under £15 and VAT to total. Access orders by 'phone or mail welcome.
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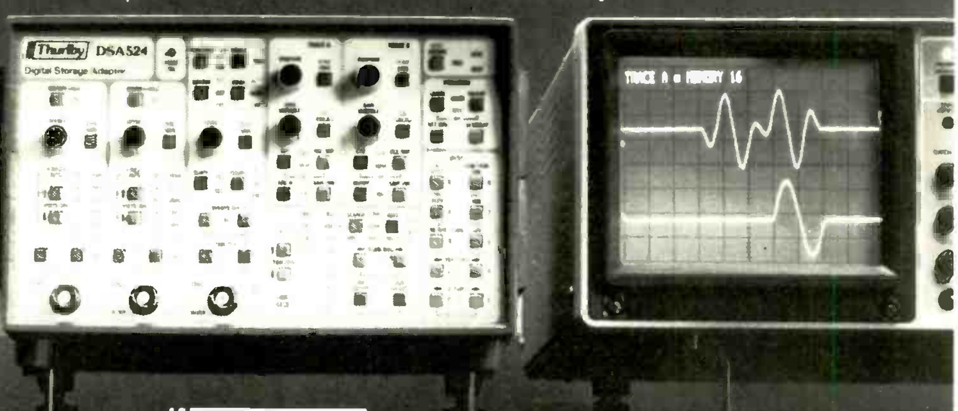
1. 20 megasamples/sec sampling rate?
2. 4K words memory per channel?
3. 35 MHz repetitive bandwidth?
4. 16 non-volatile waveform memories?
5. On-screen text display and on-screen cursor measurement?
6. Digital sweep delay system?
7. Fast storage processing including waveform multiplication?
8. Digital averaging for lower noise?
9. Digital interpolation using sine or pulse algorithms?
10. Fully programmable front panel with 50 setting memories?
11. RS-232C compatible interface plus optional IEEE-488 interface?
12. Full remote control and bi-directional waveform transfer?
13. Output to a dot-matrix printer, digital or analogue plotter?
14. A free conventional oscilloscope to connect it to?

Surprisingly it's only number 14 but you probably have that already!

Digital Storage

The Thurlby DSA524 links to any standard oscilloscope (using only one cable) and converts it into a highly sophisticated digital storage scope with all the features listed above.

If you want to pay even less, the DSA511 has a few less features but costs only £395.



Thurlby

Thurlby Electronics Ltd., New Road/Burrel Road, St. Ives, Huntingdon Cambs PE17 4BG
Telex: 32475 Fax: (0480) 64832 **Tel: (0480) 63570**

ENTER 35 ON REPLY CARD

What shall we do about those batteries?

Nicad batteries used in prostheses can present a problem if over charged or discharged. This battery-discharge manager will help to avoid battery failure.

P.E.K. DONALDSON

The engineering design of the controller for the paraplegic bladder[1,2,3], initiated in this Unit and in commercial production since 1982, recently came up for review. Clinical experience suggested some minor extension of the range of stimulus parameters available, but no major revisions seemed called for, except perhaps in the arrangement of the batteries and battery management. The manufacturer had reported that, in equipments returned to him for service, the most common fault (0.01 incidences per equipment-year) was failure of one or more in the series string of five PP3-sized nickel-cadmium batteries used. Five PP3's were originally chosen because the equipment required a supply of about 45 volts, the batteries fitted snugly into the space available and, in emergency, discharged nicads could be replaced by alkaline or zinc-carbon PP3s, easily available from High Street shops.

The battery failures probably occurred both as a result of over-charging and of over-discharging. The charger supplied with the equipment worked at the 12-hour rate until the entire string reached an average of 1.46 volts per cell, at which point the current switched down to a trickle. The switching was accompanied by the lighting of an led, intended as a non-mandatory signal to the patient to discontinue the charge. If "charging" was nevertheless continued, cells were probably protected from overheating or bursting, but not from separator failure resulting from dendritic puncture[4].

On discharge, failures were probably initiated by weak-cell voltage-reversal[5]. There are seven cells in a PP3 nicad. A string of 35 equally good cells, discharging at the one-hour rate, will show about 45 volts at the beginning of discharge, and 38 at the end. There is no way of telling, monitoring the voltage across the whole string, whether an indicted voltage of 37, say, means a good set of batteries nearing the end of discharge, or one or two voltage-reversed weak cells in an otherwise good and well-charged string; in consequence, no discharge-monitoring arrangements were provided. We merely sought to impede the development of weak cells by urging users to charge sufficiently often; we recommend weekly.

A PROPOSED SOLUION

The discharge curve for a nickel cadmium cell has the form shown in Fig.1. Discharged over 10 hours, A will be about 1.4 volts and B 1.2 volts. Discharged over one hour, A and B will be respectively approximately 1.27 and 1.07 volts. In both case there will be a decline of some 200 mV during discharge.

Monitoring the progress of discharge of a mature battery requires that the number of cells be sufficiently few for it to be possible to detect the fall to zero volts of the weakest cell against the background of general small decline in voltage of the stronger cells. At the one-hour rate, exhaustion of the weakest cell will produce a fall in battery voltage of 1.27. This must be detected and discharge halted at once. But we have seen that, for a new battery of n cells, all equally good, there will be a fall in voltage on discharge of 0.2 n, so 0.2 n equals 1.27 and n lies between 6 and 7. A battery of up to six cells can be safely monitored by allowing the voltage to fall through 1.2 volts. A battery of seven cells can be safely monitored by allowing the voltage to fall 1.3 volts, at the theoretical cost of not using all the stored charge, or rather less safely by allowing the voltage to fall 1.4 volts, extracting all the useful charge from a pristine battery. As the number of cells increases beyond seven, discharge of the battery becomes increasingly haphazard.

There seems little doubt that the most reliable "battery" would comprise a single cell. The voltage cannot reverse, so discharge monitoring is unnecessary as regards "battery" reliability, though of course still helpful to the user. Furthermore, precise charging becomes easy; the charger would be arranged to run the cell down completely before delivering an accurately timed charge. Unfortunately there are severe dificulties in making 45 volts efficiently from the output of a single cell.

The compromise we chose is to drive a voltage-raising device from a seven-cell nickel-cadmium or, in emergency, six-cell zinc carbon battery. At around 9 volts, one can look for efficiencies of at least 85% in the voltage-raising, with safe discharge monitoring. If space should prove to permit it, we would provide also an audible end-of-discharge warning. Beside its obvious convenience, this has the merit that, if the warning has not yet sounded, a user should be deterred from endangering his batteries by charging them unnecessarily. If he ignores the warning and does not switch off and charge, then, at 7.5 volts, an automatic shutdown operates and no further appreciable drain on the battery is possible until at least some charge has been given.

The charger would deliver a timed charging current comprising direct current heavily modulated with alternating current[6].

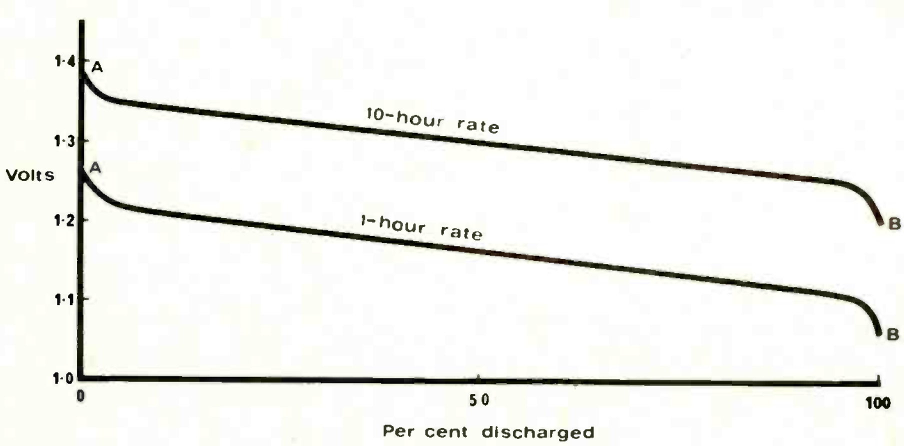


Fig.1. Form of the discharge curve for a nickel-cadmium cell.

Choice of cell size. We measured the time for the voltage to fall to 7.5, when feeding 40 ohms, for freshly-charged batteries having various cell sizes. The results, plotted as a function of the volume of the parallelepiped into which the battery will just fit, are shown in Fig.2. The discharge time goes up roughly as the square of the volume of the cell. We may attribute this to the larger cells having both more stored charge and a lower internal resistance; both factors are roughly equal in their contributions. Cylindrical cells last about 2.5 times longer than the button cells, in this application.

It follows that one should use a battery of seven of the largest cylindrical cells that one can accommodate in the space available.

CHOICE OF VOLTAGE-RAISING DEVICE

The efficiency of the Mosmarx voltage-multiplier, described in an earlier article[7], is quite high, nearly 90%. Unfortunately, the constancy of the multiplication factor is itself a source of inefficiency, because of the inconstancy of the battery voltage. Suppose a perfect sextupler, 100% efficient, is interposed between a seven-cell nickel-cadmium battery and the pulse amplifiers in the stimulator, which constitute the principal load on the multiplier. At the end of discharge, the battery voltage is 7.5, the sextupler output is 45 volts, the correct supply to the power amplifiers, and the arrangement is efficient. But at the beginning of discharge, when the battery voltage is 8.9, the sextupler output is 53.4 volts. Feedback round the pulse amplifiers[3] will ensure they draw the correct current, but the extra voltage will be wasted across the output transistors, making unnecessary heat. The efficiency of the voltage-raising is now only $(7.5/8.9)\times100 = 84\%$, while the average efficiency during the discharge will be about 92%. Since the efficiency of the Mosmarx multiplier is only 90%, the average overall efficiency of the voltage-raising process will be only 90% of 92%, or 83%.

The switching regulator ought to be a more promising voltage-raiser because its step-up ratio is self-adjusting; as the battery voltage declines, the regulator compensates by drawing an increased current. Any switching regulator with an efficiency exceeding 83% is therefore likely to be preferable to a voltage-multiplier for this application, and as we have seen from the previous article[8], the switching regulator of Perkins and Chaffey has an efficiency of 93%. It is therefore easily the device of choice.

THE BATTERY-DISCHARGE MANAGER

A possible circuit is shown in Fig. 3, in which the battery-discharge manager comprises essentially two c-mos amplifiers arranged as trigger circuits, one to control the audible warning and one to control shutdown. The former has moderate backlash, 0.5V referred to the supply rail, and typically is set to turn the warning sound on when the supply rail voltage falls to 8V, and to turn it off again when it recovers to 8.5V. The shutdown trigger has much more backlash, 3.5V referred to the supply rail, for the following reason. End of discharge in nickel cadmium battery is best thought of as an increase in internal resistance, rather than a decline in e.m.f. When the shutdown trigger removes the load from a newly-discharged battery, the battery voltage rises again and would trip the trigger back to "on" (output high) unless the backlash is so great that the voltage never rises far enough. By setting the trigger to go "off" at 7.5 on the supply rail, and "on" at 11, the latter is achieved.

The 4.7μF start-up capacitor enables the shutdown trigger to go to "on" when the equipment is first switched on, even though the battery voltage is less than 11V. For at the instant of switching on, this capacitor is discharged, ensuring the trigger output goes high. Only after it has charged does the rail voltage determine whether the trigger remains "on" or not.

The audible warning ceases either when the battery, relieved of 99% of its load by the shutdown, climbs above 8.5V again, or when the user switches off, whichever happens first.

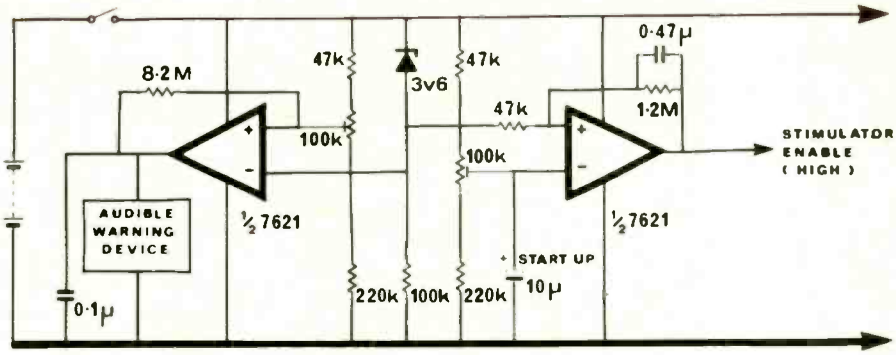


Fig.3. Possible design of battery-discharge manager. During discharge, with the stimulator operating, the battery current is typically 250 mA. At the end of discharge, with the stimulator disabled and the audible warning operating, the remanant battery current is 130 μA.

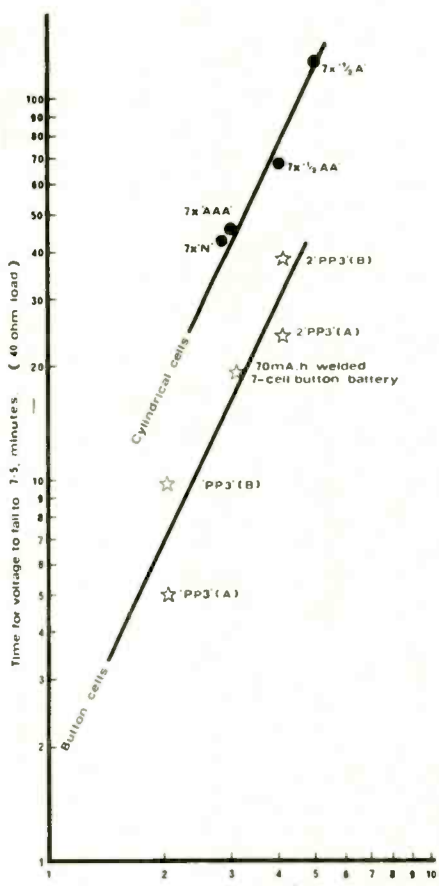


Fig.2. Time to end-of-discharge for various sizes of cell and two different forms of construction. 'PP3' (A) and 'PP3' (B) are by different manufacturers.

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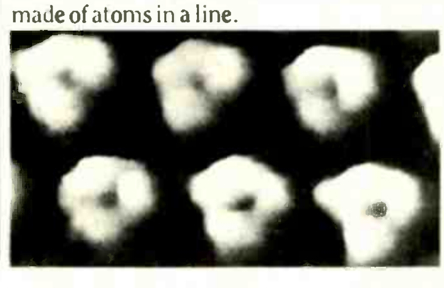
Small wonder

Researchers at the IBM Almaden Research Centre in San José, California, have produced the first pictures showing the arrangement of atoms in individual benzene molecules. The pictures are obtained by the Scanning Tunnelling Microscope described in Research Notes in the May 1988 issue, this one showing rows of ring-shaped clusters, each of which is a single benzene molecule.

The photograph confirms a vision the German chemist August Kekule saw in a dream in 1865. He and his contemporaries had worked to explain the arrangement of the benzene molecule, using the existing laws of chemistry. In the dream, Kekule saw a snake, twisting and biting its own tail; it occurred to him that the molecule could similarly be composed of atoms in a ring, unlike other organic molecules which are made of atoms in a line.



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2K29	250.00
2K48	140.00
2K56	250.00
2X2A	5.00
3A/107B	12.00
3A/108A	9.00
3A/109B	11.00
3A/110B	12.00
3A/141K	11.50
3A/146J	7.50
3A/147J	7.50
3A/167M	10.00
3A3A	3.95
3A4	1.10
3A5	4.50
3AT2	3.35
3B22	25.00
3B24	12.00
3B26	24.00
3B28	15.00
3BZ6	1.50
3C45	39.50
3CX3000A7	650.00
3CYS	1.50
3D21A	29.50
3E22	49.50
3E29	39.50

3EJ7	1.95
3H	0.40
3J.170E	1450.00
3L	0.40
3Q4	2.50
4-65A	75.00
4-250A	85.50
4-400C	87.50
4-1000A	425.00
4B32	35.00
4B/551B	125.00
4BQ7A	1.75
4BZ6	1.95
4C28	25.00
4C35	145.00
4XC125C EIMAC	150.00
4CX250B	45.00
4CX250BM	65.00
4CX250K EIMAC	115.00
4CX250R AMPEREX	125.00
4CX350A	100.00
4CX350F	95.00
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4CX1500B	475.00
4CX5000A	1000.00
4D21/4-125A	85.00
4D32	125.00
4GS7	2.25
4GV7	2.25
4J6A	2.95
4KT6	1.50
4X150A	35.00
4X500A	350.00
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5A152M	9.00
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5A170K	6.25
5A-180M	9.00
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5R4GB	5.50
5R4GY	4.95
5T4	5.95
5T8A	1.95
5U4G	4.50
5U4GB	4.50
5V4G	2.50
5X4	4.95
5Y3GT	1.95
5Z3	4.50
5Z4G	2.50
6/30L2	0.70
6A/203K	9.00
6A7	4.95
6A8	1.50
6AB7	4.50
6AC7WA	2.00
6AG5	2.50
6AG7	1.95
6AH6	3.50
6AJ4	3.50
6AJ7	2.00
6AK5	1.95
6AK6	2.50
6AL5	0.85
6AM4	3.25
6AM5	6.00
6AM6	1.95
6AN5	4.50
6AN8A	4.50
6AQ5	1.75
6AQ8	1.00
6AR5	5.95
6AS5	1.50
6AS6	2.50
6AS7G	4.50
6AT6	1.95
6AT8	1.75
6AU4GT	2.00
6AU5GT	4.50
6AU6	0.95
6AV6	1.95
6AW8A	3.50
6AX4GT	1.95
6AY3B	1.95
6AZ8	4.50
6B8G	1.50
6B10	1.95
6BA6	1.50
6BA7	4.50
6BA8A	3.50
6BC8	0.85
6BE6	1.50
6BG6G	3.00
6BH6	1.95
6BH8	1.50
6BJ6	1.50
6BK4	6.50
6BL6	85.00
6BL8	1.15
6BM6	115.00
6BN6	1.65
6BN8	3.95
6BQ5	0.95

6BQ7A	1.50
6BR7	4.95
6BS7	5.50
6BW6	5.35
6BW7	1.50
6BZ6	2.50
6BZ7	2.95
6C4	1.50
6C5	1.95
6C6	3.50
6C8G	1.50
6C9	4.95
6CA4	4.95
6CA7	3.50
6CB5	3.95
6CB6	1.95
6CD6GA	4.50
6CF6	1.95
6CG7	4.50
6CH6	6.95
6CL6	3.25
6CL8A	1.50
6CM7	2.95
6CS6	0.75
6CS7	0.95
6CW4	8.00
6CX8	2.50
6DC6	2.35
6DJ8	1.00
6DJ8 SPECIAL	3.50
6DK6	1.50
6DQ5	8.50
6DQ6B	2.50
6DT6A	1.50
6DW4B	3.50
6E5	3.95
6EA7	2.50
6EA8	2.50
6EB8	1.75
6EJ7	0.85
6EM5	2.50
6EM7	2.50
6EU8	1.75
6EV7	2.95
6EW6	1.50
6F1	2.00
6F5	5.50
6F7	5.50
6F13	3.00
6F14	1.00
6F17	2.75
6F23	0.60
6F24	1.25
6F25	1.25
6F28	1.25
6F32	1.25
6F33	12.50
6FH5	6.50
6FH8	5.95
6FL2	4.50
6FQ7	4.50
6GE5	3.95
6GH8A	2.50
6GJ7	0.85
6GK6	3.95
6GM6	2.65
6GS7	21.5
6GV8	0.95
6GW8	2.50
6GY5	4.95
6GY6	2.50
6H1	9.50
6H6GT	1.95
6HB7	1.95
6HF8	2.50
6HM5	2.50
6HQ5	3.50
6HS6	4.95
6HS8	2.95
6HZ6	3.50
6J4	2.15
6J5GT	2.50
6J6	2.00
6J7	4.15
6J7G	4.15
6JB6A	7.95
6JE6C	8.50
6JM6	7.50
6JU8A	2.50
6JS6C	7.50
6K7G	2.00
6K8G	3.00
6KD6	8.95
6KG6A	6.95
6L1	2.50
6L6GC	2.95
6L6GC USA	6.50
6L6GT	2.95
6L7	3.50
6L15	3.15
6L19	3.95
6LJ8	2.50
6LD20	1.15
6LF6	7.50
6LQ6	7.50
6P28	2.00
6Q7GT	1.50
6R7	3.15
6RHH8	10.00
6S4A	1.50
6SA7	1.35
6SC7	1.50
6SH7	1.35
6SJ7GT	1.20
6SK7	1.35
6SL7GT	1.95
6SN7GT	1.95
6SQ7GT	1.50
6SS7	1.95
6T8	1.50
6U6GT	3.50

6U7G	3.50
6U8A	1.50
6V6G	1.25
6V6GT	1.95
6W4GT	1.50
6Y6G	3.95
6X2N	1.00
6X4	1.50
6X5GT	1.00
6X5GTY	1.00
6X8A	2.25
7A6	4.50
7AU7	1.50
7B6	3.50
7B7	2.50
7D8	4.50
7J7	5.50
7K7	7.50
7L	1.50
7Q7	4.50
7Y4	2.50
8B8	2.50
8B10	2.50
8BQ5	1.95
8CW5	1.50
8EB8B	1.50
8FQ7	1.95
10D2	1.25
10DE7	2.50
10DX8	2.50
10EB8	1.95
10EW7	2.95
10F1	0.75
10GK6	1.95
10P14	2.50
11E3	55.00
11R3	5.50
12A6	3.95
12AD6	1.50
12AE6	5.50
12AH7GT	4.95
12AL5	1.00
12AT6	1.25
12AT7	1.15
12AT7WA	2.50
12AU6	1.50
12AU7	0.85
12AV6	1.95
12AV7	2.50
12AX4GTB	1.50
12AX7	0.95
12AX7WA	2.50
12AX7S	7.95
12AY7	3.95
12B4A	4.50
12BA6	2.50
12BE6	1.50
12BH7A	3.50
12BL6	1.75
12BR3	1.95
12BY7A	3.50
12C8	2.50
12CA5	1.95
12CX6	1.20
12DQ6B	3.50
12DW4A	3.50
12DZ6	3.95
12E1	19.50
12E14	38.00
12FX5	1.95
12GN7	3.95
12GH7	3.95
12J5GT	3.95
12J7GT	3.50
12JZ8	2.95
12KGT	1.50
12K8Y	1.95
12KU7	1.95
12S7GT	1.50
12SA7GT	1.95
12SG7	4.75
12SK7	1.95
12SJ7	1.95
12SN7GT	1.85
12SW7	3.50
12SY7	4.50
12X4	1.95
13D7	3.20
13DE7	2.50
13DR7	2.95
13E1	145.00
13EM7	3.50
14B6	4.50
14R7	3.50
15E	5.50
16AQ3	1.95
16GY5	2.95
16H	0.40
16L	0.40
17A8	3.50
17AX4GTA	1.95
17BE3	2.50
17DW4A	2.95
17EW8	0.95
17JZ8	4.50
18D3	6.00
18GB5	3.50
19AG5	3.50
19AU4GT	2.50
19BG6	3.50
19G3	19.50
19G6	9.00
19H4	35.00
19H5	33.50
20CV	9.50
20DT	0.70
20LF6	7.95
20L1	0.95
20P1	0.55
20P4	1.95
20P5	1.15
21JZ5	4.95

21KQ6	4.95
21LU8	3.75
24B1	39.50
24B9	39.50
25BQ6	1.75
25DQ6B	2.95
25L6GT	1.75
29C1	19.50
29KQ6	6.50
30C15	0.50
30C17	0.40
30C18	1.48
30FL2	1.35
30FL12	0.95
30FL13	1.10
30FL14	1.25
30L1	0.45
30L15	0.60
30L17	0.60
30P4MR	1.00
30P12	1.00
30P18	0.60
30P19	1.00
30P1	2.50
30PL13	0.60
30PL14	1.75
31JS6C	5.50
33A/158M	19.50
35A3	3.95
35A5	4.50
35C5	4.50
35L6GT	2.00
35Z3	1.95
35Z5GT	3.50
38HE7	5.95
40KD6	5.50
42	6.95
47	6.00
50A5	1.50
50B5	1.95
50C5	0.95
50CD6G	1.95
50EH5	1.50
50JY6	2.95
53KU	4.50
75B1	3.50
75C1	4.50
80	4.50
83	8.50
83A1	7.50
85A1	6.50
85A2	2.95
90AV	17.50
90C1	3.50
90CG	17.50
90CV	17.50
91AG	9.00
92AG	19.50
92AV	19.50
95A1	6.50
100E1	10.00
108C1	2.50
150B2	6.50
150C1K	9.00
150D2	2.50
150C4	2.50
185BT	1.50
211	25.00
230D	15.00
231D	15.00
250TH	150.00
307	5.00
328A	15.00
572B	65.00
705A	12.50
713A	25.00
723A/B	75.00
724A	275.00
725A	275.00
726A	75.00
801A	15.00
802	25.00
803	14.95
805	59.00
807	3.50
811	15.00
812A	35.00
813 Philips	35.00
813	27.50
829B	14.50
833A	95.00
845	59.50
866A	8.50
872A	20.00

873	60.00
954	1.00
955	1.00
1849	315.00
1927	25.00
2040	25.00
2050A	5.95
2050W	6.50
4212H	250.00
4471	35.00
4687A	9.50
5544	79.50
5559	55.00
5636	5.50
5642	9.50
5643	9.50
5651	2.50
5654	1.95
5670	3.25
5672	4.50
5675	28.00
5678	7.50
5687	4.50
5696	4.50
5702	3.50
5704	3.50
5718	6.15
5725	2.50
5726	2.50
5727	2.50
5749	2.50
5750	1.85
5751	2.95
5763	6.50
5814A	3.25
5823	9.50
5829WA	6.50
5840	3.50
5842	11.00
5847	10.95
5863	95.00
5879	9.50
5886	13.95
5894	39.50
5899	4.50
5963	1.75
5965	2.15
6057	3.75
6058	2.50
6060	2.25
6072	6.95
6080	8.50
6080WA	9.50
6132	10.50
6136	2.50
6146B	9.50
6146W	12.50
6155	72.00
6156	72.00
6157	2.50
6158	3.20
6189	4.50
6201	6.45
6350	3.50
6360	4.50
6386	14.50
6442	75.00
6463	7.50
6550	8.50
6550A GE	10.95
6550 RCA	15.00
6870	11.50
6883B	9.95
6973	7.95
7025	2.50
7025S	6.95
7027A	8.50
7119	9.00
7189	5.50
7199	7.50
7247	4.95
7475	5.00
7486	155.00
7527	85.00
7551	8.50
7581A	9.95
7586	15.00
7587	19.50
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7868	7.50
7895	17.50
8156	9.95
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FEEDBACK

Alan M. Turing

This is a feedback of the feedback on Turing in the April 1988 issue of *EWW*.

By a computable number we mean a number such that, given any accuracy except the exact value, we can compute this number in a finite number of steps to within this accuracy. In this sense there is no difference between integers, rational numbers or irrational numbers. An integer can be harder to compute than an irrational number.

To avoid arguments, to which the obvious reply is: "Well, just double the memory capacity of the computer and double the length of the tape", the Turing machine has an infinite memory capacity and uses an infinitely long tape.

There is nothing wrong with the mathematics of Alan M. Turing.

Lars Ödlund
Falun
Sweden

Real and Imaginary

In my November letter I mentioned some mathematical insights about vectors and complex numbers which were developed about the turn of the century. "Joules Watt's" response (February letters), raised some matters which actually illustrate my points.

First the amplitude and reference phase of a phasor constitute a 2-D vector. Phasors add vectorially, but they do not have vector products. The entities which transform the phasors representing the current or voltage at one point in, say, a ladder network into those representing the current and/or voltage at another are 2-D vector operators, which rotate and re-scale the original vectors. They include transfer impedance and admittance operators, and also operators which relate currents to currents, and voltages to voltages (See L.E. Weaver, *WW* Sept. 1982, pp. 71). Vector operators *can* be multiplied together to give other vector operators, and provided they combine to transform between sensible pairs of phasors the product will have a valid physical interpretation. Thus products of transfer admittance and impedance operators relate currents to currents or voltages to voltages, depending on operator order.

The 2-D vectors characterising phasors on the one hand, and the 2-D vector operators characterising transfer (and ordinary) impedances, etc. on the other, can both be represented mathematically by ordered number pairs, but physically they are quite distinct. Visualising complex numbers in terms of an Argand diagram helps in understanding how they can characterise phasors, but gives no help whatever in understanding how they can characterise vector operators. In three dimensions vectors and vector operators require obviously different mathematical characterisations. What we have above is a 2-D analogue of the fact that in three dimensions triads of numbers can characterise both 3-D vectors and 3-D vector products, which again are physically distinct.

For reasons best known to himself Joules Watt accuses me of wanting to throw out matrices. When multiplied together matrices give products dependent on the order of the factors. Suppose we consider two third order matrices A and B, with non-zero determinants, which have the product C, i.e. C=A×B. Since C, like A and B, is a third order matrix with a non-zero determinant, A is the 'post-ratio' of C to B, i.e. $C \times B^{-1}$, and B is the 'pre-ratio' of C to A, i.e. $A^{-1} \times C$, which is usually different from the 'post-ratio' of C to A, $C \times A^{-1}$. The reason why one can't form such ratios of three-dimensional vectors is not because vector products don't commute, but because the pseudo-vector product of two vectors simply isn't the same sort of animal as the vectors from which it is formed.

C.F. Coleman
Grove
Oxfordshire

Atomic fission

I was surprised to find from H. Aspden's April letter that he doesn't know what the Mössbauer effect is. It refers to the phenomenon that in solids resonant absorption of nuclear gammar radiation can sometimes occur with *no recoil shift*. In Mössbauer measurements Doppler tuning is used to compensate, not for energy losses arising from nuclear recoil, but for minute changes in the energy of the absorbed or emitted radiation arising from the different environments of the emitting and absorbing atoms within different solids. For this purpose the velocities available from loudspeaker cones are adequate. Resonance measurements have been made on a few of the many nuclei which show now significant Mössbauer effect, but these measurements required the use of something like a high speed rotor to compensate for the nuclear recoil. Unfortunately the Doppler techniques are effective only over very small solid angles.

He goes on to talk about '...two species of *atom* that are driven into instability...'. However nuclei which are isotopes of the same elements are just as varied in their binding energies and energy level structures as are nuclei containing the same number of neutrons, but different numbers of protons, and have as strong a bias in favour of having even numbers of protons and neutrons. Anyone familiar with nuclear structure will be aware that the protons and neutrons in nuclei show independent shell closure phenomena analogous to those shown by atomic electrons. However the numbers associated with the closure of 'shells' of protons and of neutrons bear no simple relationship to those associated with the closure of the electron shells of atoms, and it is the latter numbers which determine the chemical classification of the elements embodied in Mendeléeff's Table. A particular nucleus is likely to be stable if it is more tightly bound than the nuclei which are related to it by exchanging one patron for a neutron, or the converse. Even if the ether oscillations Dr Aspden postulates were shown to exist, to affect proton binding, and not to affect neutron binding, I doubt whether they would produce more than a tiny fraction of the effects associated with the nuclear shell structure.

C.F. Coleman
Grove
Oxfordshire.

Rupert and his PALS

On your Comment column in the August issue, may I respectfully suggest that Rupert Murdoch has it right and that yourself and BSB are out of touch with viewers' needs.

Take radio, for example: after 25 years of f.m. broadcasting, the BBC is still trying to persuade people to give up medium wave and go for f.m.

A walk down any shopping precinct on a Saturday afternoon will show the quality of colour pictures that the layman is happy to accept. If anyone in BSB thinks that the public is going to scrap its terrestrial PAL receivers *en masse* for the dubious advantage of no colour subcarrier patterning, they are living in cloud-cuckoo land! The most likely outcome would be a black box to convert from (X)MAC [where X=C,D,D2,E,S, etc., etc.] to PAL to feed their existing receivers – i.e. back to square one, negating the so-called MAC advantage and at the cost of two standards converters and a 12GHz LNB.

There is but one reason for using MAC, and that is its ability to be scrambled with a very high level of security.

To existing satellite viewers who are already set up on 11GHz like myself and many others, it will be BSB that will be the odd man out, not Rupert Murdoch and SKY.

Finally, the wide use of video libraries suggests that the public is quite happy with the lower-resolution picture that is gener-

FEEDBACK

ally attainable on the average v.c.r. Apparently, PAL as broadcast is better than they seem to require: how, therefore, can anyone justify the extra cost of MAC and/or h.d.tv?
D.S. Jones
Pontardulais
Swansea

Human word processing

John Wilson's Research Notes report (June, 1988) on the work at St Louis on brain patterns involved in human word-processing could explain something I had noticed a number of times when I have been reading a bedtime story to my three year old son, Mark. There have been occasions, particularly when I am tired, when I have found that after beginning the story reading aloud with 'understanding' I have been amazed to find myself later thinking about something else quite different even though I was continuing to read the story aloud. I wonder if other parents have had a similar experience.

The phenomenon fits in very well with the following paragraph taken from page 623 of your June issue.

"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."

Perhaps if other parents had reported this earlier, it would have taken so long to cast doubts on the nineteenth century model of the brain's activity.
David F. Haslam,
Stockport
Cheshire

Moving-coil head amplifier

I found Mr Nalty's letter in the August issue a disappointment, though admittedly not an unexpected one. In my letter in the June issue I directly challenged him to be more specific in his speculations about insidious audio impairment, so that they could be tested for existence. Regrettably he appears to be unable to do so.

I therefore remain unconvinced that dielectric absorption has any relevance to a competently-designed audio circuit. If I may repeat myself, can any Subjectivist provide a hypothesis as to how an audio signal can be modified by this effect? It is I think not unreasonable to ask for a diagram of how the waveform is modified, so I shall know what to look for.

As for why Mr Nalty's customers profess themselves happy with his £10 resistors, I suggest the answer lies in psychology rather than technology. Few people are prepared to admit to themselves that they have been made fools of, if there is any way of avoiding the issue. Psychologists call this "avoidance of cognitive dissonance" and while the jargon may be recent the result is as old as humanity.

I regret that I find Mr Nalty's list of references unconvincing Repetition does not constitute verification, and the fact that he has been saying the same thing for some time does not make it true. For example, reference 4 (August) confuses series with shunt feedback, and reference 7 contains the statement "Harmonic distortion measurements have no direct relevance at all to sound quality" from which I can only assume that he has never used a telephone. Similarly, for Mr Nalty to claim that his ears are "the best instrumentation of all" strikes me as downright silly, as I contemplate my Audio Precision, which effortlessly resolves down to 0.0005% under computer control. I should be happy to try the same measurements with Mr Nalty's ears, if he is prepared to submit to the surgical procedures involved.

Mr Nalty then administers the *coup de grace* to rationality by insisting that scientific measurements "are only valid provided they reinforce the judgements made with our own ears". Or alternatively, only valid if they fit pet theories and hidebound preconceptions.

To summarise, the basic problems for Subjectives remain much as they have done. There is a chronic lack of hypotheses suitable for experimental testing. By now any impartial observer must have concluded that this is because to put forward a mechanism is simply to invite embarrassment when it turns out not to exist. There is no help whatsoever from the huge body of knowledge that is psychoacoustics; experiments on aural perception, carried out all over the world, and endlessly replicated and confirmed, show beyond doubt that the human ear functions strictly within the known laws of science. There are too many internal contradictions, e.g. esoteric speaker cables that vary wildly in their construction – just about any configuration that conducts electricity has its devotees. This alone strongly suggests that no real physical effect is involved. Subtraction tests prove beyond cavil that the imperfections of a competent amplifier are inaudible when presented alone. They are clearly doubly inaudible when masked by the main signal. And finally, no help at all from the likes of Peter Belt.
Douglas Self
Forest Gate
London E15

The Catt Anomaly

I see you have provided your readers with some more thought provoking entertainment from Ivor Catt. His Anomaly appears yet again in a contribution to the letters columns (August, 1988 issue). Amongst other things the Anomalous Catt says "since we are discussing a transverse electromagnetic wave, all electric flux is in the plane normal to the wires". This is rubbish. Because there is a potential difference between points on the wires before and after the step wavefront there must be a potential gradient and a component of electric field parallel to the wires, as well as normal to them. It does not take a great deal of genius to appreciate that it is this parallel component that accelerates the surface electronics to the net drift velocity they have once the wavefront has passed.

Perhaps Mr Catt might address another aspect of his anomaly. Let us assume for simplicity's sake that before a wavefront passes there is no potential difference between the wires and no current in either, and that afterwards there is a potential difference between the wires and that they then carry equal and opposite currents. Considering one conductor only, we have a situation in which current is flowing into one end of *any* section of wire touching the wavefront, but no current yet flowing out the other end. The result must be a change in the total charge on that section of wire. Since Catt insists that this current cannot be the source of the required extra charge on the conductor surface at the wavefront, we now have another puzzle – where is this current going? We now have not one but two mysteries: (a) charge appearing from nowhere, and (b) charge disappearing to nowhere. This is all at the same time and in as small a section of conductor as we care to examine in the region of the wavefront. Not only that, but the charges just happen to be equal. Very anomalous indeed!
Alan Robinson
Bounds Green
London N11

Patents

The article in your March 1988 issue, entitled "Variations on the Theme of Patents," by R.J. Redding, purports to describe the outcome of patent litigation in the United States involving a "small company" in Colorado that evolved a new flowmeter based on Coriolis forces. While the name of the company is not stated, those who know the story of Coriolis mass flow meters will recognize it as Micro Motion, Inc. of Boulder, Colorado. The article is incorrect, unfortunately, in asserting that "the patents were not upheld" in the United States patent litigation it describes.

FEEDBACK

Actually, the defendant stipulated that the patent claims in suit were valid for purposes of the suit, so that the only issue tried before the jury was the question of whether they were infringed. While the jury verdict *was* adverse to Micro Motion, the court set it aside because of prejudicial irregularities in the trial and has ordered a new trial. The new trial has not yet been scheduled, but we expect it will ensue within this year.

Dennis G. Perkins
President
Micro Motion, Inc.
Boulder
Colorado
USA

A.m. stereo

Re your discussion of a.m. stereo in your latest edition, (page 415) "A.m. stereo or hi-fi?", you make a statement that "However, this system (Kahn/Hazeltine) did not show up well in the various field trials." Unfortunately, this is incorrect.

The field trials that were conducted in the United States were of two different types. On-the-air tests were conducted by four of the five a.m. stereo system competitors *under the control of these proponents* and in the case of the fifth system, the Kahn/Hazeltine system, on-the-air tests were *under the complete control of a.m. broadcasters*. Indeed, of the ten stations that conducted field tests on our system, nine were highly positive and a tenth station, which turned out to be controlled by an engineer who was closely associated with the Motorola engineers, gave us mixed marks. I believe that you will agree that 9 out of 10 highly favourable reports is a pretty good score.

But something strange happened to these reports. The results of the on-the-air tests of the Kahn/Hazeltine system were sent to the FCC, not by Kahn Communications, but by the individual stations. Somehow they did not get into the proper FCC files and, as a result, were *given no weight* by the FCC. Indeed, if you examine the FCC's final Report and Order you will find that they give our system no credit for test results covering a number of facets of a.m. stereo performance. Neither Kahn nor Hazeltine submitted test data because the information had been submitted by the stations that actually did the testing. Those independent broadcasters included some of the most prestigious broadcast groups in the country, such as ABC, RKO General, etc.

The facts are that the test, like actual on-the-air experiences throughout the US, prove that the independent-sideband (i.s.b.) Kahn/Hazeltine system provides *vastly superior performance* over the Motorola system. The i.s.b. system also has a well confined spectrum and does not degrade mono reception.

We expect that in the near future stations will be operating with the Kahn/Hazeltine system in Europe. Accordingly, your readers will be able to make their own judgements regarding the advantages of independent-sideband operation. As you well know, Europeans have already made plans to convert medium-wave a.m. broadcasting from double-sideband to single-sideband. Since our form of stereo is a step toward that goal, its implementation should make the transition more graceful and more expeditious. Indeed, our i.s.b. stereo system is not only compatible with conventional a.m. receivers, but it can also be received with conventional independent-sideband, reduced-carrier type receivers. Such dual compatibility is needed if the public is to be convinced to convert their receivers to the optimum form of amplitude modulation, i.e., s.s.b. for monophonic reception and independent sideband for stereo reception.

Possibly the most convincing argument I can offer concerning the question of which a.m. stereo system is superior is that all Motorola a.m. stereo-decoder integrated circuits incorporate circuitry which causes the receiver to revert to mono operation under even moderately disturbed receiving conditions. Conversely, the optimum a.m. stereo radio for the Kahn/Hazeltine system remains in its stereo mode *at all times* and under all conditions. Indeed, receivers for the Kahn/Hazeltine system offer improved performance during reception of weak mono signals. The reason for this improvement is that in i.s.b. stereo receivers adjacent-channel interference is caused to appear "off stage" to the far left or right, providing a signal-to-interference improvement via the "cocktail party" effect. Furthermore, if the stereo receiver is equipped with a "balance control", you can turn the control fully in one direction and effectively "turn off" the adjacent channel. Thus, equipping listeners with independent-sideband receivers should certainly be an important by-product of implementing the Kahn/Hazeltine a.m. stereo system in Europe.

Since the basic strength of a.m. broadcasting, vis-a-vis f.m. is its coverage, any stereo system that improves coverage, rather then degrades it, certainly should be welcomed by forward thinking broadcasters.

Leonard R. Kahn,
President,
Kahn Communications Inc.,
New York, USA.

Perpetuum mobile

It is commonly thought that you can have perpetual motion if energy can be conserved in a system. That is algebra. What of physical mechanisms?

If we accept the need for an aether theory, perpetual motion seemingly occurs in the ground state of atoms (and superconducting crystal lattices) by the eternal exchange of virtual photons between the orbiting electron and the aether.

But it all depends upon the mechanisms for gravity: it is my conjecture that gravity is related to field density of virtual photons diffusing from dense matter (and speed c because of zero rest mass). A quantitative calculation would involve consideration of 'tunnelling' – escape of a few virtual photons even in the ground state of matter, explaining the relative intensities of electromagnetism and gravity, always attractive, and such a weaker flux.

So you cannot have the ideal of absolute perpetual motion because of the need for gravity-flux.

P.J. Ratcliffe,
Stevenage,
Hertfordshire.

Invention

I am very pleased to have been given the opportunity to reply to the letters which were published in response to my article in the *EWW* of March 1988, and am very pleased also with the way these letters serve to complement my own words so well.

Regarding the letter from H.W.Shipton, published in the July edition, this is very valuable in showing the depressing fact that the written word is very limited when it is intended to pass on information in an accurate way and, with the greatest effort made to avoid any sort of ambiguity, to forestall any misunderstanding in the mind of the reader.

As far as the writer of letter is concerned, my attempt seems to have failed since, apparently by a process of selective comprehension, he managed to miss several times the point I was making.

In case there were other readers with the same difficulties, I therefore would like to re-emphasize these major points.

Regarding inertial navigation, I had tried to point out the loss to the RAF and also allied forces in that, as a result of closing the door on my offer of contribution to the solution of navigation problems, the value of my design effort *was not even tested*.

As a result, not only was the possibility of success removed, but so also were the spin-offs which would undoubtedly have resulted from such work not only by myself but also by any likely collaborators in the effort, with a loss to the war effort and also the future UK economy.

Regarding the last paragraph of the letter, I fully agree that performing such activities as

FEEDBACK

mentioned can be harmless fun; but in the relevant paragraph of my article I had tried to compare the scale of values shown by reards in the successful R&D in the medical field, and the vastly higher reward for the undoubted pleasure of achieving a high standard in some sport, i.e. a scale of values and priorities which, in my opinion, is damaging to the R&D effort, the status of the inventor, and thus to the economy and success of British industry.

Most of my article was devoted to stressing the fact that, however great the R&D component in a patented invention is, it is mostly ignored and the invention is nearly always represented as nothing more than an idea, followed by an automatic expression of doubt whether it would have worked or would have been capable of execution at the time of conception.

This, I found, was also always accompanied by the premise that my abilities to overcome any such 'predicted' difficulties were just as limited as were those of other people who found the problems insurmountable; suggesting that, if it could not be done by 'them,' then it was impossible, and any assertion on my part that 'I' could have, or indeed already *HAD* done it, was treated by some as the boasting of a crank, and systematically ignored.

Eventually, after putting up with this for more than fifty years, I finally lost my patience, and decided, in the full glare of publicity, to put to the test what I could do in comparison with the rest of the world, utilizing the concept of the 'U-Plane' for this purpose, and for once pulled out all the stops. This test is now on the boil, and, whatever the result, I sleep soundly. There are two possibilities now, either I am wrong – which I can live with – or I am right, in which case the effect upon the navies of the world, and NATO, will be a fatal degree of obsolescence, and a bill amounting to billions of dollars.

So, any bets on the outcome?

Capt. Heinz Lipschutz,
Rhoose,
Glamorgan.

Relativity on a soapbox

I was fascinated by the letter of Taylor and Yau in the July issue of *EWW* (pp. 682-683). Introducing themselves as 'students of physics' they imply that those who attack Einstein's relativity are 'soapbox' preachers who offer nothing to show why all the prior data in fact support one's claim in preference to the theory under attack.

I was a student of physics in 1946, in my first year at Manchester University. In that year I purchased a book, printed in that same year, entitled Modern Physics. It was written by a well-known Professor of physics, H.A. Wilson, a former Fellow of Trinity College, Cambridge. It gave me my first real introduction to Einstein's theory. The preface declared that the book presented a concise but intelligible account of no more than a serious student of physics ought to be familiar with when he begins to specialize on some particular branch. It did not preach the 'flat earth' theory mentioned by Taylor and Yau and was certainly not soapbox preaching. Indeed, it included a concise mathematical treatment of Einstein's derivation of the equation for the perihelion motion of planet Mercury, showing that in Professor Wilson's opinion a serious physics student, even one not specializing in that topic, should not only have heard of that aspect of General Relativity but understand it in some depth.

What I discovered from the first chapter of the book was that $E = Mc^2$ and the formula for mass increase with speed were fully explicable in terms of classical electron theory. Messrs Taylor and Yau quoted Bucherer's 1909 experiment on the velocity dependence of electron mass, no doubt having in mind that Einstein's work on this dated from 1905. However, in 1946 this textbook I was learning from, besides giving due credit to Bucherer, did mention the earlier 19th century experiments of Kaufmann, which were the basis of J.J. Thomson's pre-1904 explanations of the tendency of electron mass towards infinity as lightspeed was approached.

It was by being taught that Einstein's theory was not the only way of interpreting such phenomena that I, and no doubt Dr Essen, could be alert to weakness in the Einstein position. It is a great pity that the fruits of research endeavour probing these weaknesses can be now be regarded as 'soapbox' preaching when heard by students who should, in view of their youth, be prepared to encounter a future that could well reveal something basically new in their chosen field, namely physics.

This letter would become rather lengthy if I were to try to satisfy the challenge posed by Taylor and Yau of explaining why I believe that all the relativists are wrong. I end, therefore, by making two comments. Firstly, a conference is to be held at Imperial College in London from 16th-17th September. The subject is 'Physical Interpretations of Relativity Theory'. The reader may well wonder what Einstein has done to us if 83 years after presenting his theory we have to meet to discuss how it is to be interpreted in a physical sense. If we do not know that then we should not be teaching the subject to undergraduates. We do not have meetings to discuss the physical significance of Newton's laws, because they are expressed in physically meaningful terms. Secondly, speaking for my own contribution, I really believe that my book Physics Unified published in 1980 gave the scientific alternative to Einstein's theory on all counts. In the light of what Messrs Taylor and Yau say in their *EWW* letter, I am wondering if I would have done better in getting my opinions heard by a worthy audience had I used the soapbox they mention. As it is, at a meeting I attended in Canada a few days before writing this, it was gratifying to hear the praise extended to *EWW* for encouraging contentious debate on relativity and on the taboo subject of ether.

As a final aside and with the Coleman letter on p.681 of the July issue of *EWW* in mind, I should like to give readers a reference to a refereed paper disclosing the full analysis of the ether action in rendering the elements promethium and technetium unstable, thereby accounting for their absence from the Earth's crust. This reference to my paper is *Hadronic Journal*, vol. 10, pp. 167-172 (1987).

H. Aspden,
Department of Electrical Engineering,
University of Southampton,
Southampton.

Geography again!

Thank you for publishing my note "Inventions" in your July issue.

For your files, please note that St Louis is in the State of Missouri, not Montana. It was my error, as not even in America does anyone understand the US Postal Service's two-letter abbreviations.

Harold W. Shipton,
School of Engineering and Applied Science,
Washington University in St Louis,
Missouri.

Readers' letters for publication are always very welcome, and it is helpful if they can be kept as short as possible to enable us to print a varied selection. Please do not feel inhibited about starting new hares for correspondents to chase – there is no need to confine your letter to matters already mentioned in the journal – *Ed*.

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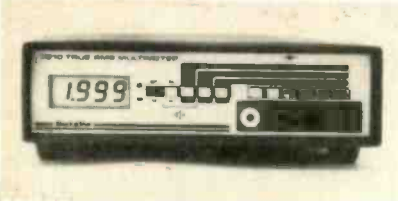

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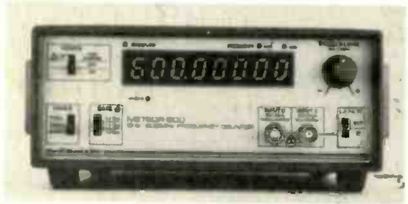

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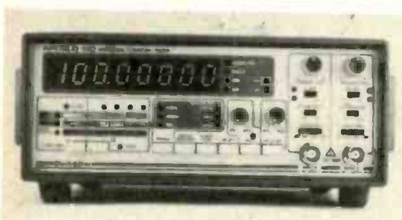

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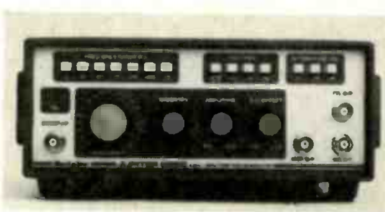

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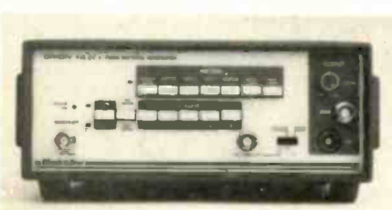

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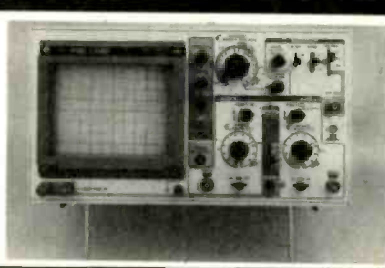

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A.J.P. WILLIAMS

About 20 years ago I designed a remote-controlled oscillator based on the Wien-bridge with resistors switched by reed relays. The aim now was to update the design by using analogue switches and investigate any alternatives that might prove useful.

For a remote-controlled oscillator it is convenient to switch the main resistors in the frequency selective CR network. Thus it is desirable to have a small amount of variable resistance for fine frequency adjustment.

In Fig.1, R_1 gives a relatively large frequency shift when R is small and a relatively small frequency shift when R is large. Adjustment of R_1 also alters the gain requirement for the maintaining amplifier so that the signal amplitude varies when R_1 is rotated. In Fig.2, R_2 gives a relatively small frequency shift when R is small and a relatively large frequency shift when R is large. As before, the amplitude will vary as R_2 is rotated.

These effects may be minimized by combining the arrangements of Fig.1 and Fig.2 in both arms of the network and using a four-gang potentiometer. The result is still not ideal and is hardly suitable for remote operation where, ideally only one component is varied for fine frequency adjustment.

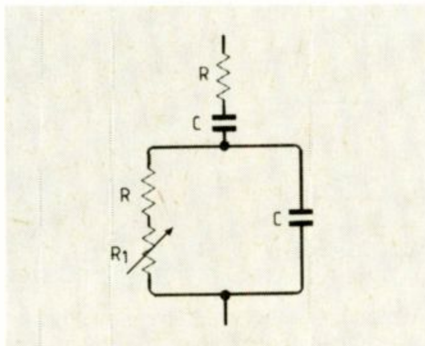


Fig.1. The variable resistor gives a large shift in frequency when R is small and vice versa.

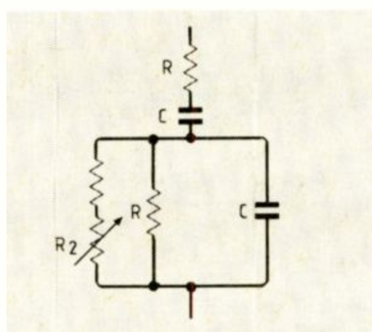


Fig.2. In this arrangement, R_1 gives a small frequency shift when R is small.

ANOTHER APPROACH

A well known network which gives a phase shift without amplitude change is shown in Fig.3, where

$$V_o=(V_1-V_2)=V_{in}\underline{/180^\circ-2\tan\omega CR} \quad (1)$$

When $\omega = 1/CR$, i.e. $f = 1/2\pi CR$,

then $V_o=V_{in}\underline{/90^\circ}$ (2)

This looked promising, since two stages would give 180° phase shift. An inverting stage would then give the overall 0° phase shift required for oscillation. The problem in this case is that we now have four variable components if the frequency is to be varied and yet be determined by $f=1/2\pi CR$.

From Fig.3 it can be seen that V_1 and V_2 are present on both arms of the network: therefore only one arm is needed if op-amps are used to obtain (V_1-V_2) as shown in Fig.4.

The op-amp (Fig.4) can be thought of as an inverting amplifier with common input and output at point B – i.e. input is V_2, output is $-V_2$, and so relative to earth the output is V_1-V_2.

Alternatively, consider the amplifier as non-inverting, with common input and output at point A. Input is $-V_2$ and output relative to point A is $-2V_2$. The resulting

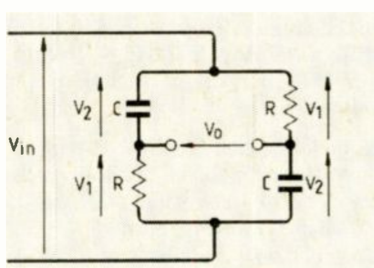


Fig.3. Circuit arrangement to give phase shift without amplitude change.

output relative to earth is $V_1+V_2-2V_2$ or $V_o=V_1-V_2$ as before. I prefer the second method since it emphasises the fact that, as far as phase shift inside the amplifier is concerned, the amplifier has a voltage gain of 2; i.e. only half the output is returned as negative feedback.

Possible configurations using the basic phase shifter of Fig.4 are shown in Fig.5-Fig.8. In each case amplitude stabilization has been omitted.

From equation (1),

$$V_2=V_1\underline{/180^\circ-2\tan^{-1}\omega CR}$$

for the first stage of Fig.5. At frequencies for which there is negligible phase shift in the amplifiers, when $f=1/2\pi CR$, $V_2=V_1\angle 90^\circ$ so $V_3=V_1\underline{/180^\circ}$. Thus the inverting amplifier makes $V_4=V_1\underline{/0^\circ}$, the necessary condition for oscillation. An advantage over the Wien-bridge is that both frequency-adjusting resistors are connected to the common line.

In the oscillator shown in Fig.6, the first two stages give a 90° *lag*, which results in

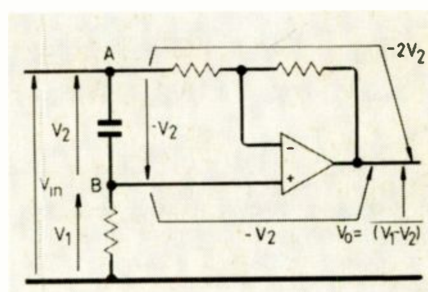


Fig.4. Op-amp version of Fig.3 circuit.

both frequency-adjusting capacitors being connected to the common line; this is convenient for a twin-ganged capacitor. The circuit configuration shown in Fig.7 removes the inverting stage, because the first stage gives 90° lag and the second stage gives 90° lead when $f=1/2\pi CR$. Unfortunately, in this case the d.c. output is in the wrong

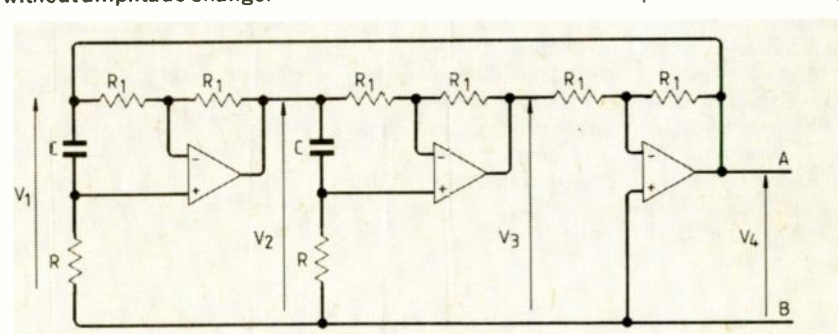


Fig.5 Possible circuit using the arrangement of Fig.4.

Fig.6.

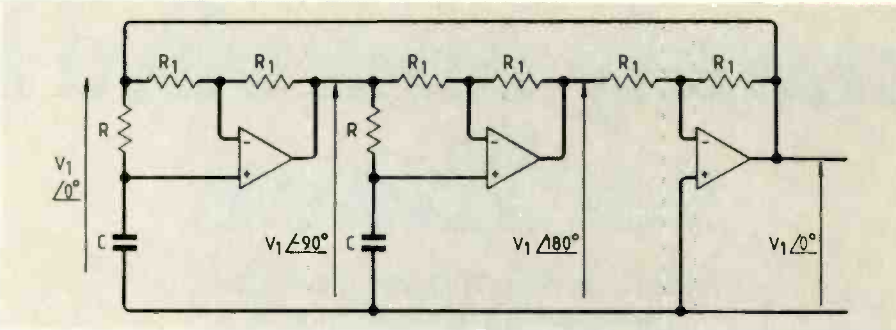


Fig.7.

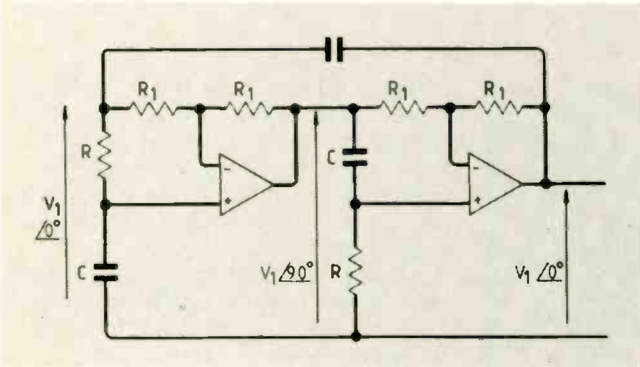
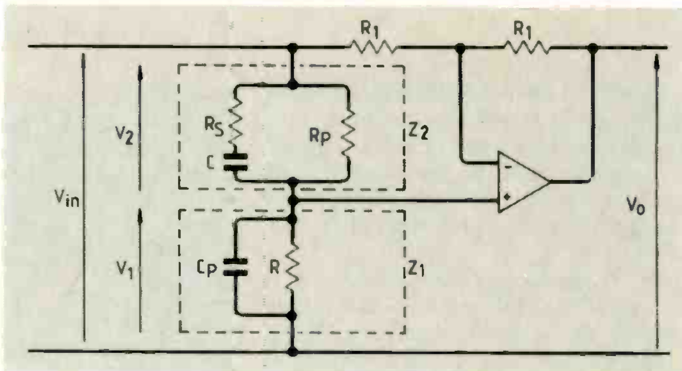


Fig.8.



sense for direct coupling back in the input.

EFFECT OF IMPERFECTIONS

In Fig.8, R_s represents the series resistance of any device that switches values of the main capacitor C to give different frequency ranges. R_p is the effective input resistance of the amplifier and C_p is any parallel capacitance across R.

Consider first the effects of R_s only.

$$V_o=V_{in}\sqrt{\frac{1+[\omega C(R-R_s)]^2}{1+[\omega C(R+R_s)]^2}}\angle 180°-\tan^{-1}\omega C(R-R_s)-\tan^{-1}\omega C(R+R_s) \qquad (3)$$

Let R_s be 10% of R, i.e. $R_s=0.1R$; then

$$V_o=V_{in}\sqrt{\frac{1+[0.9\omega CR]^2}{1+[1.1\omega CR]^2}}\angle 180°-\tan^{-1}0.9\omega CR-\tan^{-1}1.1\omega CR \qquad (4)$$

At frequencies where there is negligible phase shift within the amplifier, the conditions for oscillation will occur when the angle of equation (4) is 90°; i.e.

$180°-\tan^{-1}0.9\omega CR-\tan^{-1}1.1\omega CR = 90°$

or $\tan^{-1}0.9\omega CR+\tan^{-1}1.1\omega CR = 90°$

This equation will be satisfied when $\omega CR = 1.005$, i.e.

$$\omega = 1.005/CR \qquad (5)$$

Putting the value of ω from equation (5) into the amplitude portion of equation (4) gives $V_o = 0.905\,V_{in}$.

Conclusion: when R_s is 10% of R, the frequency increases by only 0.5% but the amplitude reduces by 10% compared with the conditions when $R_s=0$. Equation (3) also shows that the reduction in amplitude is maximum at the h.f. end of each range when R_s/R is maximum. At the l.f. end of each range when R_s/R is minimum the amplitude approaches the conditions of $R_s=0$.

Consider now the effects of R_p alone.

In this case,

$$V_o=V_{in}\sqrt{\frac{(R_p-R)^2+(\omega CRR_p)^2}{(R_p+R)^2+(\omega CRR_p)^2}}\angle 180°-\tan^{-1}\frac{\omega CRR_p}{(R_p-R)}-\tan^{-1}\frac{\omega CRR_p}{(R_p+R)} \qquad (5)$$

At frequencies where there is negligible phase shift in the amplifier the conditions for oscillation will occur when the angle of equation 5 is 90°, i.e.

$$90°=180-\tan^{-1}\frac{\omega CRR_p}{(R_p-R)}-\tan^{-1}\frac{\omega CRR_p}{(R_p+R)}$$

$$\text{or } \tan^{-1}\frac{\omega CRR_p}{(R_p-R)}+\tan^{-1}\frac{\omega CRR_p}{(R_p+R)}=90° \qquad (6)$$

Let $R_p=10R$; then

$\tan^{-1}10\omega CR/9 + \tan^{-1}10\omega CR/11 = 90°$ (6)

Equation (6) is satisfied when $\omega = 0.995/CR$. Putting $\omega=0.995/CR$ and $R_p = 10R$ into the magnitude portion of equation 5 gives $V_o=0.905\,V_{in}$.

Conclusion: when $R_p=10R$ the frequency reduces by only 0.5% and the amplitude reduces by 10% compared with the conditions when R_p is open-circuit.

Consider now the effects of C_p alone. In this case,

$$V_o=V_{in}\sqrt{\frac{1+[\omega R(C-C_p)]^2}{1+[\omega R(C+C_p)]^2}}\angle 180°-\tan^{-1}\omega R(C-C_p)-\tan^{-1}\omega R(C+C_p) \qquad (7)$$

Let C_p be 10% of C, i.e. $C_p=0.1C$; then

$$V_o=V_{in}\sqrt{\frac{1+[0.9\omega CR]^2}{1+[1.1\omega CR]^2}}\angle 180°-\tan^{-1}0.9\omega CR-\tan^{-1}1.1\omega CR \qquad (8)$$

Note that equation (8) is exactly the same as equation 4.

Conclusion: when C_p is 10% of C the frequency increases by only 0.5% and the amplitude reduces by 10% compared with the conditions when $C_p=0$.

Overall conclusions: from the point of view of frequency, the circuit is insensitive to resistance in the capacitive arm and insensitive to capacitance in the resistive arm. The main consideration in this case is the amount of amplitude variation that can be tolerated.

METHODS OF FREQUENCY CONTROL

For a conventional oscillator the choice is usually between a dual-ganged variable resistor (or switched resistors) with switched capacitors for changing range, or a dual-ganged capacitor with switched resistors for changing range. For a remote-controlled oscillator a switched resistor system is more convenient, with switched capacitors for changing range.

Switched resistors. C-mos analogue switches have a significant series resistance, in the order of 30 ohms. The value of the resistor being switched can be reduced by the nominal value of the analogue switch resistance. The lowest value of resistor being switched should be high compared with the analogue switch resistance so that any variations of switch resistance have a negligible effect. This is helped by using a 1-2-4-4 weighting combination as shown in Fig.9.

The oscillation frequency is given by $f=1/2\pi CR_t$ where R_t is the total value of the resistor network shown in Fig.9. The oscillation frequency is given by

$$\frac{1}{R_f}=\frac{1}{R/10}+\frac{1}{R/N}=\frac{1}{R}(10+N)$$

where N is the sum of the resistor weightings.

$$\text{Thus } f=\frac{10+N}{2\pi CR}=\frac{1+N/10}{2\pi CR/10}=\frac{1+N/10}{2\pi C\,Rf} \qquad (9)$$

This combination enables stepped frequencies of 10-11-12-...98-99-100...129-130-131 to be selected. Thus frequencies can be selected with a worst resolution of 10% at the l.f. end and a resolution of about 1% at the h.f. end.

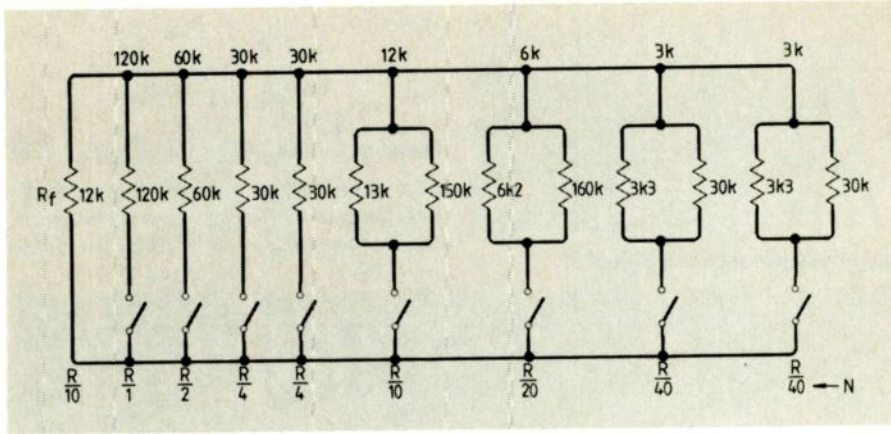


Fig.9. 1,2,4,4 switching combination for frequency control.

Using feedback. In Fig.10, x is the fractional reduction due to the potential divider R_1 and R_2. i.e. $x = R_2/(R_1+R_2)$ (10)

The equivalent circuit of Fig.10 is shown in Fig.11, where $I=(V_1-xV_1)/R$.

The effective value of $R=V_1/I = V_1R/(V_1-xV_1)$ i.e. $R_{effective}=R/(1-x)$ (11)

Substituting x from equation (10) into equation (11)

$$R_{effective}=\frac{R}{1-R_2/(R_1+R_2)}=\frac{R(R_1+R_2)}{R_1+R_2-R_2}$$

i.e., $R_{effective} = R(1+R_2/R_1)$ (12)

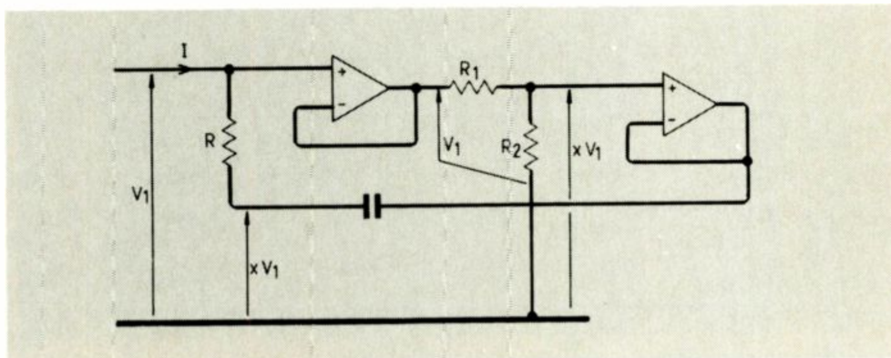


Fig.10. Varying the effective value of R by feedback.

To get a 10:1 variation in the effective value of R the ratio R_2/R_1 can be varied between 0 and 9. The worst error will occur when $R_2/R_1=9$ and R_2 is at maximum tolerance and R_1 at minimum tolerance (or vice-versa).

The main advantages of this method are

- The effective value of R is dependent on the ratio of R_1 and R_2 rather than their absolute value, so their values can be kept low enough for capacitance effects to be minimized.
- It is moderately easy to incorporate fine frequency control by the same method.

The main disadvantages are

- Over a 10:1 frequency range the error at the l.f. end of a range is 2% using 1% resistors.
- Phase shift in the amplifiers introduces some error at the high frequencies.

Wide-range control. The frequency of the circuit shown in Fig.12 is given by

$$f=\frac{\tan\left\{\tfrac{1}{2}\cos^{-1}\left[\frac{xR_1}{2R_2}\right]\right\}}{2\pi CR} \qquad (13)$$

where $-1<x<1$ depending on the position of the slider in Fig.12. The maintenance conditions are satisfied when $R_1/R_2=2$. In this case

$$f=\frac{\tan\{\tfrac{1}{2}\cos^{-1}x\}}{2\pi CR} \qquad (14)$$

When x=0 (mid position of slider) $f=1/2\pi CR$.
When $x\rightarrow 1$ $f\rightarrow 0$
When $x\rightarrow -1$ $f\rightarrow\infty$
Theoretically, the frequency can be varied from zero to infinity with one control. In practice, of course, factors like phase shift and gain changes within the amplifier limit the frequency range, but a shift of three decades has been obtained using the CA3130 op-amp.

Varying the gain of the basic phase shifter. With reference to Fig.13,

$$V_o=V_{in}\sqrt{\frac{\left(\frac{R_2}{R_1}\right)^2+(\omega CR)^2}{1+(\omega CR)^2}}\Bigg/180°-\tan^{-1}\frac{\omega CR}{R_2/R_1}-\tan^{-1}\omega CR \qquad (15)$$

At frequencies where the amplifier phase shift is negligible the angle of equation (15) must be 90° for oscillation.

$$\text{i.e. } 90°=180°-\tan^{-1}\frac{\omega CR}{R_2/R_1}-\tan^{-1}\omega CR$$

$$\text{or } \tan^{-1}\frac{\omega CR}{R_2/R_1}+\tan^{-1}\omega CR=90° \qquad (16)$$

Equation (16) is satisfied when

$$\omega=\frac{\sqrt{R_2/R_1}}{CR} \qquad (17)$$

$$\text{i.e. } f=\frac{\sqrt{R_2/R_1}}{2\pi CR} \qquad (18)$$

Substituting equation (17) back into the amplitude portion of equation (15) gives

$$V_o=V_{in}\sqrt{\frac{R_2/R_1+1}{R_1/R_2+1}} \qquad (19)$$

Equations (18) and (19) show that, as the ratio R_2/R_1 is increased, the frequency and the output amplitude increase.

By limiting the frequency variation to ±10%, i.e. $\omega=0.9/CR$ to $\omega = 1.1/CR$, then $\sqrt{R_2/R_1}$ must have varied between 0.9 and 1.1 (from equation (17)), that is R_2/R_1 must have varied between 0.81 and 1.21. Substituting these values into equation (19) gives an amplitude variation between $|V_o| = 0.9|V_{in}|$ and $|V_o| = 1.1|V_{in}|$, that is a ±10% variation in amplitude, so this method (on its own) is only suitable for fine frequency adjustment.

FREQUENCY ERROR DUE TO AMPLIFIER PHASE SHIFT

Any phase shift in the amplifiers must be compensated by an equal but opposite phase shift within the frequency determining network, so that the phase shift around the complete loop is always zero. This compensation occurs automatically by the frequency altering its value away from $1/2\pi CR$ determined by C and R alone.

The greater the change in phase of the frequency determining network for a given frequency shift, the smaller the unwanted frequency change will be.

The error for the Wien-bridge (equal value C and R in both arms) is given by

$$[3/2\tan\theta-1\pm\sqrt{1+(3/2\tan\theta)^2}]\times 100\% \qquad (20)$$

For the circuit shown in Fig.5, the error is given by

$$[\tan(\theta/4+45°)-1]\times 100\% \qquad (21)$$

To enable a comparison to be made between the Wien-bridge circuit and the one shown in Fig.5, assume that a unity-

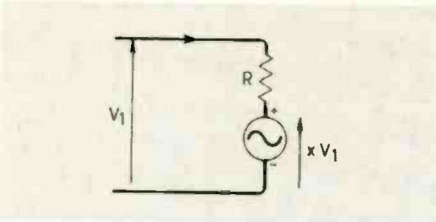


Fig.11. Equivalent circuit of Fig.10.

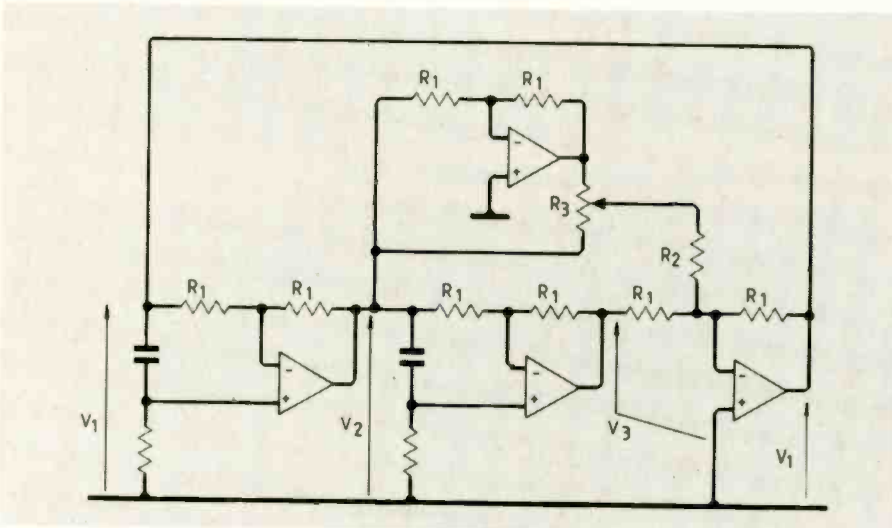


Fig.12. Wide-range frequency control, one variable resistor.

gain, non-inverting stage has a phase shift of −1 degree. The standard Wien-bridge oscillator requires an amplifier voltage gain of 3; therefore the amplifier phase shift will be approximately −3 degrees.

Substituting $\theta=-3$ into equation (20) gives an error of −7.55%. For the oscillator shown in Fig.5, each stage has an effective voltage gain of 2 as far as phase shift is concerned. Thus each stage will contribute approximately −2 degrees, a total of −6 degrees.

Substituting $\theta=-6°$ into equation (21) gives an error of −5.1%. The effective capacitance of the CR network across the output of the amplifier is greater in the case of the Fig.5 circuit, which results in a small extra phase shift.

Overall, the circuit in Fig.5 is still significantly better than the Wien-bridge regarding frequency error.

PRACTICAL TESTS

Before finalizing the design, the circuits shown in Fig. 5,6 and 7 were constructed using the LM324 quad op-amp. A good sinusoidal waveform was obtained over a range of 0.1Hz (for Fig. 5 and 6) to about 10kHz, the upper frequency being limited because the LM324 is a low-frequency device.

The circuits were then modified to accept CA3130 op-amps. This increased the upper frequency to about 100kHz, but now oscillations occurred at a much higher frequency on the lower frequency ranges.

Unwanted oscillations. With reference to Fig.5 consider the upper feedback line disconnected.

$$V_2=V_1\angle 180°-2\tan^{-1}\omega CR$$
$$V_3=V_2\angle 180°-2\tan^{-1}\omega CR$$

Therefore
$$V_3=V_1\angle 180°-2\tan^{-1}\omega CR\;\angle 180°-2\tan^{-1}\omega CR =V_1\angle -4\tan^{-1}\omega CR.$$
$$V_4=-V_3.$$

Therefore
$$V_4=V_1\angle 180°-4\tan^{-1}\omega CR \qquad (22)$$

Using equation (22), a phasor diagram for V_1 and V_4 can be plotted, as shown in Fig.14. It can be seen that, as $\omega \gg 1/CR$, the phase

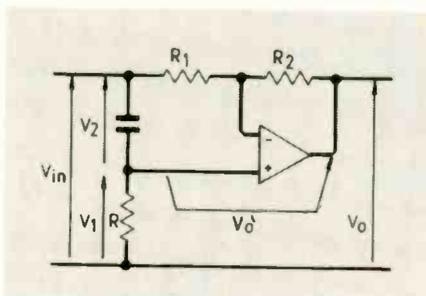


Fig.13. Frequency variation by gain variation, suitable only for fine control.

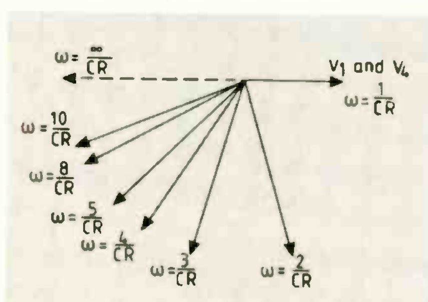


Fig.14. Phasor diagram for V_1 and V_4 ($-V_3$) in Fig.12, showing that as exceeds 1/CR, phase angle nears 180 degrees.

angle approaches 180°. When the total phase shift in the amplifiers approaches a lag slightly over 180°, the output is again brought into phase with the input, so that oscillation is again possible. This unwanted oscillation can occur in preference to the wanted oscillation because, as the phase shift in the amplifiers increases, the negative feedback ceases to be wholly negative, so that the gain of the amplifiers rises.

Note that when the circuit is switched to a low-frequency range, the phase of the output voltage moves nearer to 180° (before considering the effects of amplifier phase shift) than for a high-frequency range for any specified frequency above the normal oscillation range. This makes the unwanted oscillation more likely to occur on the low-frequency ranges.

Using the CA3130 op-amps, the unwanted high-frequency oscillation was cured by putting a series-tuned circuit between points A and B in Fig.5. At first sight it may seem incorrect to put the series-tuned circuit across a low impedance point, but at a frequency of several megahertz the feedback in the amplifiers can hardly be described as negative, so that the output impedance rises at these frequencies. By keeping the L/C ratio large and including some series resistance to spread the bandwidth, the effect on the highest wanted frequency was significant but not excessive.

To be continued.

Logic simulation on a Mentor Graphics workstation: part of the equipment at Motorola's Asic design centre in Aylesbury.

Asic design centre

Support for UK users of applications-specific integrated circuits is now available through a design centre established by Motorola Semiconductors. The centre, at Aylesbury in Buckinghamshire, is a satellite of the company's European design centre at Munich, through which it is connected by high-speed data links to Motorola's mainframe cad installation in Arizona. With the help of the local staff, customers can design their own devices on the centre Apollo workstations, which provide a standard platform running Mentor Graphics software. Design support software is also available for most other popular graphics workstations, and remote operation is possible via a telephone line and modem link. Access to the Munich centre makes it possible for users to create their own special-purpose cells, in addition to those available from the standard cell library. Completed designs can be manufactured at Motorola's wafer fabrication plant in Chandler, Arizona, which is dedicated wholly to Asics. For details, contact Motorola UK at Fairfax House, 69 Buckingham Street, Aylesbury, Buckinghamshire HP20 2NF; tel. 0296-395252.

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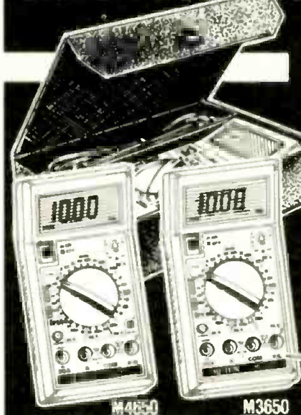

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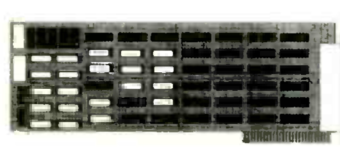

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RESEARCH NOTES

Pioneering still

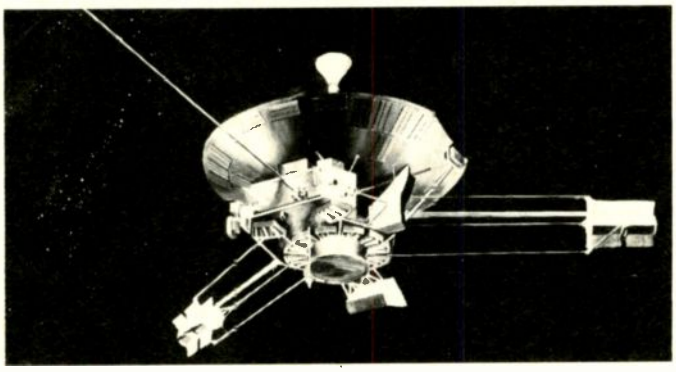
Pioneer 10, launched in 1972, has travelled further into space than any other man-made object. Now about 7×10^9km away, this 230kg spacecraft continues to transmit back to Earth new information about the electric and magnetic environment outside the solar system.

The spacecraft, whose original mission was planned to extend only as far as Jupiter, is now five years' journey beyond the orbit of Pluto and travelling away at nearly 5×10^7km/h. Radio signals take over six hours to reach Earth and must surely represent something of a dx record for a transmitter of only 30 watts or so!

One of the surprises from the Pioneer 10 mission is the discovery of how far the solar wind extends into space. This is the stream of energetic particles that flows outwards from the Sun and which, among other things, causes the aurora. Years ago scientists predicted that the limit of this solar wind would be just beyond the orbit of Jupiter, yet Pioneer 10 is six times further away and still detecting charged particles. Latest predictions based on actual measurements from deep space suggest that the craft will eventually leave the Sun's influence in about another three years.

Long before that, however, Pioneer 10 may well be making other fundamental discoveries. Dr John Anderson of NASA's Jet Propulsion Laboratory in Pasadena explained recently that NASA will be using its deep space network in Australia, Spain and California to try and detect the effects of the gravity waves predicted by Einstein's theory of General Relativity. If such waves exist then they will have the effect of causing fluctuations in the spacecraft's motion, something which will, in turn, produce Doppler irregularities in the received signal.

Less probable, but with much greater publicity value, would be the discovery of a tenth planet outside the orbits of Neptune and Pluto. Although there's no direct evidence at this stage, unexplained gravitational perturbations continue to affect the known planets. But Pioneer's crowning glory could well be even further away. NASA's scientists calculate that it will arrive, complete with its inscribed plaque, at our nearest star system in about 26 000 years. So if there's any intelligent life around Proxima Centauri it could well be in for something of a surprise.



Getting into hot water

The Electricity Council Research Centre at Capenhurst undertakes a considerable amount of excellent practical research on behalf of the electricity supply industry and its consumers. Though much of it is inevitably of a detailed and specialist nature, one recent monograph (ECRE M2237) reveals some interesting inner secrets of UK domestic bliss. It's a study of how the electrically-heated British use their hot water.

Flow meters were fitted in 43 homes (family size: 2-6) to provide detailed information on the quantity and outflow temperature of hot water at different points around the house. Data was also recorded on electrical input power and total hot water consumption.

What this research shows, *inter alia*, is that poorly lagged hot-water cylinders can account for a 30% wastage of electricity. It also reveals that much of what we draw from hot water taps isn't hot water at all. At the kitchen sink, where we use 40% of all our 'hot' water, the most frequently drawn volumes are under one litre... all very economical until you realise that the average volume of 'dead leg' (the pipe from the cylinder) is, on average, 2.3 litres. The Electricity Council Research Centre found that 37% of all 'hot' water drawn in the kitchen is in fact cold.

Upstairs, now, to the bathroom, where worse horrors emerge. Not, I hasten to add, in terms of thermal efficiency, since even the most parsimonious of us would find it hard to bath in under 2.3 litres of hot water. No, the figure that caught my eye was to be found in a table labelled 'mean number of baths per day'. Apparently in an average household of four, the figure is a mere 1.04. It must be just luck that the other three always seem to travel on the 7.20...

Flash pictures by X-ray

Any photographer knows that an electronic flash-gun can freeze fast motion. But until recently it hasn't been possible to apply the same principle to X-ray photography, especially when it comes to taking pictures of atoms and molecules. Such pictures are made doubly difficult by the fact that they depend on computer analysis of diffraction patterns rather than direct imaging. By analysing how molecular structures diffract high energy X-ray beams, physicists can obtain unique information on their structure.

To get a good picture it's necessary either to use a large crystal, which can be difficult to grow, or else to use a powerful beam with a long time exposure. Of these various options the easiest has generally been to lengthen the exposure just as you'd do to take an ordinary photograph under dull conditions. In the case of X-ray diffraction photography this is fine if the molecules don't move, but it rules out completely the chance of taking pictures of living molecules. It would be wholly impossible, for example, to take a time exposure of the molecular changes that take place in the pigments of the eye as they respond to light. The result would be an unintelligible blur.

Now the picture has changed – literally – thanks to the development of an X-ray source that is both ultra-bright *and* ultra-rapid. Using a device called an undulator, physicists at Cornell University have amplified pulses of X-rays emerging from a 2km diameter storage ring and used them to take pictures of biological enzymes in action.

The undulator, 2m long, consists of two sets of small powerful magnets with a field strength of about 5 000 gauss, made of a neodymium-iron-boron alloy. The 123 magnets of the undulator bend the electron beam of the storage ring back and forth 61 times, resulting in synchrotron radiation at X-ray wavelengths that is a million times more intense than a typical medical X-ray. The key to this intensification is that, instead of producing a continuous range of X-ray wavelengths, the undulator-treated beam is transformed into a discrete set of wavelengths whose intensity far exceeds the average of the normal beam. The pulse duration – around 120ps – is also fast enough to freeze the fastest action.

As well as being able to take action pictures of biological molecules, including perhaps viruses, the Cornell team are planning to use their new technique to investigate a range of the new high-temperature superconductors.

Of wider significance, this work establishes that the beam intensification process, which is the key component of America's most advanced facility for X-ray studies, will work as planned. The facility, the Advanced Photon Source, which will provide X-ray beams 10 000 times brighter than is now possible, is to be built at the Argonne National Laboratory in 1989, funded by the U.S. government.

Low-noise squeezed light

Noise, the engineer's constant bugbear, is deeply ingrained in nature. Even when thermal fluctuations are accounted for, there still remains a random component in all electromagnetic radiation. Contrary to the classical physicist's notion of radiation as a smoothly propagating wave, quantum theory postulates an inescapable random

RESEARCH NOTES

element. A wave ceases to be the locus of a point and becomes an 'envelope of uncertainty'. According to quantum theory, even a dark, screened chamber must include random irregularities in the electromagnetic domain – vacuum fluctuations as they are called.

For most macro-engineering this is largely academic. There are, however, cases where the vacuum fluctuations in light make it impossible to undertake really accurate measurements. Gravity wave detectors using laser interferometry are an example of systems whose sensitivity is limited by quantum effects. So too are spectroscopes in which the characteristics of radiation emitted by atoms and molecules are investigated. Ultimately the same effects may put a limit on fibre optic communications and optical computing.

It's therefore interesting to learn (*Science* vol.240 p.604) that researchers at AT&T Bell Laboratories in Murray Hill, New Jersey and elsewhere have discovered how to circumvent this natural limitation and produce 'blacker than black' light. They haven't actually violated the uncertainty principle: they've merely transferred the random noise from one part of the electromagnetic wave to another in a predictable way.

Overall, this 'squeezed' light has the same mean noise level as normal light. But if detection equipment is arranged to 'see' only the 'quiet' part of the wave, then the practical effect is to defy quantum theory.

The apparatus needed to produce squeezed light is inevitably complex, involving a resonant cavity, a laser pump at double the input frequency and a variable non-linear mixing element. The effect of all this is that twice in every input cycle the net field strength corresponds to an almost complete absence of electromagnetic noise.

Other groups, notably at the University of Texas and at IBM's Almaden Research Laboratories, have managed to squeeze light in a variety of media such as lithium niobate crystals and optical fibres. They have also developed detectors that are able to make full use of squeezed light by separating the quiet portions from the remainder.

Although this is still all at the laboratory stage, the prospects of being able to circumvent quantum noise in wide areas of the electromagnetic spectrum seem likely to open new areas not only of basic physics but also of commercial application.

A bigger slice of pi?

3.14159 is about as far as I can go from memory. But for Japanese computer scientist Yasamasa Kanada of Tokyo University the task of calculating the numerical value of pi knows no limit. Dissatisfied with his own 1987 record of 134 million digits he has recently pushed it up to 201 326 000 decimal places using an NEC SX-2 supercomputer. This year's effort took only six hours compared with last year's 36-hour number crunch using a less efficient computational method.

Why do it? Kanada claims (*Science News* vol.133 No 14) that, although it's a good way of testing the power of new computers, his real motivation is more akin to that of climbing Everest... "because it's there". By next year he hopes to reach 400 million digits but says that he will need a machine with a much larger memory to hold the results of intermediate calculations.

Unfortunately the Editor has refused me permission to print the result. It's not because of any copyright restrictions; merely that it would (according to my £3.50 super number cruncher) occupy the whole of every issue of *E&WW* until about the year 2030!

Lasers in the blue

Two recent developments in semiconductor lasers have led to devices capable of generating light in the visible part of the spectrum. These are both seen as prime candidates for increasing the data rate of recording systems (e.g. CD players) that rely on laser emission for write or read operations.

The first of these advances comes from Philips Laboratories and is essentially a refinement of existing semiconductor lasers. Based on a number of layers of pure crystals of III-V compounds, the Philips laser is the result of research into new techniques for optimizing chemical vapour deposition. The semiconductor substrate is gallium arsenide mounted on solid copper to ensure effective cooling. Tests so far have resulted in good monochromatic emission at 650mm – roughly the middle red part of the spectrum.

The other development, which takes solid-state laser emission even further up the spectrum, is reported by a research team at Matsushita Electric in Japan. It's not so much a new type of laser as a frequency doubler. What the Matsushita engineers have done is to design a lithium niobate waveguide which, when fed with infra red emission from a conventional laser at around 800nm, converts it into blue light at around 400nm.

The clever part of this invention lies in the hydrogen doping of the lithium niobate which allows it to operate at room temperature. Nevertheless, because of various practical difficulties, not least the optical coupling between the i.r. laser and the doubler, efficiencies so far haven't exceeded about 2%.

In spite of that, Matsushita hopes to press ahead with commercialization of the device. It also aims to integrate the infra red laser diode with the lithium noibate doubler so as to maximize efficiency. That way the output might be raised beyond the sub-milliwatt level of which the device is at present capable.

Chips with everything

Texas Instruments Central Research Laboratories in Dallas have produced what is thought to be the first example of silicon-gallium arsenide co-integration. Unlike previous experimental chips this device is not merely a set of GaAs transistors and silicon transistors deposited on a silicon substrate.

What Texas has done is create a silicon-GaAs ring oscillator consisting of 76 c-mos fets and 76 gallium arsenide mesfets. The silicon wafer is fabricated first and then etched to provide wells in which the GaAs parts can be created.

The resulting flat chip surface is easy to process and offers the possibility of low-cost, high-density fabrication without the need for exotic processes. This in turn promises a significant price reduction for components such as optical devices which require a III-V ingredient in order to function at all.

Killer bees have had their chips

Many of us have heard by now of the northward progress of so-called 'killer' bees from Brazil to the USA. These bees, of African origin, were accidentally released from a laboratory in 1956, since when they've been ousting the more placid honey bee and stinging to death a few unfortunate human victims. This in itself would be of little interest to electronics professionals except for one of the ingenious counter-attacks being mounted by the US Department of Agriculture.

With the help of engineers at

the Oak Ridge National Laboratory in Tennessee they've produced a solar-powered chip containing a laser diode, so small that it can be attached to a bee without interfering with its normal activities. The idea is to catch some of the killer bees and glue the chips to their undersides. Then, when the bees are released back to into the wild, it should be possible to track the movements of a whole swarm using infra-red detectors on the ground. Ultimately, by learning more about the feeding and breeding habits of the killer bees, the scientists hope to stem their entry to the USA using pesticides. Let's just hope that the bees don't in the meantime discover other uses for their on-board lasers.

Research Notes is written by John Wilson of the BBC External Services Science Unit at Bush House.

Butterworth low-pass filters with equalization

Cascading an all-pass filter with a low-pass Butterworth type leads to the design of a remotely tunable filter with a flat characteristic.

KAMIL KRAUS

Equalizers have been used to effect both the equalization of the attenuation characteristic of a Butterworth low-pass filter and the compensation of phase shift[1]. This article shows that a low-pass filter, together with an equalizer of the first order, gives the basic network leading to the design of crossover filters of higher order.

An all-pass filter in cascade with a low-pass filter of the Butterworth type affects the incoming input signal in two ways: it equalizes the attenuation characteristic; and it gives rise to a network free of phase shift, since the phase shift caused by an all-pass filter is twice as large as that caused by a low-pass filter of the same order.

In considering the equalization of the attenuation characteristic of a Butterworth low-pass network, one must decide which of the possible combinations of low-pass plus equalizer is the most efficient. To obtain the answer to this question, consider the transfer function of a Butterworth low-pass filter of the second order, which can be written in the form

$$F_1(s)=\frac{1}{s^2+1.41421s+1}. \qquad (1)$$

The phase shift θ_1 is given by

$$\theta_1=180°-\arctan\frac{1.41421\omega}{1-\omega^2}, \qquad (2)$$

and the phase delay is then defined as

$$D_1(\omega)=-\frac{d\theta_1}{d\omega}=1.41421\frac{1+\omega^2}{1+\omega^4}. \qquad (3)$$

The measure of the effectiveness of the equalization is given by

$$\Delta D_1=D_1(\omega=\omega_{max})-D_1(\omega=0). \qquad (4)$$

where ω_{max} is the maximal frequency computed under the condition

$$\frac{dD_1(\omega)}{d\omega}=0. \qquad (5)$$

Thus, after some computation, we get from (5)

$$\omega_{max}=0.6435942529.$$

With this value of ω_{max}, we obtain

$$\begin{aligned}\Delta D_1&=D_1(\omega=0.643594)-D_1(\omega=0)\\&=1.707102481-1.41421 \qquad (6)\\&=0.292892481\ \mathrm{s}\end{aligned}$$

The transfer function of an all-pass filter of the first order can be written in the form

$$F_2(s)=-\frac{\sigma_1-s}{\sigma_1+s} \qquad (7)$$

where $\sigma_1=1.2271$. Hence

$$\theta_2=180°-\arctan\frac{2\sigma_1\omega}{\sigma_1^2-\omega^2} \qquad (8)$$

With respect to (2) and (8), the total phase shift is then

$$\theta=\theta_1+\theta_2 \qquad (9)$$

The phase delay of a cascaded Butterworth

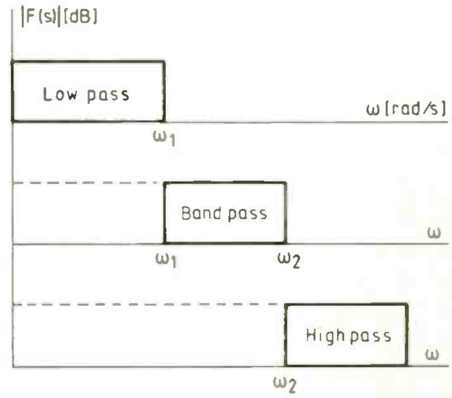


Fig.1. Modelling various filter types by use of low-pass filter.

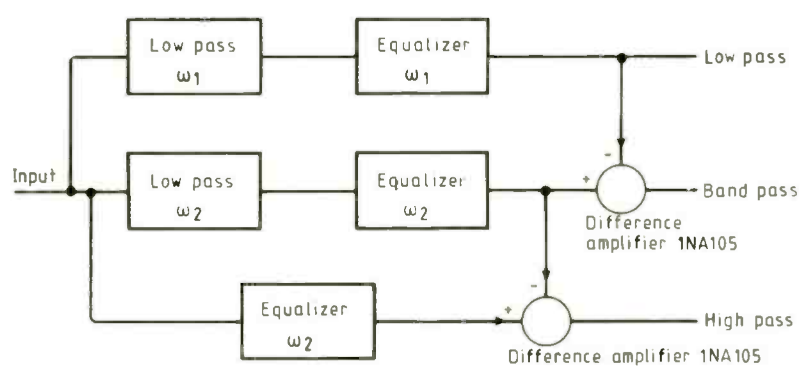


Fig.2. Connecting various filter types using a cascade of a low-pass filters with an all-pass filter. For subtracting signals, fully integrated difference amplifier INA 105 is recommended.

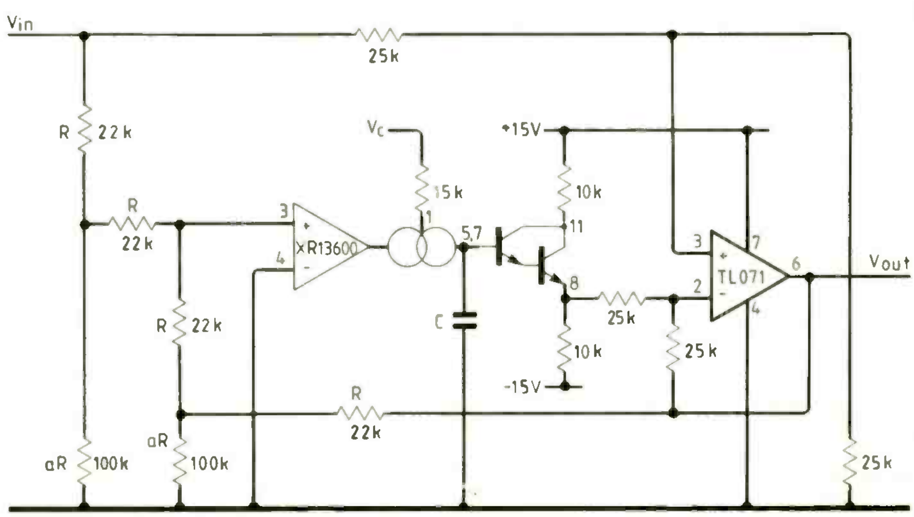


Fig.3. Inverting all-pass filter of the first order using a transconductance op-amp.

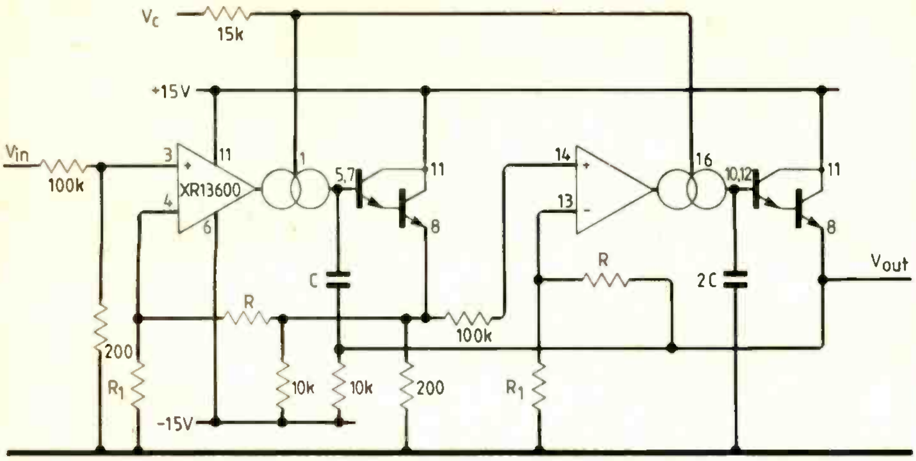


Fig.4. Butterworth low-pass of the second order using a double transconductance op-amp.

low-pass of the second order and an all-pass of the first order is then

$$D(\omega)=1.41421\frac{1+\omega_2}{1+\omega_4}+\frac{2\sigma_1}{\sigma_1^2+\omega^2}. \quad (10)$$

The maximal frequency, ω_{max}, follows from solving the equation $dD(\omega)/d\omega = 0$, giving the result

$$\omega_{max}=0.3977740235.$$

and the measure of flatness of the attenuation characteristic is then

$$\begin{aligned}D&=D(\omega=0.39777)-D(\omega=0)\\&=3.072848338-3.044069017 \quad (11)\\&=0.0287793211 \text{ s.}\end{aligned}$$

Comparing (6) and (11) shows that the flatness of the attenuation characteristic of a Butterworth low-pass of the second order in cascade with an all-pass of the first order is then ten times better than that of a Butterworth low-pass of the same order without an all-pass in cascade.

The computation process as outlined here has been applied to other filter combinations, the results of which are summarized in the table. From comparison of the numerical values thus obtained, it follows that the best combination is as described above. Cascading of a Butterworth low-pass of the second order with an all-pass of the first order gives the basic block for arranging filter networks of higher orders.

Phase equalization provided by an all-pass gives the further possibility of connecting phase-linear filters according to the scheme as given in Fig.1 and Fig.2. Although this problem has been discussed earlier, the results given here lead to a considerable improvement of networks used as cross-over filters. In the paper of Lipshitz and Vanderkooy[3], two Butterworth low-pass filters of the second order in cascade with an all-pass of the second order have been applied as basic blocks for connecting cross-over networks. With respect to the value of ΔD it follows from the table

$\Delta D=0.6$s for the Lipshitz network

$\Delta D=0.06$s for the network of the same order as discussed above.

Comparison table of the influence of an all-pass filter on flatness of attenuation characteristic of Butterworth low-pass filter.

Filter type	D (2)
Butterworth low-pass of the 4th order	1.296503128
Butterworth low-pass of the 4th order plus equalizer of the first order	0.727984
Butterworth low-pass of the 4th order plus equalizer of the second order	−0.7463950866
Two Butterworth low-passes of the second order in cascade	0.585784962
Two Butterworth low-passes of the second order in cascade with an equalizer of the second order	0.585784962
Butterworth low-pass of the second order	0.292892
Butterworth low-pass of the second order in cascade with an equalizer of the first order	0.0287793211

Many all-pass circuits using op-amps have been published. The aim of this paper is to give a network, the cut-off frequency of which may be set up by voltage or by current. One solution to this problem uses transconductance op-amps, XR 13600, with a difference amplifier as given in Fig.3. The transfer function of the circuit as given in Fig.3 is given as

$$F(s)=-\frac{A-C'}{A+C'} \quad (12)$$

where $A = (a+1)/a$ and $C'/19.2I_B$, I_B being the control current. The cut-off frequency is then given by

$$\omega_A=\frac{19.2}{C}I_B \quad (13)$$

and is proportional to the current I_B. Equating the constant A to the constant σ_1 gives the value of a at 4.4.

It follows that a Butterworth low-pass of the second order can be connected by use of a double transconductance op-amp as given in Fig.4. The cut-off frequency of the circuit is given by the expression

$$\omega_A=19.2\frac{R_1}{2C(R_1+R)}I_B\simeq I_B \quad (14)$$

and is therefore proportional to the control current I_B. Thus, with few inexpensive components, a tunable cross-over filter may easily be implemented.

References

1. Valkenburg van, M.E.: Analog Filter Design. Holt, Rinehart and Winston, New York, 1982.
2. Lipshitz, S.P. and Vanderkooy, J.: A Family of Linear-Phase Crossover Networks of High Slope Derived by Time Delay. *J. Audio Eng. Soc.*, vol. 31, January/February 1983/, No 1/2, p. 2-20.
3. Vanderkooy, J. and Lipshitz, S.P.: "Is Phase Linearization of Loudspeaker Crossover Network Possible by Time Offset and Equalization?" *J. Audio Eng. Soc.*, vol. 32,/December 1984/, No 12, pp.946-955.

Electromagnetic Theory

This single 80 track disc produced by Ivor Catt for the BBC range of computers, contains material for a computer-aided learning session pertaining to a particular kind of wave motion travelling on a transmission line. This means that only a tiny portion of the title subject is covered; further, the coverage is idealized and has hardly a hint of the usual messy "real life" approximations we all have to make.

The aim seems to be to introduce digital engineers without any knowledge of transmission lines to the way d.c. steps travel and reflect. With the animated display, this aim is reasonably attained.

The material is divided into four parts. Part 1 covers Ohm's Law and introduces field line models (*a la* Faraday). Part 2 goes on from the strip and round parallel line geometries introduced in Part 1 in an attempt to relate currents and voltages to the H or B and the E (or D) fields. There follows a statement (no derivation) that the impedance of a square of space is 377 ohms. This fact is used to "count squares" in a curvilinear square model set up between the conductors in order to establish the kind of effect conductor geometry has on the line's characteristic impedance (resistance).

Part 3 goes on to develop the impedance ideas introduced in Part 2 and shows step functions absorbed by a matched line, reflected in one phase by a shorted line, and in the opposite phase by an open line. Part 4 attempts to relate the actual voltage amplitudes on the line as voltage pulses travel "through" each other up and down the line.

In its very limited way, the material should given an elementary idea of the way pulses might turn up in unexpected places when conveying sharp-edged pulses around systems. This reviewer liked the way curvilinear squares were used to show the impedance relationships. The most important geometry now used on circuit boards etc. is the microstrip line, but this was omitted. Also absent was any mention of superposition, although this was implicit in the wave additions. Reciprocity, losses and the possibility of dispersion were all absent.

The program, once started, moved through the sequence at its own rate. There was no possibility of a student repeating a sequence, speeding up or slowing down a section, or otherwise interacting with the presentation. This is a great pity, as the power of computer animation is the (usually menu-driven) interactive mode of use. Travelling sine waves would have enhanced the presentation, as would a few reflected samples of these – with the possibility of adding them to demonstrate standing waves and the s.w.r.

This material should help those digital people to whom I suspect it is directed. It should also be useful to the bright sixth former, and (if sine waves are added) to people studying amateur radio courses. But I wonder if a good book still gives much more material for your money?

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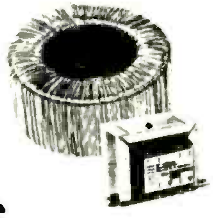

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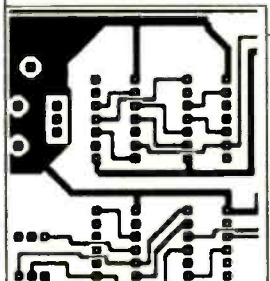

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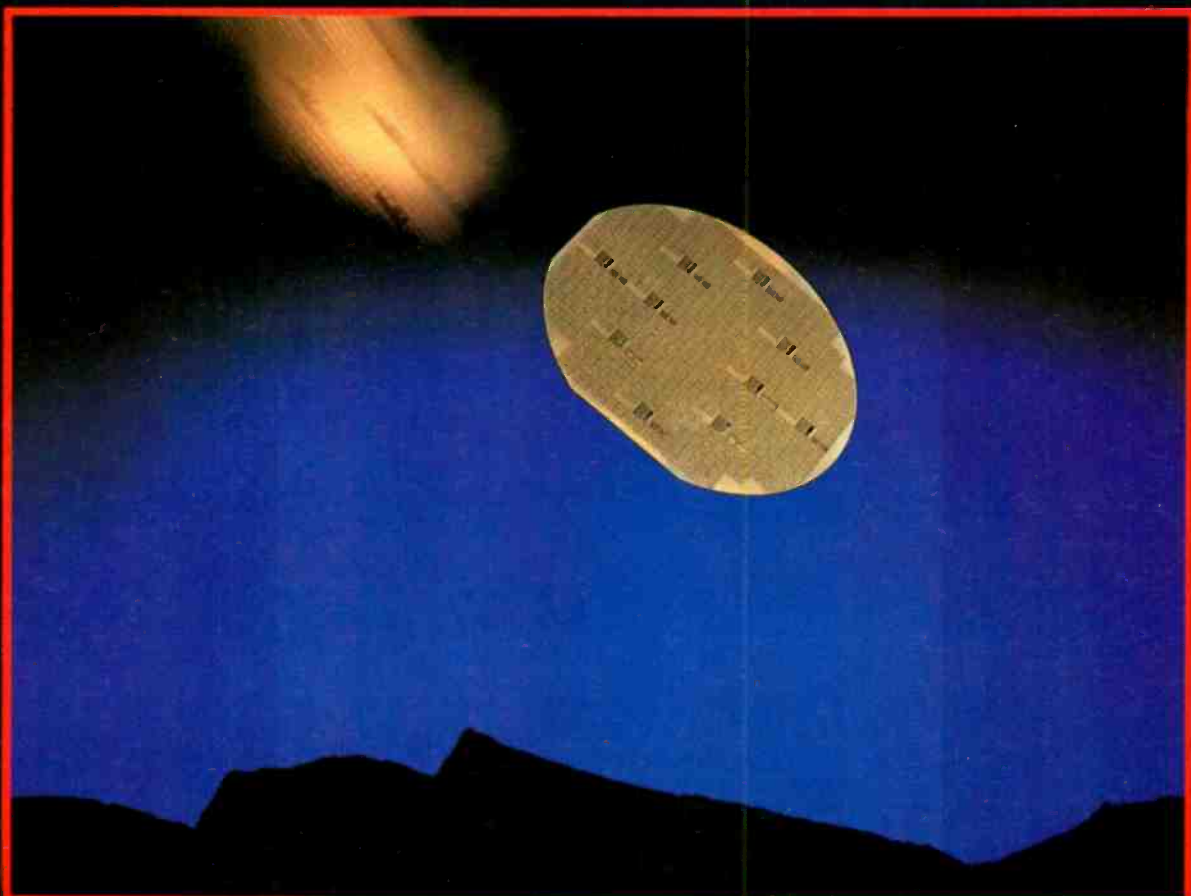

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The Hotels

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dep	Gatwick	07 15	dep	Heathrow	09 45
arr	Munich	10.00	arr	Munich	12 20
Thursday, 10 November			Thursday, 10 November		
dep	Munich	11.25	dep	Munich	12 20
arr	Gatwick	18.00	arr	Heathrow	15 20
TOUR B – 3 days (2 nights)			TOUR E – 3 days (2 nights)		
Thursday, 10 November			Thursday, 10 November		
dep	Gatwick	07.15	dep	Heathrow	09 45
arr	Munich	10 00	arr	Munich	12 20
Saturday, 12 November			Saturday, 12 November		
dep	Munich	11 15	dep	Munich	12 20
arr	Gatwick	12 00	arr	Heathrow	15 20
TOUR C – 3 days (4 nights)			TOUR F – 5 days (4 nights)		
Tuesday, 6 November			Tuesday, 8 November		
dep	Gatwick	07 15	dep	Heathrow	09 45
arr	Munich	10 00	arr	Munich	12 20
Saturday, 12 November			Saturday, 12 November		
dep	Munich	11 15	dep	Munich	12 20
arr	Gatwick	12 00	arr	Heathrow	15 20

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BEST FOOT FORWARD

The fast-approaching deadline of 1992 creates immense pressure for the power supply industry to "get its act together" on such vital issues as harmonisation of international standards in order to get the benefits of a tariff free market. At the same time the pressure is also on to maintain the pace of technical development. The demands of the customers – from o.e.ms requiring sub-unit power supplies purchased as components to major plant users demanding high-power u.p.s. systems – continue to be for better, more reliable and more compact equipment. Inevitably, the challenge is to achieve all this at increasingly competitive prices.

Some companies, like my own, operate in the wide market spectrum from small component power supplies to high-power u.p.s. and find that the trends are very much the same across the board. Others see only one part of the industry and are seriously concerned that they may be alone in facing the pressure of a fast moving competitive business environment. Hence the increasing importance of the Power Supply Manufacturers Association at a time when the industry has to prepare for the next challenge – a single European market – but still maintain the pace of technical innovation and development.

It is a challenge and an opportunity. For the truth is, while we cannot afford to be complacent, the British power supply industry has always been a highly active exporter and is well equipped to face the future.

For anyone who plans to be around by the end of the 1990s, preparing for harmonisation and getting to know the new markets started a long time ago.

The electronics industry should see the power supply arm as pivotal to its own success. Wherever there is an interface between electrical and electronic equipment and the public power supply we are there. In fact the equipment will not work without us. And even when it cannot work – a power cut, local disturbance or local interference, for example – we are still there with u.p.s's and battery systems bridging the gap.

The point is that the power supply industry is alert to the needs of the customers; o.e.ms and end users and is gearing its efforts to keeping ahead. This, of course, is a major reason why the PSMA has recently joined up with BEAMA – to be seen as an integral part of the electrotechnical industry and to participate in the forum that will influence the important decisions to be taken between now and 1992.

PSMA member companies are involved in the manufacture of all forms of power conversion equipment, ranging from low-power d.c:d.c. converters to high-power u.p.s. and standby power systems.

We believe it is crucial that more people should understand what the power supply industry, through the individual companies and the PSMA, is actually achieving. We all live in an electronic world and computers, robots and communications equipment all play an important role in everyday life. Indeed life is inconceivable without them.

The trends and pace of developments are largely set by the demands of the marketplace. At the present time, with so much emphasis on the reducing size of electronic and microprocessor-controlled equipment, the need continues for more compact, higher specification power supplies. Technical developments, like higher frequency switching conversion permit miniaturisation of electronic equipment, while auto-ranging or full-ranging power supplies open the way to using equipment anywhere in the world. Specifications are also being tightened on radio frequency interference and acoustic noise.

Manufacturers wishing to simplify safety approval procedures and to eliminate the need for fan cooling, for example, are increasingly keen on using external power supplies. Also, as the use of computers in offices continues to grow and dependence on them becomes almost total, the need for compact, stylish u.p.s. systems fitting snugly on the desk or alongside a supermarket checkout follows. The industry is raising its visibility in the marketplace.

So it must be apparent that the power supply industry truly has its finger on the pulse of the British and European electrotechnical industry.

Mike Taylor is Chairman of the Power Supplies Manufacturers Association and a Director of Dowty Power Conversion Ltd.

INSIDE

Cover: With all the functions of a switch-mode power supply on one chip, the Siliconix Smartpower series of devices uses double-diffused cmos technology to reduce power loss when converting a high voltage input to a low voltage output. The original type has most recently been augmented with type 9110, extending power conversion to 20 watts, and 9115, extending input voltage to 300 volts.

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POWER SUPPLIES PRESENT AND FUTURE

Peter Bardos of Advance reviews the state of the art in switched-mode power supplies and points to future design influences.

Low voltage d.c. power supplies must fulfil four essential requirements: isolation from the mains, change of voltage level, convert to d.c., and energy storage. Isolation is required to make the end-user safe, and low direct voltage is required since that is the supply level that low power electronics operates on, and energy storage is required to ensure continuity of the d.c. supply during the zero crossing of the a.c. input. The components performing these functions are a transformer, rectifier and a capacitor, so the simplest power supply which performs these elementary functions consists of a transformer, rectifier and capacitor. Whilst such a simple device is perfectly adequate for powering a load, it has several shortcomings – the output isn't stabilized against changes in either line or load, nor is it overload or short-circuit proof.

If stabilization is only required against input changes, the transformer could be replaced by a c.v.t. – simple and reliable but usually heavy, bulky and hot, as well as sensitive to changes in input frequency.

Although c.v.ts may be compensated against load variations as well, this is normally achieved at the expense of line regulation, so if a better regulation is required one normally goes to the good old closed-loop linear regulator. This operates on the well-known principle of comparing the output level with a reference, extracting the difference error signal, amplifying it and controlling the control element with it. The real problem is in the control element, in that in a linear stabilizer the basic method of regulation is to derive more power than the load needs under worst-case conditions, and then dissipate the surplus in the control element. It is immediatly obvious that this is an inefficient system not only because a lot of power is dissipated under normal conditions, but also the input components have to be dimensioned to cater for the total power, including that power wasted in the control element so they are much larger and bulkier than they would have to be otherwise.

In terms of performance, the linear regulator can be made to be near ideal with very low noise, excellent stability and good regulation, but it is heavy, bulky and inefficient. A low voltage linear power supply would be somewhere between 30-45% efficient, which means that it will dissipate roughly twice as much power as that supplied to the load. If you overload a series regulator it will attempt to do exactly what is asked of it, i.e. deliver too much power and blow itself up in the process. To overcome this problem we need current limiting, which is basically a separate, independent control loop looking at the state of the output current rather than the output voltage, and overriding the voltage regulator if need be.

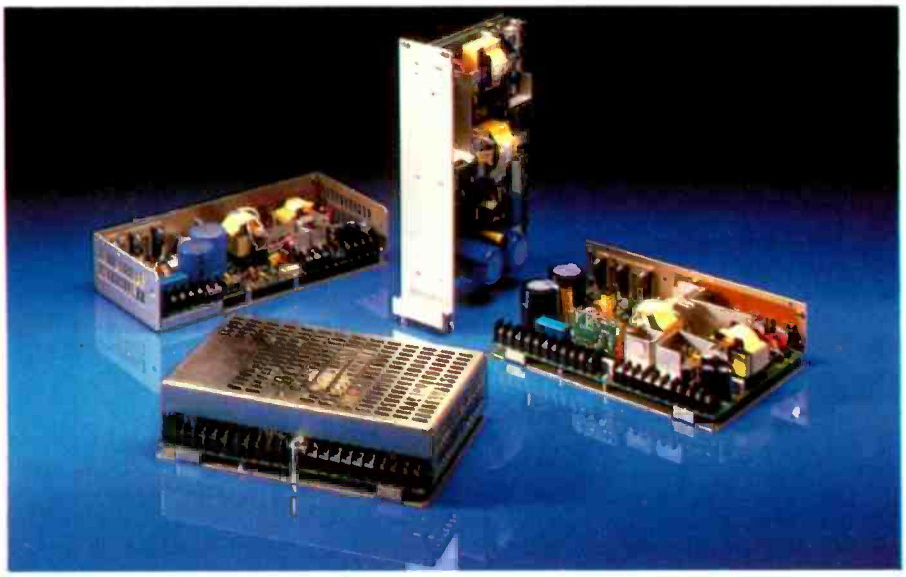
To reduce the size and weight of the transformer you have to operate it at a high frequency rather than at 50Hz; to reduce the size and weight of the energy storage capacitor you have to operate it at a high voltage rather than at the low output voltage level (rectifying the mains gives roughly 370V peak), and to reduce the size and weight of the regulator it has to be a "lossless" regulator rather than a dissipative one. Fitting these requirements and components together gives rise to the well-known direct off-line stabilized switch mode supply.

To make such a system work it is necessary to provide additional components and functions which were not part of the linear design. These include an h.f. converter to convert from the high voltage d.c. to high frequency a.c. a second rectifying system to rectify the high frequency a.c. and an output filter to recover the direct voltage at the output. In addition, a switching regulator is normally controlled through a timing signal controlling the mark to space ratio, and this is more difficult to obtain than the simple error signal in a linear system. Therefore,

FARNELL ACQUISITIONS

Farnell Electronics plc, the Leeds-based component distributor and manufacturer of power supplies, acquired Bonar Advance Ltd and Bonar Wallis Hivolt Ltd from Low and Bonar plc. Finalized at the end of July, the deal was worth £4.15 million cash (goodwill) plus £2 million subject to audit, in respect of net asset value, around £2 million less than originally announced.

"With existing manufacturing bases trading profitably, our market position is significantly strengthened by the move", say Farnell, "which brings complementary products, a broader customer base, and an important presence in the South of England." With subsidiaries in Chesterfield, Ohio and Frankfurt, Advance currently exports about 40% of its products, mainly to West Germany, France and the USA. The German location could provide a launchpad for market penetration in Europe in the run up to 1992. Both Advance and Wallis join Farnell's power supplies group, to be headed by Eric Hall, m.d. of Farnell Instruments since 1986. More recently, Farnell announced that an offer for a.t.e. company Wayne Kerr, also with subsidiaries in Germany and the USA, has been recommended by its board, and irrevocable undertakings bring acceptance to 52% of Wayne Kerr's share capital.

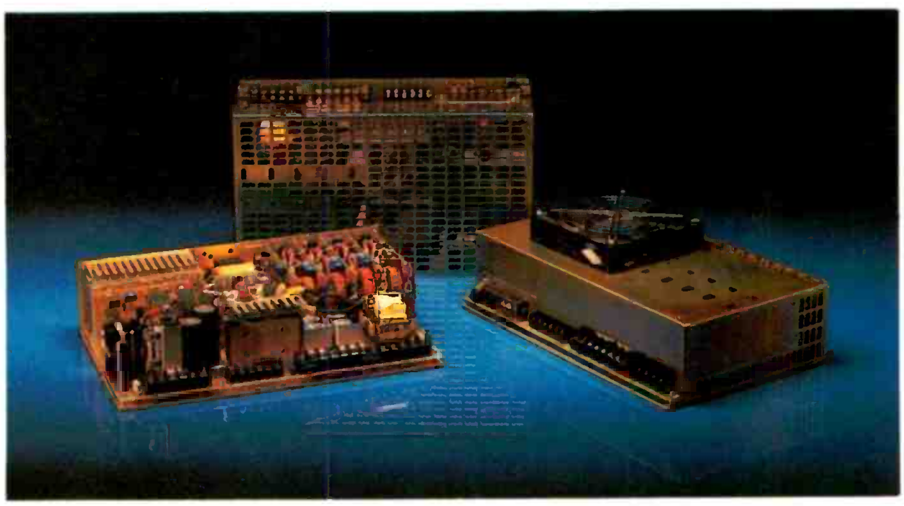


Power trading is the main feature of the Powerite supplies in which the 200-watt rating can be shared in a variety of ways between the five outputs.

such a system is more complex in terms of component count. It has other disadvantages too such as more noise, both on the input and on the output and is more difficult and critical to design. However, it is very much smaller and lighter than a linear. It is also very much more efficient, and because of these savings it is of lower cost above a few hundred watts.

Such direct-off-line switchers did not happen overnight and have their roots in an interim topology used initially by military designers, which was a low voltage secondary switcher. In this scheme, the regulator was very efficient because it used the switching technique. The transformer and energy storage were still used in a non-optimum manner. Low voltage secondary switchers were used for quite some time but the era of the direct-off-line switcher had to wait for the commercial availability of fast, high voltage, switching transistors in the late 1960s.

The first switched-mode power supplies to be designed and made in the UK were these MG series single-output types, still the backbone of the Advance range.



Modular output cards give the 500watt Powerflex system a flexibility hitherto unknown, say Advance. New versions with d.c. input for telecom use are just released.

State of the art

At lower powers there are the well-known three-terminal regulators which are small power supply systems containing the regulating circuitry on a chip. They are very convenient, very low cost, but are only usable at low powers. At the level of a few watts, complete linear regulators are available on a chip, and, in applications where higher powers are required, switching regulating systems are also obtainable but need a lot of external components. These are widely used in commercial and industrial applications.

In the military field, the engineering trade-off between size, weight and cost, is totally different. Basically cost is no object, within limits, but size and weight must be minimal and the environmental capabilities a maximum. Due to these special requirements, the circuits and topologies used in military power supplies tend to be old, well-established and well-proven ones, and so are the components. However, assembly and cooling techniques are advanced. Due to e.m.i. requirements, special filtering circuits and components would be used; due to the mechanical environment, special metalwork, and mounting methods may be used and, if nuclear hardening is required, this would further restrain the availability of suitable components and circuits.

In the industrial field, by contrast, whilst size, weight and efficiency are important, it is even more important to design the unit at a cost which the customer can bear. Normally, but not always, the environmental requirements are rather kinder than those in the military field and this results in a different sort of compromise which enables newer components and newer topologies to be used.

To satisfy these requirements the tendencies are, at the moment, for frequencies to creep up. Market forces dictate that modularity is more and more a requirement since this enables the customer to change the system specification without the manufacturer having to redesign the power supply completely. Such a design is more expensive, in terms of piecepart cost, than an out and out special design, but there are significant savings on the engineering costs and timescale.

Improved regulation and a large number of multiple outputs are also a requirement and for these reasons magamps are becoming popular since they provide an independent method of stabilization, of high efficiency and reliability.

At the very low power end – a few tens of watts – there are very small d.c. converters available using innovative techniques such as hybrids, thick films, surface placement and operation at several hundred kHz. Such devices lend themselves to the system approach distributed power supply where local regulation is obtained through inverters at the p.c.b. level, and power is distributed within the system at a higher voltage level.

Future influences

The three major influences for the future are the market, the legislative, and technical. The market influence is obvious in a way, though, it is not as simple as saying that the market wants the smallest, cheapest product. They do of course, but there is a price to be paid and the trade-offs change all the time. There are also new opportunities and new market segments with their own specialist influences, and there are competent power supply manufacturers available to serve these special markets. Hopefully we have lived through the era of measuring a power supply's performance in terms of watts/cu.inch and that users would now recognise the importance of long term reliability, rather than power density, as being the important parameter.

The legislative influences are also obvious in a way. Clearly the complete equipment relies on the power supply to meet the safety requirements for the system, since it is in the power supply that we have the safety barrier between the live input mains and the safe low voltage outputs. It is also in the power supply that we have most, but not all, of the e.m.i. filtering and as safety and e.m.i. specifications change so will the power supply design.

These parameters do not operate in isolation; if, one looks at the number of unity power factor designs or the number of uninterruptible power supply designs available they show an interesting trend which is driven by a combination of market forces, legislative forces and technical trade-offs.

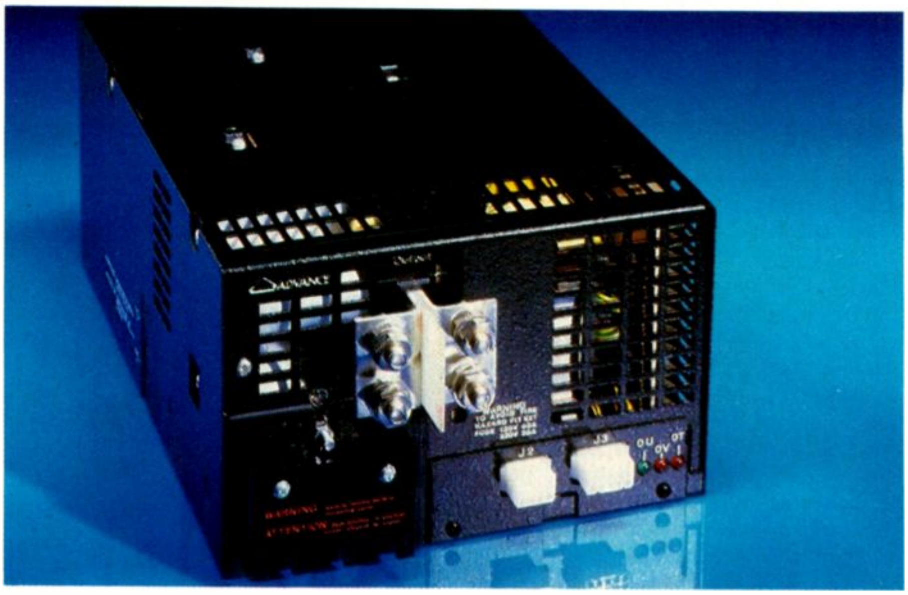
Unity power factor systems have been available at a cost for quite some time, but have only increased in popularity recently. The influences affecting this trend due to technical advances show that the size and cost penalty for incorporating this feature is becoming smaller with the availability of better technology and components. The legislative influence is that long-standing specifications and regulations about harmonic currents taken from the line are becoming activated, due to economic reasons, within Europe. The market influence originates from the fact that with a unity power factor circuit, more power can be taken for a given line current from the supply. As computers and other related equipment become more and more powerful, and therefore require more power, we get to the critical point where some mini computers cannot run off a mains plug without this circuitry.

Whilst in the past both safety and r.f.i. standards used to be widely different between nations, there is a unification process and a harmonization process resulting in standardized standards. Such standards make the design process easier, and of lower cost, since with harmonized standards we would no longer have to obtain separate UL, VDE, CSA, certification for our products.

The technical trends are really a delayed response to the market pressure in that manufacturers can take advantage of new topologies and new components becoming available. This means that we are dealing with a mature technology, improving by evolution rather than by revolution, and I can see no great revolutionary change in the technologies used in the near future. What I do see is a steady evolution resulting in better, smaller and more cost effective power supply systems:

- Higher frequencies going up from the present 20-40kHz to over 100kHz. This will result in a small size reduction and better transient response within the power supply. Two main factors limiting the amount of improvement, one is the legislative requirement for 8mm clearances and creepages, which means that wound components in particular cannot be decreased in size significantly to decrease the size whilst not increasing the temperature within the power supply. Unfortunately, increasing the frequency does not improve the efficiency and so any size reduction possible has to be weighed carefully against the temperature rise and therefore decreased reliability that might result.
- New topologies. There are several new topologies available to the power supply designer, including resonant circuits, current fed circuits, etc. These topologies do not represent an improvement which obsoletes other designs, they are simply a new tool available to the designer for use as and when appropriate. It is for this reason that it is very important that end users leave the choice of topology, frequency, etc., free to the specialist designer, so that he may choose the one that is most appropriate to that particular application.
- There are several new manufacturing methods available to decrease the size and, in some instances, the cost of power supply systems. These include surface mounted components, l.s.i. and v.l.s.i. control systems, hybrid and thick film approaches. There are also power hybrids which include some power components as well.

Some of these technologies are rather costly and therefore more appropriate to the military market, such as power hybrids, whilst others such as surface mount need a high investment but which will result in a reduced unit cost and are therefore more appropriate to the high quantity industrial/commercial market. The component manufacturers are also improving their own manufacturing technologies and this results in further improvements such as smart power devices and amorphous alloy magnetic components.



Powermag 1500watt power supplies are typical of supplies for the larger system builder and offer a variety of sensing, warning and programming facilities.

Harmonization

The Power Supply Manufacturers Association, which represents most of the power supply industry in the UK, has its representatives on the various BS and IEC committees and sub-committees, as well as other influential bodies in this field, and have been pushing for some time for harmonisation of standards. Not just for the simple reason for making the manufacturers' life easier, which it will undoubtedly do but to enable the cost to be optimized and the choice to be maximized to the end user. It is clearly advantageous to everyone to have a single safety and e.m.i. standard rather than to have to manufacture different designs for the UK market, Germany, USA etc. They have been very effective and no doubt everyone has heard that January 1992 is the deadline for doing away with import and export barriers within the EEC, which will be to the advantage of all. But, the barriers can't be lowered until the technical and legislative requirements for power supplies are identical in each country. So this has to be done first, and is scheduled for January 1990. By then we should have totally harmonized e.m.i. safety and power supply standards within the EEC and harmonisation of test requirements so that national approval of a product should be internationally acceptable. This is truly a giant step for mankind.

Peter Bardos is technical director of Advance Power Supplies, now part of the Farnell Electronic Components group. This review is based on a lecture given at Power Sources & Supplies, April 1988.

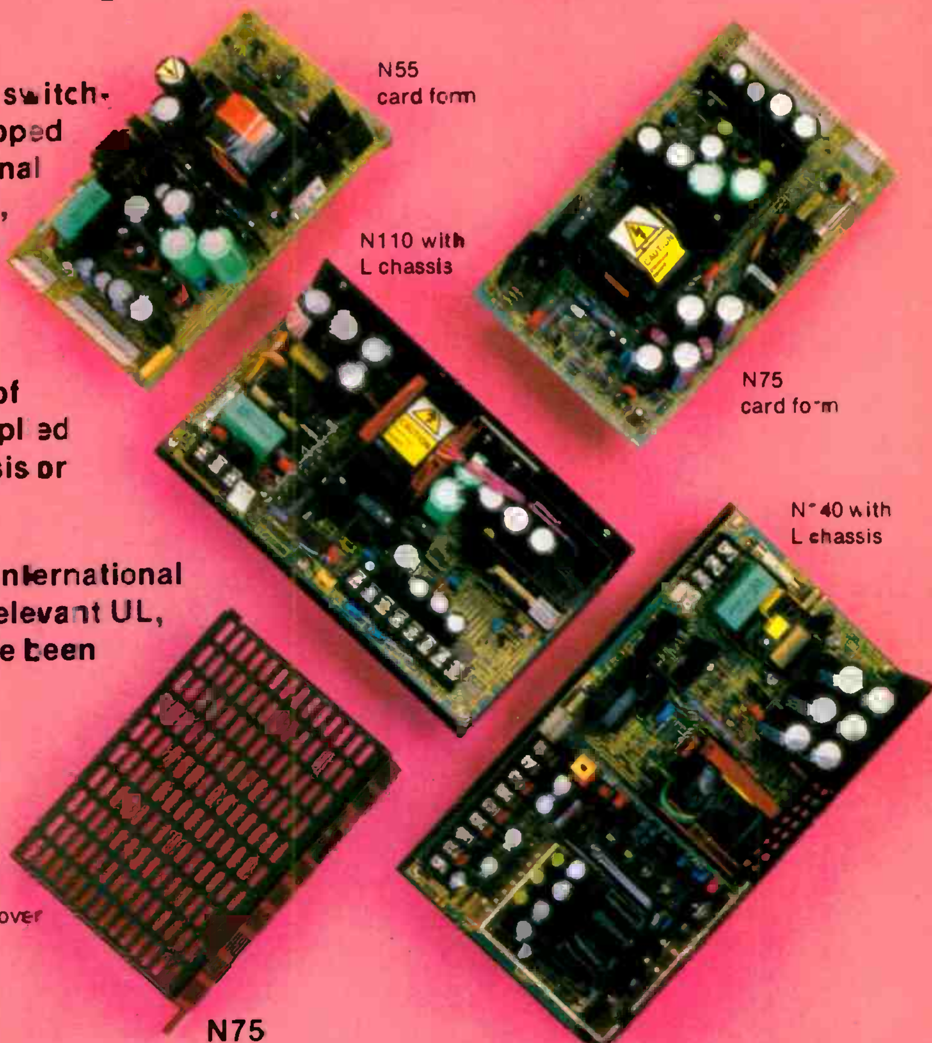
Single and multi-output power supplies

The Farnell N55, N75, N110 and N140 switch-mode power supplies have been developed to meet the volume needs of the Original Equipment Manufacturer - a low cost, compact, reliable and highly efficient power source to build into equipment.

Available in single or multi-output versions, these models offer a choice of mechanical formats - units can be suppl ed in card form, mounted on an 'L' chassis or fully enclosed in a ventilated cover.

Designed and manufactured to meet international standards for safety, noise, etc., the relevant UL, BS, IEC, CSA and VDE approvals have been obtained.

A useful range of options is available.



N55

2, 3 or 4 outputs. 55W total output power.
5 versions available:
+5V 6A, +12V 3A, 12V †2A, 5V †1A
+5V 6A, +12V 3A, 12V †2A, 24V †1A
+5V 3.5A, +12V 3A, +24V 1A
+5V 3.5A, +12V 3A, -12V 1A
+5V 3.5A, +12V 3A
† Floating.

NS55

Single output, 55W output power.
7 versions available:
5V 11A, 12V 4.5A, 15V 3.6A, 24V 2.3A, 30V 1.8A, 48V 1.1A, 56V 1A

N75

2, 3 or 4 (optional 5th) outputs. 75W total output power.
5 versions available:
+5V 8A, +12V 3A, 12V †2A, 24V 1A
+5V 8A, +12V 3A, 12V †2A, 5V †1A
+5V 8A, +12V 3A, +12V *2A, -12V *0.5A
+5V 8A, +12V 3A, +12V 2A
+5V 8A, +12V 3A
† Floating. *Can be supplied floating to order

NS75

Single output, 75W output power.
7 versions available:
5V 15A, 12V 6.25A, 15V 5A, 24V 3.2A, 30V 2.5A, 48V 1.6A, 56V 1.4A

N110

2, 3, 4 or 5 outputs. 110W total output power.
7 versions available:
+5V 12A, +12V 5A, -12V 2A, -5V 1A, +24V 2A
+5V 12A, +12V 5A, -12V 2A, -5V 1A, +12V 2A
+5V 12A, +12V 5A, -12V 2A, +24V 2A
+5V 12A, +12V 5A, -12V 2A, -5V 1A
+5V 12A, +12V 5A, +12V 3A, -12V 2A
+5V 12A, +12V 6A, -12V 3A
+5V 12A, +12V 6A

NS110

Single output, 110W output power.
7 versions available:
5V 22A, 12V 10A, 15V 7.5A, 24V 5A, 30V 4A, 48V 2.5A, 56V 2A

N140

3, 4 or 5 outputs. 140W total output power.
6 versions available:
+5V 14A, +12V 5A, 12V †3A, 24V †3A, 5V †1A
+5V 14A, +12V 5A, 12V †3A, 12V †1.5A, 5V †1A
+5V 14A, +12V 5A, 12V †3A, 24V †3A
+5V 14A, +12V 5A, 12V †3A, 5V †1.5A
+5V 14A, +12V 5A, 12V †3A, 12V †1.5A
+5V 14A, +12V 5A, 12V †3A
† Floating

NS140

Single output, 140W output power.
7 versions available:
5V 28A, 12V 12A, 15V 10A, 24V 6A, 30V 5A, 48V 3A, 56V 2.5A

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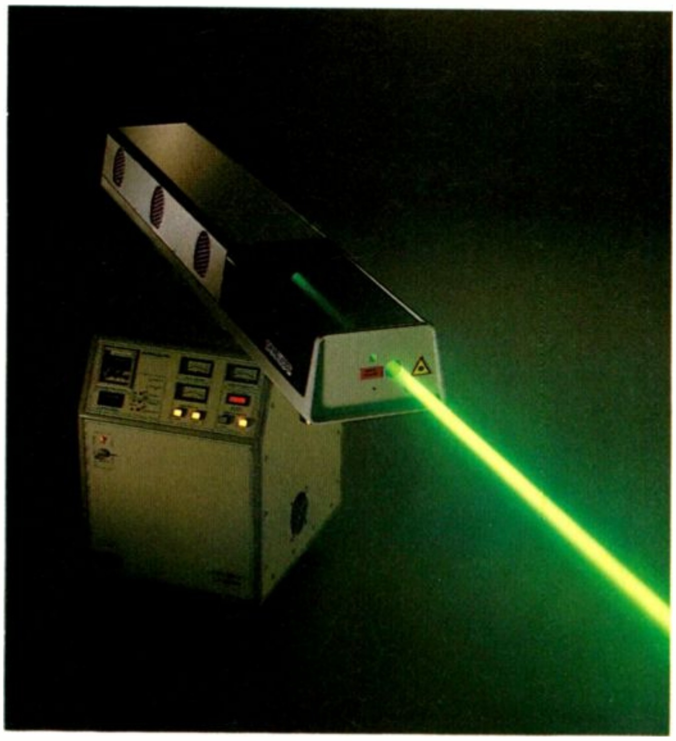


In a switched-mode power equipment there is a need for a high power switching device. Generally, three types of semiconducting switching devices are used in this type of application, thyristors, bipolar junction transistors and field effect transistors.

Thyristors handle very high power, but suffer from relatively slow switching times, and are generally used at frequencies below 10kHz. Bipolar transistors with high power handling capabilities are also slow, particularly high current devices, and maximum switching frequencies are typically under 50kHz.

Field-effect types can be switched very fast and can operate at frequencies above 100kHz. However, their power handling at high voltages is not as good as thyristors or bipolar transistors.

Oxford Lasers have used a technique for paralleling two low-cost, medium-power b.j.ts driven by a single low voltage, high current fet to form a high voltage, high power, high speed switching module. Single devices with comparable performance are not readily available and are far more expensive than the circuit described here.

The circuit of the complete switching module is shown in Fig.1. Tr_1, a low voltage, high current fet, is used to switch the emitters of both Tr_2 and Tr_{21}. This module has been used in a s.m.p.s. typically switching 16A at 300V, with turn-on and turn-off times of 200 and 500ns respectively. Both these b.j.ts are driven by identical current transformers connected to provide equal amount of base current to each. The b.j.ts were found to share currents within 10% and the temperature stability was good.

Operation of the complete switching module is best understood by considering the simplified circuit shown in Fig.2. Diodes D_3 and D_4 form a Baker's clamp[2], ensuring that the b.j.t. does not go into hard saturation. During the on-time the clamp ensures that the collector voltage does not fall below the base voltage. Diode D_4 diverts any excess current from the base drive into the collector, thus improving the turn-off time of Tr_2.

How to achieve the performance of expensive bipolar transistors by paralleling low-cost types

Emitter switching. A low voltage fet switches the emitter of a high voltage, high current transistor[3]. The base is biased at a fixed voltage, typically 15V. Diode D_6, in Fig.2, clamps the base voltage to the zener voltage of ZD_1 plus the diode forward voltage drop during the turn-off time of the b.j.t. Emitter switching is no different from the conventional base drive technique turn-on, the fet is switched on the current starts to flow through the b.j.t. and the fet.

At turn-off, the fet is switched off rapidly and the current out of the emitter of the b.j.t. drops quickly to zero but the current still flows into the collector. This collector current is diverted into the base giving rise to reverse base current equal in amplitude to the collector current, which removes the base charge and switches off the b.j.t. rapidly. Both storage and turn-off times are minimized. The risk of failure due to secondary breakdown is also reduced using emitter switching compared with conventional direct base switching arrangements.

Proportional base drive. Proportional base drive is an effective method of driving b.j.ts[4,5]

In a conventional fixed base drive method of switching the base current must be large enough to handle the full-load collector current. Under lightly loaded conditions the b.j.t. is severely over-driven with fixed base drive and is probably saturated, resulting in long storage and turn-off times. The proportional base drive method as well as being simple, optimized performance under varying load conditions.

The current transformer in Fig.2, provides regenerative base drive to the b.j.t. The amplitude of the base current provided by the base drive transformer is proportional to the collector current being switched. The ratio of collector current to base drive current is determined by the transformer turns ratio.

As shown in Fig.2, C1 provides initial base current to the b.j.t. The use of proportional base drive allows this capacitor to be small as most of base drive current required is provided by the proportional base drive transformer.

Paralleling bipolars. To handle higher load currents two or more b.j.ts may be paralleled, extending the circuit of Fig.2, to that of Fig.1. The current gain of high power b.j.ts is low, and variations in the current gain of a particular type of device is usually small. Driving equal currents into the bases of two b.j.ts connected in parallel ensures that the load current is almost equally shared.

To achieve this the proportional base drive technique is developed so as to drive two b.j.ts. Two identical current transformers in series provide equal base current to each of the two b.j.ts connected in parallel, sharing the load current. Maximum load current is almost double that of a single device, with the circuit as shown in Fig.1.

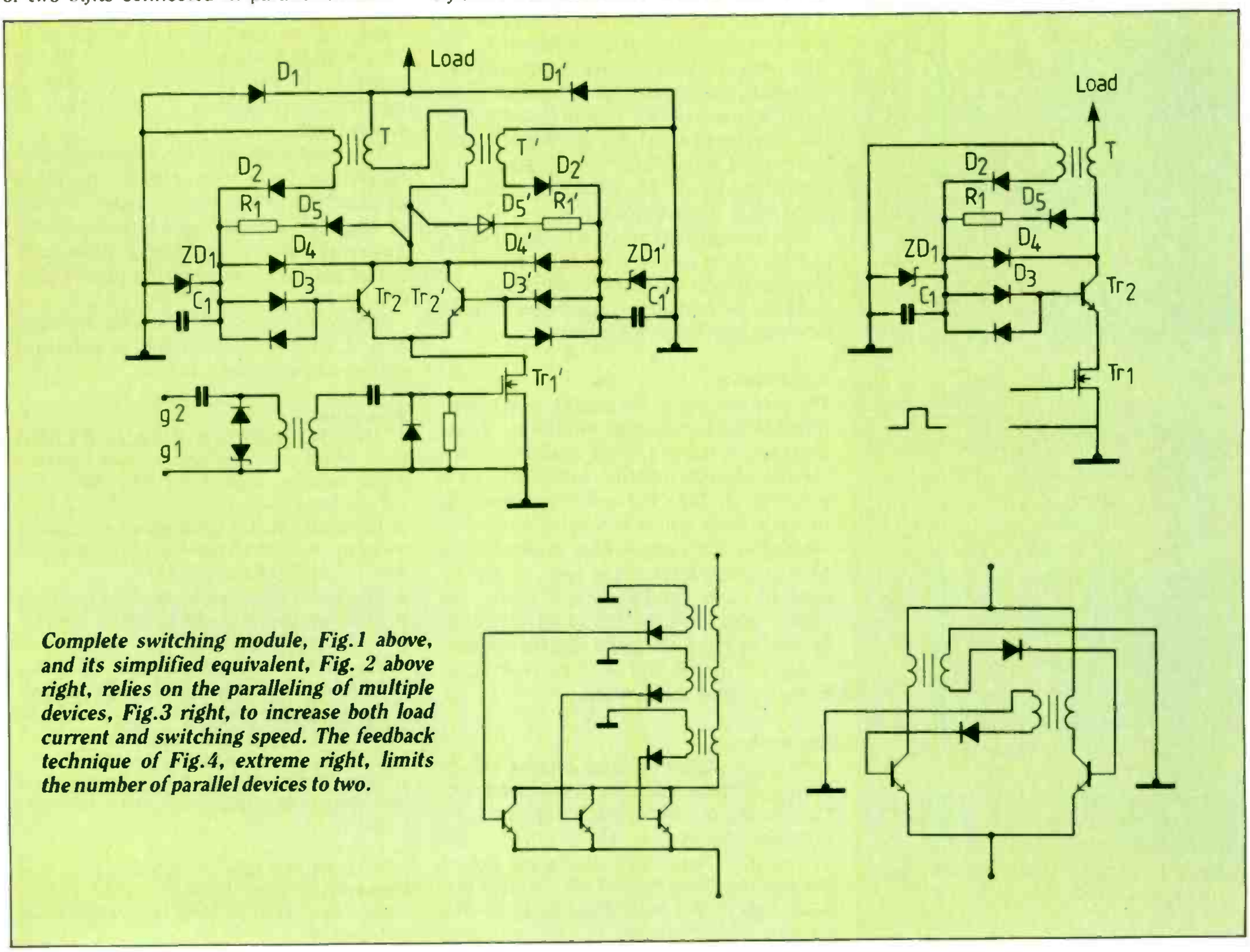
METAL VAPOUR LASER USES HIGH POWER SMPS

Since 1982 by far the most important and rapidly growing of the product lines manufactured by Oxford Lasers has been the range of metal vapour lasers (m.v.ls). There are two types of m.v.l. of greatest commercial interest; the copper vapour laser (c.v.l.) and the gold vapour laser (g.v.l.). While the majority of sales are c.v.ls because of their high efficiency, there are some specialized applications for which the g.v.l. emitting red light at 628nm is especially well suited.

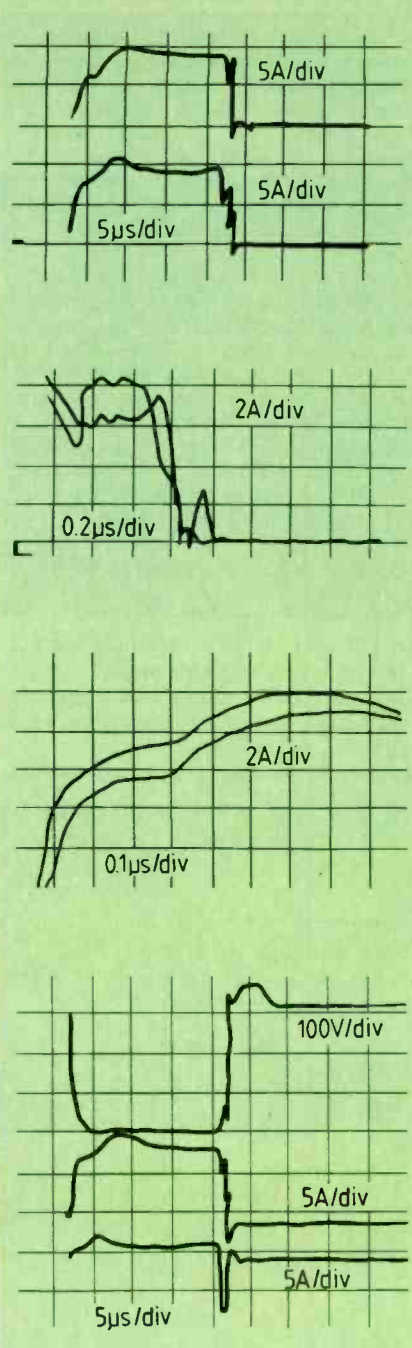
As with all m.v.ls, the copper vapour laser emits a beam of pulsed laser radiation comprising a train of short pulses (each lasting about 20-40ns) depending on operating conditions) but with very much higher repetition rates (5-20 thousand per second) than the few hundred per second typical of other types of pulsed laser system. The c.v.l. emits a two-colour beam made up of green (511nm) and yellow (578nm) components in which the green component predominates under normal operating conditions.

The principle power supply requirement for the m.v.l. is a d.c. source with a stable output of some 6kV, capable of providing output current up to 400mA. Design engineers at Oxford Lasers have developed a cost-effective s.m.p.s. to provide this d.c. source and are incorporating this supply into their product range. The work was presented at the third International Conference on Power Electronic and Variable-Speed Drives held in London last July.

Oxford Lasers design and manufacture high performance lasers used for industrial, scientific and medical purposes and their products are sold world-wide. After only ten years, since the company was founded they gained the Queen's Award for Export Achievement in 1987. Design work is carried out in-house, specialized parts are made by subcontractors and standard components are assembled into lasers. The final phase of manufacture involves rigorous testing and physical conditioning of the lasers and, increasingly, an integration into complete laser instrument systems.



Complete switching module, Fig.1 above, and its simplified equivalent, Fig. 2 above right, relies on the paralleling of multiple devices, Fig.3 right, to increase both load current and switching speed. The feedback technique of Fig.4, extreme right, limits the number of parallel devices to two.



Both bipolar transistors shared the load current equally without selecting matched devices. Top diagram shows collector current while the middle curves are of rising and falling edges with an expanded timebase. Traces in lower diagram are collector voltage and current and base current (bottom).

This paralleling technique can be extended using additional parallel b.j.ts, each of which requires a further base drive current transformer; as shown schematically in Fig.3.

Circuit operation

The module shown as Fig.1, is a four-terminal switch used instead of a b.j.t. in a s.m.p.s. application requiring a fast high power switch. The fet gives the device a high input impedance and very high current gain.

Initially when terminal g_1 and g_2 are at constant relative potential the switch is off. Capacitor C_1 (C_1') is charged to zener voltage ZD_1 (ZD_1'), via D_5 and R_1 (D_5' and R_1'). When a pulse is applied between g_1 and g_2, Tr_1 is switched on, switching on both Tr_2 and Tr_1'. Capacitor C_1 (C_1') provides initial charge to the base of Tr_2 (Tr_2'). Once some current is established through Tr_2 or Tr_2', the current transformers will provide equal base current to each transistor.

When the input pulse falls, Tr_1 switches off and the current through both emitters fall to zero. The collector currents are diverted into the respective bases, rapidly removing the store base charge and turning off both b.j.ts, as discussed in the above section.

Each current transformer is designed to provide a base current proportional to the load current, hence ensuring that the base current through each b.j.t. is the same. Thus a similar load current should flow through the collector of each b.j.t. The turns ratio of the current transformers in Fig.1 with two parallel b.j.ts will be twice that shown in Fig.2 with a single transistor.

Due to mismatch between the gains of Tr_2 and Tr_2', there may be some difference in the sharing of load current between the b.j.ts. But good performance is achievable without selecting closely matched devices.

Performance

The performance of the circuit is best illustrated by the oscilloscope waveforms. These are obtained using a single module, switching a dominantly resistive load at 300V, with a current of 16A. The collector current is shown in Fig.5, which shows similar current waveforms. Each is switching approximately 8A. Fig.6, shows the rising edges of the two currents, and similarly Fig.7 shows the falling edges, on an expanded timebase. Shown in Fig.8 are the collector voltage, collector current and base current waveforms for one of the bipolars.

Discussion

Both b.j.ts shared the load current almost equally, without selecting matched devices. The sharing of current was also found to be temperature stable. The devices were mounted on separate heatsinks and one of the heatsinks was heated with an external heat sources. No noticeable change in the current being switched in each b.j.t. was observed even with a temperature difference of 65°C, as measured between the two heatsinks.

This current sharing technique is flexible and can equally be applied to higher power or lower power transistors. The circuit as described has very high current gain and switching times are relatively fast compared with a single transistors of comparable power rating. This technique need not only be used to increase the load current being switched but can also be used to achieve faster switching times by using two lower power, faster devices.

Feedback technique

An alternative technique for paralleling may also be used. This method differs from the above in that the current transformers are not connected in series to ensure the same base current to each transistor, but are connected in series separately with each as shown in Fig.4. The current transformer in series with one transistor provides proportional base drive to the other. This method introduces negative feedback into the system. If the current through one is higher than the other, the current transformers will drive more base current into the one passing less load current and less base current into the one passing more load current, hence balancing the load current through each. This method is self-stabilizing and will also compensate for any mismatch due to temperature instability or differences in current gain.

The results obtained for this circuit configuration were very similar to those obtained in the first method. Due to the use of feedback in the second method it is inherently more stable. However a drawback is that only two devices can be paralleled in this way.

Thanks to the IEE for releasing copyright of ref.1. to enable this work to be published in this issue of Industry Insight.

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THE CHANGING SHAPE OF SECURE POWER

Ken Bishop's team at Contant has come up with an alternative solution to the ups problem.

The vast majority of electronic loads operate from direct current derived from the mains supply computers, communication systems, process controls, automatic test equipment, etc. These rely on a high-quality mains supply, but if this is lost there is the possibility of a damaged system, not to mention lost revenue.

The conventional method of overcoming the problem of mains disturbances is to use an uninterruptible power supply. These equipments use a battery as an energy store and maintain a sinusoidal output irrespective of whether they are taking power from the mains supply or the battery.

In the typical uninterruptable supply shown in Fig.1, the incoming mains supply is converted to a controlled direct output voltage by a thyristor converter. This direct voltage is smoothed by a choke/capacitor filter and becomes the float voltage of the battery. Voltage and current controls maintain the battery in the optimum state of charge. The inverter circuit is powered from this voltage, converting the nominally constant voltage into a fixed-voltage, fixed-frequency output. This a.c. output is filtered to a sinusoidal voltage and the output impedance has to be matched to the distorted input currents of many loads.

The regulating controls of the inverter maintain its output irrespective of load and voltage variations. If the mains voltage falls too low, so that the float voltage cannot be maintained, the battery starts to discharge and provide the input power of the inverter. The output voltage of the inverter is therefore independent of the actual mains voltage.

The majority of the power components are operating at mains frequency and thus relatively heavy and bulky. At low battery voltages of 24-48 volts it is usually necessary to have an input transformer and of course this is a bulky component. When it is necessary to have one pole of the battery earthed it is also necessary to have a double-wound input transformer to isolate the battery from the mains system.

This arrangement is typical of an uninterruptible power supply. But it is a series connection, so that if any component fails it is possible to lose a.c. power to the load. The usual modification is to add a static switch arrangement, Fig.2, which shows the output voltage of the inverter being fed to the load via a thyristor switch. If the control circuit detects any deviation outside the design specification then switch A is turned off and switch B is turned on. This assumes that the mains supply is still present and is of a suitable quality to power the load.

With this static-switch-backed supply the reliability is then more dependent on the loads being powered. The power however is being controlled three times before reaching the load and this results in a low overall conversion efficiency.

If the load is purely power supplies and does not actually need a.c. power then perhaps we should seek an alternative solution – an alternative u.p.s. Switched-mode power supplies that are being manufactured today are the result of extensive development programmes. Their circuits have been designed to minimize size and cost and to maximize reliability to suit different application criteria. In high reliability systems therefore one should try to

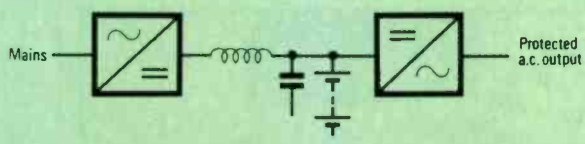


Fig.1. The conventional means of secure power – a u.p.s. – uses battery as an energy store. A sinusoidal output is maintained irrespective of whether it is taken from the mains or the battery.

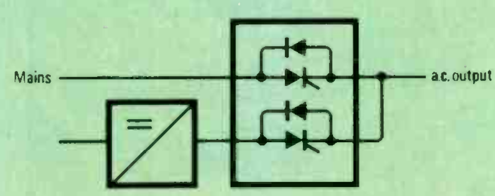


Fig.2. This static switch arrangement shows the output voltage of the inverter being fed to the load via a thyristor switch. Any deviation from the design specifications causes switch B to turn on.

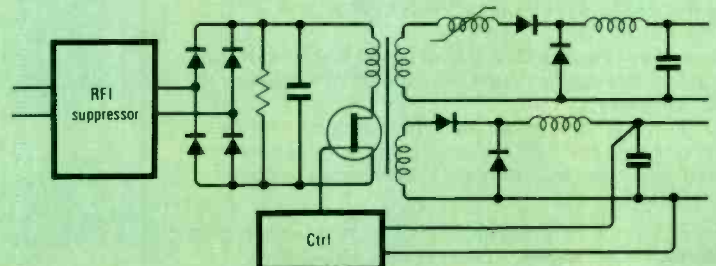


Fig.3. Keeping the input d.c. capacitor charged can be achieved in an alternative u.p.s. by using a d.c. converter to step up the voltage and using this output to keep the capacitor charged.

inherent high reliability of the power supply and not add series connections which could degrade its performance. (The main constituents of a switched-mode power supply are shown in Fig.3).

The input circuit comprises an r.f.i. suppression circuit and full-wave rectifier. The bridge rectifier output charges the input capacitor and maintains it at a voltage directly proportional to the mains voltage. This direct voltage is switched by a transistor or f.e.t. into the primary of a double-wound transformer, with secondary windings to power as many separate outputs as required by the load. Depending on the control strategy one can either use close-loop control from the main output to the primary switch plus post regulators, or use only post regulators. Primary side components are designed to operate over a particular mains voltage range and to be capable of withstanding at least a half-cycle break. It is obvious that if the input d.c. capacitor could be kept charged then the p.s.u. outputs would remain within specification irrespective of the mains voltage. This is achieved in the alternative u.p.s. by using a d.c./d.c. converter to step up a nominal 48-volt battery to approximately 240 volts d.c., and to use this output to keep the capacitor charged, Fig.4. Whilst the mains supply is healthy it is necessary to provide charging current to the battery to maintain it at its float voltage. Fig.5 therefore shows how a practical system can be constructed.

Transformer T_2 and transistor Tr_2 form a step-down d.c. converter which is extracting energy from the d.c. link capacitor of the s.m.p.s. and providing the float charge requirements of the battery. It is also providing the no-load losses of the main d.c. converter. Transformer T_1 and Tr_1 are the main components of the step-up d.c. converter, running continuously whenever there is a battery connected but producing no output power as D_2 is reverse biased. As soon as the d.c. link capacitor voltage of the s.m.p.s. falls below the output voltage of the step-up converter, D_2 becomes forward biased. The s.m.p.s. will therefore continue to operate for a time dependent of the battery capacity. When the main step-up d.c. converter is operating the battery charging converter is inhibited.

Attributes of alternative scheme

An alternative u.p.s. based on the foregoing arrangement has the following technical attributes over competing schemes. High-frequency switching circuits give high efficiency and small volume. The noise generated in this circuit can be easily suppressed to comply with appropriate specifications for conducted battery noise. By using the same creepage and clearance specifications as used in s.m.p.s. in the d.c. converter stages it is possible to meet BS5850 and BS6301 requirements. This means that the battery is isolated from the mains with full safety isolation and hence can be earthed.

By matching the battery discharge time to system requirements of the load it is possible to give alarm and control signals to allow a computer switch to shut down in an orderly manner. With short discharge times of 10-20 minutes, sealed lead-acid or alkaline batteries can be used to enhance the small volume of the product. It would be normal practice to fit some form of thermal shutdown in a short time rated product due to the 'high' thermal impedance. However the converter could be cooled by an internal d.c. fan, and it could then operate indefinitely from a large capacity battery.

The most significant point however is that during normal operation the energy consumption is dependent on the load power and s.m.p.s. efficiency, plus the quiescent power of the d.c. converter system. There are none of the continuous losses of a conventional u.p.s., and this means the alternative u.p.s. has the additional advantage of lower running costs.

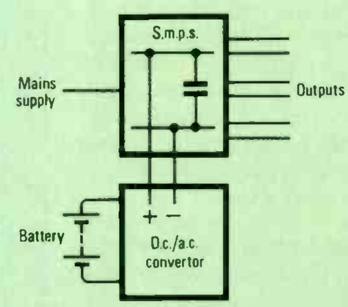


Fig.4. While the mains supply is health it provides charging current to the battery to maintain it at its float voltage.

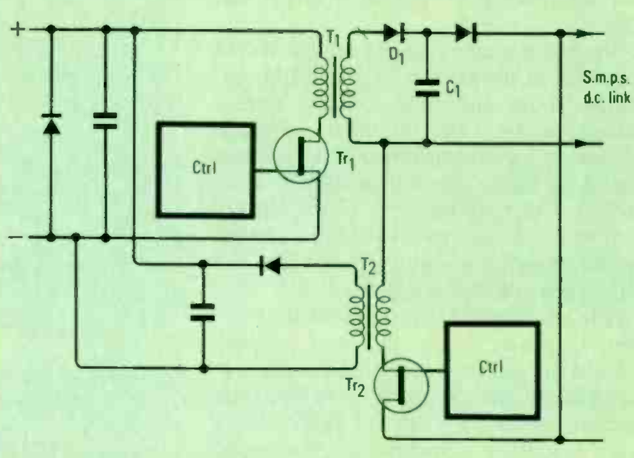


Fig.5. How a practical system can be constructed, based around Figs 3 and 4.

ADVANCES IN SOLID-STATE POWER SUPPLIES FOR RF HEATING

For heating applications requiring operating frequencies between 50Hz and 10MHz triode valve oscillator power supplies are almost universally used. A high direct voltage is applied between the anode and the cathode of the valve and the high frequency output is usually fed to a parallel resonant circuit, possibly incorporating a matching output transformer. Operating in a class-C mode, efficiency of valve oscillators rarely exceeds 60%.

Recently the capital cost of solid-state devices has fallen and their availability increased. For some years attempts have been made to replace valve oscillators with transistorized power supplies. Units using parallel combinations of bipolar transistors are available within this frequency range but they have limited power output capabilities and poor reliability. They have made little impact industrially usually being associated with applications within laboratory environments.

The development of high-power mosfets has made high power solid-state units for induction heating feasible. Research work on transistor power supplies for induction heating has been carried out by Tebb and Hobson[1], and commercial units developed and installed. The work has been mainly concerned with supplies operating between 100 and 400kHz at power levels up to 5kW, for such applications as heat treatment and cap sealing.

Brighton Polytechnic's Professor Hobson reports on how high power mosfets have made solid-state power supplies for r.f. heating feasible

Microprocessor control

A microprocessor control system was incorporated into this range of solid-state induction heating power supplies to achieve more sophisticated power control, increased reliability and improved system efficiency refs 2,3. The microprocessor control system could also monitor the performance of the supply unit and carry out general supervisory tasks such as the continuous control of the temperature and flow rate of the cooling water.

The microprocessor control unit can control the power output from the power supply and take it through any predetermined cycle required by a heat treatment process. Secondly, closed-loop temperature or power control is also a common requirement for high frequency induction heating applications which can be more easily accommodated using the microprocessor control unit. Finally, for the more highly technological applications (e.g. crystal pulling, fibre optic production) the induction heating power supply is only a small part of the process equipment and may need to interface with the supervisory control computer. The incorporation of a microprocessor means that it can be programmed with software to support handshaking protocols used on the system bus.

The microprocessor control system implemented a frequency-hunting procedure i.e. the unit found the desired resonant frequency of the tank circuit and adjusted

Fig. 2. Components of inverter circuitry incorporated in computer simulation.

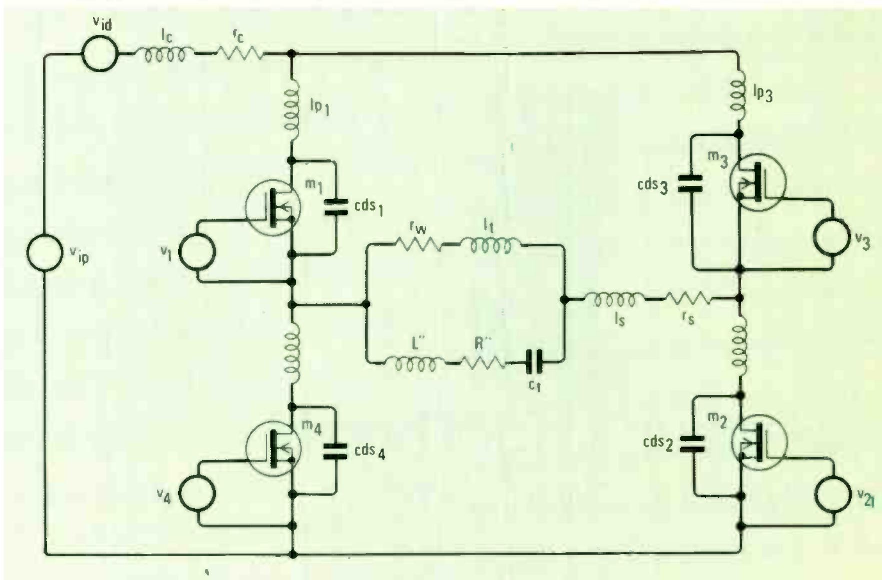
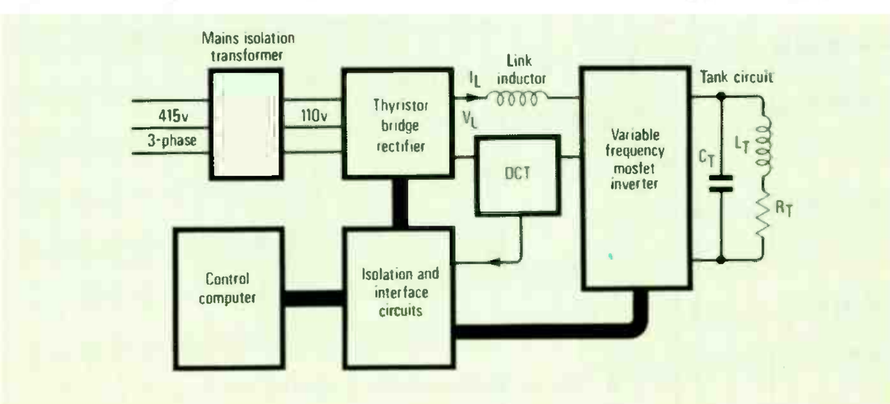


Fig. 1. Block diagram of microprocessor-controlled induction heating power supply.



the output of the power supply accordingly, Fig.1. Operation of the power supply at the resonant frequency of the tank circuit reduced the switching and diode conduction losses in the mosfets and hence increased the operating efficiency of the inverter. The subsequent reduction in the semiconductor device junction temperature improved the capability of each device to withstand transient overcurrents and hence improved the reliability of the power supply. Transient overcurrents are, of course, inherent in induction heating applications due largely to short circuits of the work coil or spurious turn-on of devices in the electrically noisy industrial environment in which these power supplies must operate.

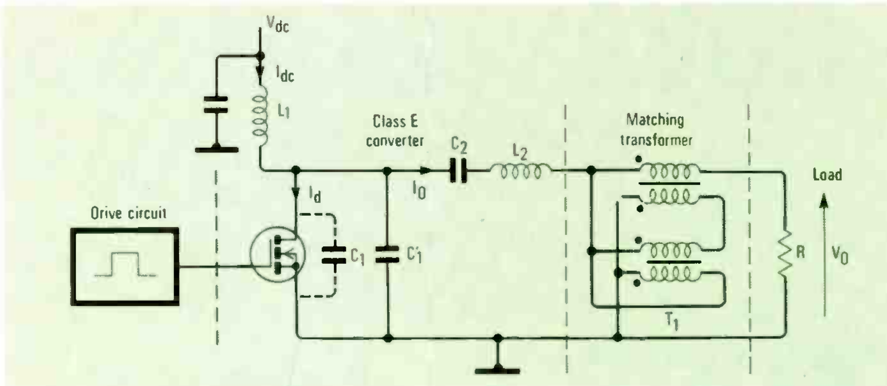


Fig.5. Basic class E amplifier circuitry.

Computer simulation

The power mosfet has high frequency capabilities, low driver power requirements and can be paralleled relatively easily to produce relatively high power units. However if switching losses are to be minimized the transistors must be switched at a fast rate and there are practical restrictions on the minimum parasitic lead inductance that can be achieved when devices are paralleled for high power units. These two factors create voltage spikes in the lead inductance and excessive ringing between the lead inductance and the drain source capacitance can be a major problem. An understanding of the causes of the ringing and the development of a method of reducing its detrimental effect on the solid-state circuitry are of paramount importance if a successful transistorized induction heating power supply is to be produced.

An elementary analysis of the current-fed full-bridge inverter has been reported[4] in which the initial design of the matching circuitry for a 100kHz, 2.5kW prototype unit was described. A more detailed and flexible computer-based analysis has since been carried out to extend the understanding of the operation of the unit and to investigate in more detail the design of the tank circuit.

Simple parallel resonance tank circuit

The circuit in Fig.2 was simulated with component values L_c 10mH, r_c 0.5Ω, $L_{p1\text{-}4}$ 50nH, $C_{ds1\text{-}4}$ 2nF, L_t 8.1μH, r_w 0.53Ω c_t 50nF, L_s 0.7μH, r_s 0.1Ω, L″ 0mH, R″ 0Ω, gate drive voltage 15V, and switching frequency of the inversion bridge 250kHz.

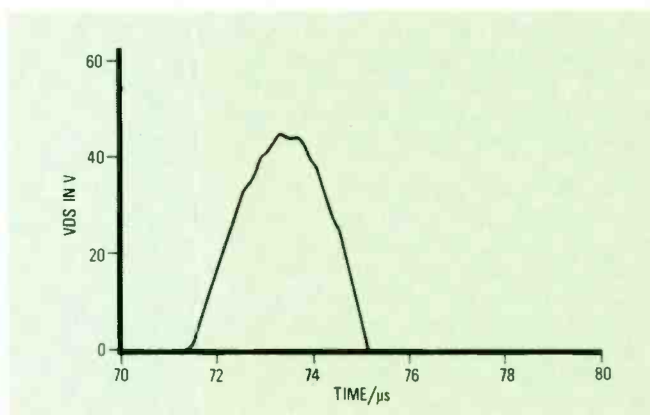


Fig.3. Theoretical waveform using Spice of drain source voltage across a mosfet feeding two-element tank circuit.

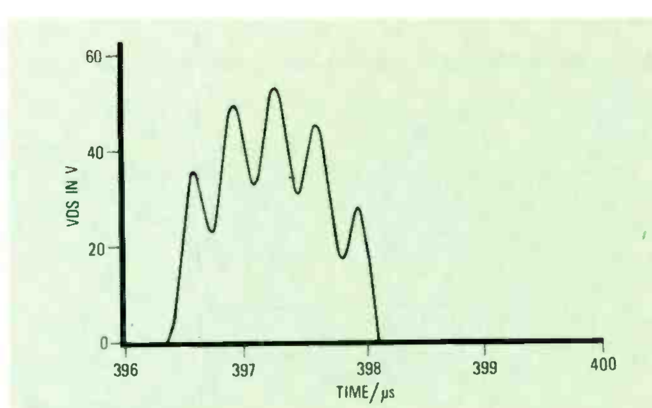


Fig.4. Theoretical waveform predicted across drain to source of mosfet when a modified tank circuit used.

The drain-to-source voltage by the analysis using the spice simulation package agreed well with practical waveforms[4], see Fig.3.

There are about five full cycles of ringing on the half sinusoid of voltage across the drain to source of mosfet2. The major component of the ringing is therefore at about 2.5MHz.

The voltage across the workcoil is free of ringing because the tank circuit capacitor presents a low impedance to ringing currents relative to other components in the path of the ringing current.

Modified tank circuit

To reduce ringing the workcoil was connected in a modified parallel resonant tank circuit, as shown in Fig.2. The circuit was simulated with the same component values as in previous section and in addition $C_{ds1\text{-}4}$ 40nF, L'' 9.8nH, r_w 0.2Ω and R'' 0.25Ω. switching frequency 140kHz. Waveforms of mosfet voltages in steady-state conditions are shown in Fig.4 which again agree well with the resultant practical waveforms[4].

Higher frequency units

To extend the frequency range of operation into the megahertz region a detailed assessment of the possible devices and circuits has been carried out[5,6]. Prototype class E switching-mode power amplifiers have been developed to assess their usefulness as high frequency power source for process heating applications.

The class E amplifier was developed in the mid-1970's for use in lightweight. low power high efficiency power converters and r.f. amplifiers. By the method of operation, the class E amplifier eliminates the simultaneous high voltage and current stress on the active device during switching transitions by shaping the device current and voltage waveforms.

The desired waveforms for class E operation can be produced to any degree of accurancy by increasing the complexity of the load network. However, first-order approximations can be achieved using only three or four discrete components in the load network and conversion efficiencies of over 90% have been achieved.

RF mosfet amplifier

The switching circuitry for the r.f. mosfet amplifier was designed around a Motorola MRF150. The specification of the prototype was for an input power of 75W and a desired operating frequency of 5MHz. This gave an anticipated maximum drain current of 12A and a drain-source voltage of 96V. Using the design equations the circuit components required (Fig.5) were C_1' 1.18nF, C_2 1.78nF, L_1 7.34μH, L_2 0.77μH, and R 4.8Ω. The initial load resistance of 4.8 ohms was chosen for ease of component choice, but in the later stages of the work a matching transformer was included so that power could be delivered to a 50-ohm load. In most high frequency heating applications the load circuitry is nominally designed to 50 ohms. An approximately 9:1 impedance-ratio transformer was used consisting of two ferrite-cored toroids with 0.9mm diameter enamelled copper wire twisted-pair windings. With a d.c. input of 30V and 2.5A (i.e. 75W) the power into the 50 ohm load was 70W at 5MHz giving a conversion efficiency of 90% (ref 7).

Power mosfet amplifier

In the initial investigations on switched-mode power supplies operating in the MHz region r.f. power mosfets were used. The cost was thought to be a major hindrance to the commercial viability of these solid-state power sources and efforts were made to utilise the much cheaper standard power mosfets. Initially the active device chosen for 150W, 7MHz prototype was the IRF630 having a 200V breakdown voltage (drain to source) 6A current carrying capability (at 100°C), 800 pF input capacitance and 450pF output capacitance (maximum values).

The prototype has been operated at a number of frequencies by altering component values from 4.5MHz through to 8MHz, efficiency in all cases has been in excess of 85% and typically is higher than 90%.

continued on page 1022

HOW TO COMBAT WAVEFORM DISTORTION BY SWITCH-MODE SUPPLIES

Wide usage of switched-mode supplies has led to high levels of mains pollution. Don Peddar of ERA Technology shows how to tackle the problem

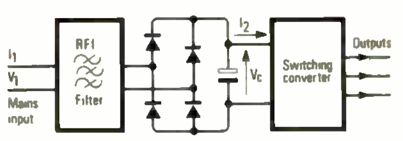
The use of linear techniques in power supply design has been largely superseded by the use of switched-mode circuits, especially in the computing, data processing, and communications industries. This change has taken place despite the higher levels of electrical noise inherent in the use of switched-mode techniques because of the considerable reductions in size, weight and power loss and the savings in cost which can be made. S.m.p.s. users – generally original equipment manufacturers – are demanding in nature especially where costs are concerned. They call for ever cheaper power supplies and as a result a large percentage of the s.m.p.s. being manufactured and installed today have simple, minimum-cost input stages which draw non-sinusoidal currents from the supply mains.

The installed capacity of s.m.p.s. increases each year (more than 130MW installed in the UK alone during 1986) and, especially in the computing and related industries, concentrations of s.m.p.s. loads are common. The power rating of a single power unit may be low, say 100 to 300W, but the total load in a concentration such as a computer terminal room or dealing room may be several kilowatts or tens of kilowatts. Under these conditions the non-sinusoidal nature of the supply components and resulting in supply current may cause severe operational problems, requiring over-rating of power system component and resulting in supply voltage waveform distortion with resultant malfunction of other equipments.

The cause

Although the base cause of current waveform distortion lies in the demand for minimum-cost p.s.us, technically it is the simplicity of the input stages that is responsible. The form of input stage most commonly employed is a simple bridge rectifier/reservoir capacitor system fed from the a.c. mains supply via a low-pass filter which serves to reduce conducted radio frequency interference to acceptable levels, Fig.1.

The reservoir capacitor acts as a d.c. source for the switched-mode power conversion stage. The capacitor charges to just less than peak supply voltage twice per cycle, partially discharging between successive charging actions as it supplies energy to the converter stage. Input current flows only when the supply voltage exceeds the capacitor voltage, that is, for a short time during each supply half-cycle, so that the input current waveform takes the pulsed form shown, Fig.2. For a given output power an increase in capacitor value results in a reduction in the fall in voltage during discharge and hence in a reduction in the duration of the recharging current pulse. Since the same amount of energy must be fed to the system a reduction in pulse duration implies an increase in pulse amplitude.



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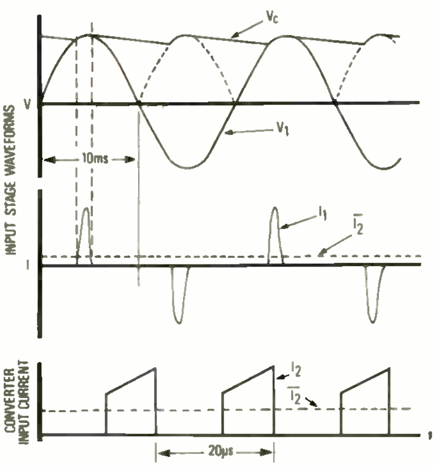

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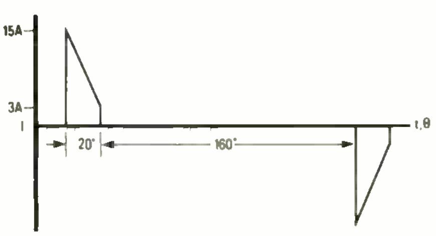


3.

The reservoir capacitor is the prime energy store of the s.m.p.s. and a major requirement is that sufficient energy be stored to provide 'hold-up' for 10-20ms in the event of transient mains failure. This requires large capacitance values so that the durations of the input current pulses are short, often only 1ms in each 10ms half-period. The current drawn from the reservoir capacitor by the switching converter takes the form of short pulses of repetition frequency typically in the range 50 to 100kHz and with short rise and fall times Fig.2(b). Because the reservoir capacitor is imperfect, having series inductance and resistive elements, this pulse discharge current results in the generation of high-frequency voltage components across the capacitor terminals. Whenever the input rectifiers conduct these h.f. components are transmitted to the rectifier bridge a.c. terminals, appearing as conducted r.f.i. components. At the end of each conduction period reverse-recovery currents flow for a short time and may terminate abruptly, generating further r.f.i. A low-pass filter interposed between the bridge rectifier and the supply mains reduces these conducted components to an acceptable level and prevent malfunction of other equipment operating from the same mains supply.

The peak value of the capacitor recharging current is determined by the mains supply and reservoir capacitor voltages and the circuit impedances. Since cost is an important criterion in selection of circuit configuration it is rare for p.s.u. manufacturers to include components specifically to limit peak current – it is assumed that the combination of r.f.i. filter impedance and mains source impedance will be sufficient to limit the peak current to a safe level. This is not always the case, and the matter will be mentioned again below.

The effect

The pulsed input current has a high r.m.s. level, low power factor and high crest factor and this results in poor utilisation of the mains distribution wiring and components. If the source impedance is not negligible then the high peak currents and rates-of-change of current associated with the pulsed waveshape can result in distortion of the supply voltage waveform which can result in malfunction of other equipments requiring a mains supply of high purity. This effect is worst where the prime power system is of limited size, as in a aircraft or ship, in off-shore applications or when operating from, for example, an uninterruptable power supply.

The severity of the problem is best illustrated by a simple numerical example. The figures given are approximate. Consider an s.m.p.s. having a 450μF reservoir capacitance operating from a 240V 50Hz supply and providing a power input to the switching converter of 330W. With these values the peak capacitor voltage will be 340V and the minimum voltage, just as recharge commences, will, in normal operation, be 320V. This gives a mean capacitor voltage of about 330V and an average input current to the switching converter of 1A.

The capacitor discharges for about 160° and recharges for 20° of each mains supply half-period. During recharging the mean recharge current will be 8A which, with the 1A switching converter current, gives a mean input current of 9A. For the sake of this example, assume an input current pulse of trapezoidal form, with peak level 15A as shown in Fig.3, this being less bad than waveforms generally found in practical systems. The r.m.s. value of this current waveform is 3.2A giving a normal-operation power factor of 0.43 and a crest factor of 4.7.

Mains distribution wiring and components are less than 50% utilised in the example given above and this figure is typical. The implication is clear; if a concentration of s.m.p.s. loads requires a total power input of 100kW, then the distribution wiring and components, including any u.p.s. system, would need to be rated at more than 200kVA. If the supply source impedance is low, the peak current levels will be much higher than suggested above with consequent worsening of power factor and crest factor. In applications where s.m.p.s. are used in close proximity to mains supply alternators, crest factors of 40 have been measured and reservoir capacitors within the s.m.p.s. have been destroyed as a result of excessive peak current levels.

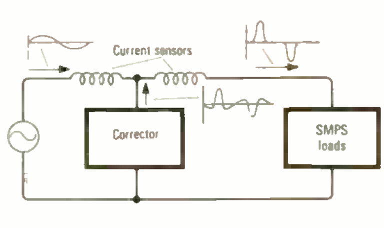
Further problems with distribution wiring occur in three-phase four-wire systems where s.m.p.s. having single-phase inputs are connected line-to-neutral and distributed among the phases. Even if the loadings on the three-phases are identical, the neutral current will not be zero and may be of the same order as the line currents.

The cures

Original equipment manufactures and equipment purchasers must learn that costs cover more than purchase prices and that there is some duty to minimize pollution of the mains supply. New installations should be designed so that the waveform distortion problem does not arrive and in existing installations corrective action should be taken. If these actions are not taken voluntarily, which is probably unlikely, then legislative action is almost certain to follow.

For new equipment there is a remedy ready to hand; s.m.p.s. manufacturers are well able to produce power supplies which operate with power factors of 0.95 or higher and which have low levels of conducted r.f.i. The penalties lie in higher costs and in some increase in size, weight and power loss. If o.e.m's specify that the input current waveform is to be of high purity, they will find the s.m.p.s. manufacturers ready to oblige. For exising installations the problem is greater. It would be unrealistic to expect users to arrange for all power supplies in their systems to be stripped out and replaced, but there is an alternative.

Recently, work has been carried out at ERA Technology on the development of active current-waveform corrector circuits. These are connected across the supply in parallel with distoring loads as shown. The supply line current is monitored on either side of the connection point and the corrector unit generates current pulses of the correct shape, size and polarity to bring the



4.

current waveform on the generator or upstream side of the connecting point back to sinusoidal. The corrector units are effectively current sources and may be paralleled to increase capability. As an example of the use of this approach, if a 5kVA u.p.s. was driving a system of s.m.p.s. loads consuming 2.5kW at a power factor of 0.5, then the use of a suitable corrector would enable the s.m.p.s. loading to be almost doubled without modification to the u.p.s. Products based on this technique are expected to be brought to market early next year.

Dr Peddar is manager of the power electronics department of ERA Technology

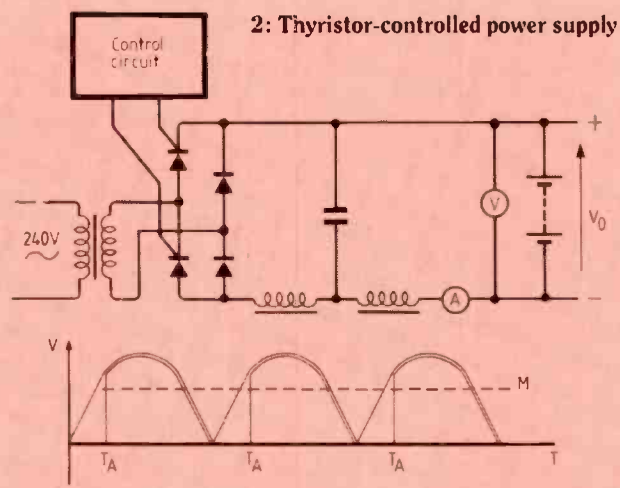
POWER SUPPLY DEVELOPMENT FROM A TELECOM STANDPOINT

Growth in data transmission has implications for power supplies, especially switched mode, according to Eltek U.K.'s technical manager, M. Bandar.

Greater use of telecoms systems for data transmission has recently emphasized the need for secure power, creating a growing demand for high quality standby power systems. Complexity of the standby power varies for different applications, but the main requirement is always the same, that is to protect the load from undesirable effects on the supply line. Many companies have suffered the consequences of improper standby power facilities, which can result in financial disaster arising from loss of data.

This article views a variety of systems based on the three methods of implementation; linear, thyristor and switched mode.

2: Thyristor-controlled power supply



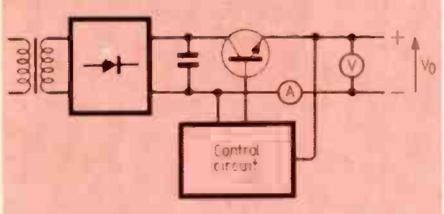
FOR

* Cheap to produce
* High efficiency
* Reliable
* High power application >100kVA

AGAINST

* Large and heavy
* Noisy
* Output voltage regulation can be imprecise
* Poor transient response

1: Linear power supply



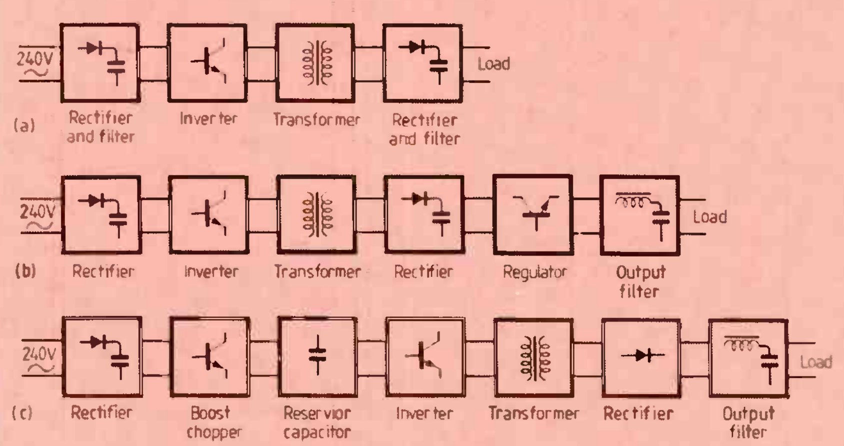
FOR

* Low cost for low power
* Min. output ripple and r.f.i.
* Good regulation
* Good transient response

AGAINST

* Confined to low power <40W
* Forced cooling required at higher ratings
* Inefficient <50%
* Low power/weight (volume) ratio

3: Switched-mode power supply



FOR

* Output of either polarity
* High efficiency
* High power/weight (volume) ratio
* Output voltage ≥ the input
* Fast transient response
* Good regulation
* Modular
* Low audible noise

AGAINST

* Complex circuitry
* r.f.i.
* Costly at low power

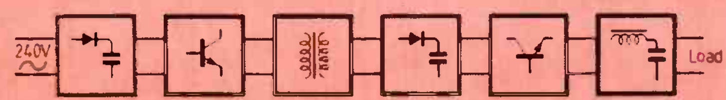
SMPS without pre regulation (a), and with, (b) & (c).

TYPES OF SWITCHED MODE SUPPLY

Switched-mode techniques are employed in the design of several types of power supplies, each with its specific requirements:

* a.c./d.c. converter(rectifier)
* d.c./d.c. converter
* d.c./a.c. inverter
* Uninterruptable power supply
* Frequency and voltage stabilizer
* Frequency converter.

4: AC/DC converter

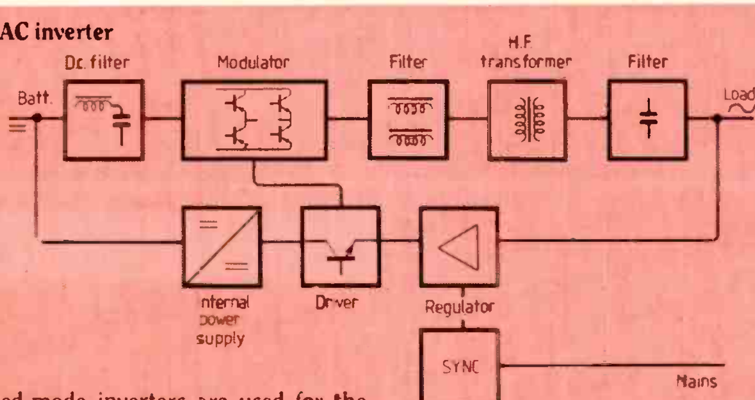


A.c. to d.c. converters or rectifiers can be used as battery chargers for standby applications or as power supplies without batteries. These converters can also be used as an integral part of an uninterruptable power supply system. Series or parallel operation of several power supplies is possible to facilitate a modular system concept. Efficiency is 90%.

5: DC/DC converter

Reliable and precise d.c. supply can be obtained from a d.c. source (regulated or not). They are used to produce stable output voltages higher or lower than the level of the input voltage, with or without isolation. Efficiency of up to 95% is possible. In a modular system, d.c. converters provide alternative supply voltages from the main d.c. output, therefore allowing other loads to be connected to the system.

6: DC/AC inverter

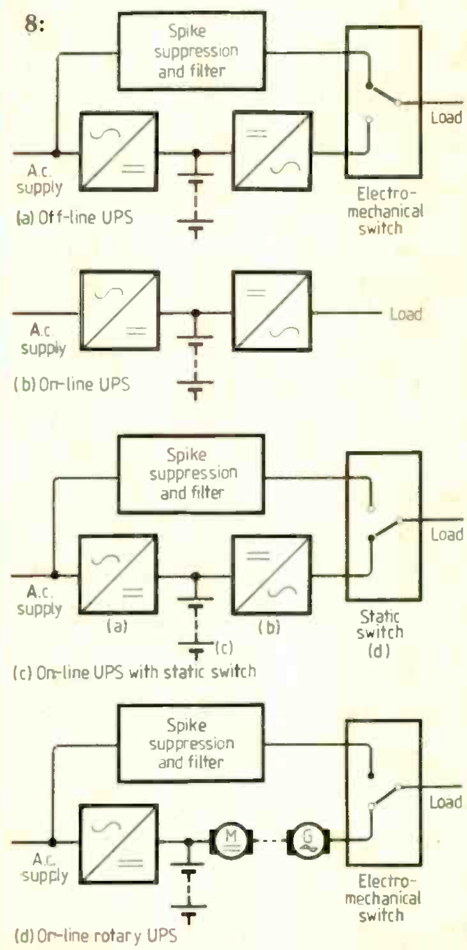


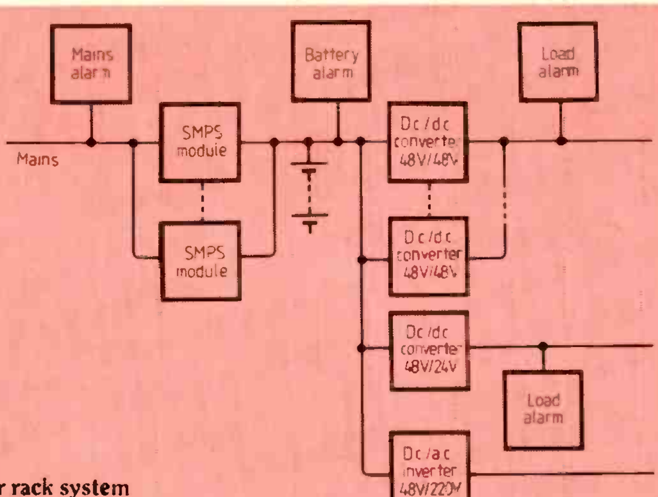
Switched-mode inverters are used for the operation of equipment, sensitive to public mains fluctuations and equipment that in the event of breakdown in public mains may effect personal safety, lead to damage of material or result in financial loss. Together with a battery and associated rectifier switched-mode inverters form an uninterruptable power supply system for loads requiring a secure source of a.c. power, independent of the public mains supply.

TYPES OF UNINTERRUPTIBLE SUPPLY

UPS systems are the only power conditioning equipments that provide protection against all the irregularities and disturbances on the commercial mains supply. These disturbances could be in the form of spikes and noise, dips and surges with varying durations. Each type of u.p.s. – below – comprises four basic elements: rectifier/charger, d.c. to a.c. inverter, storage battery, by-pass facility – not always included.

8:





7: Power rack system

In a modular system the addition of more power supplies to accommodate increasing load requirement introduces no problem. Different types of module can be mounted in a common cabinet to provide supply for different load ratings. Power rack systems incorporate many protection and alarm facilities including low and high voltage, main failure, rectifier trip, module failure, load disconnect.

FOR

* Flexible system
* Easy to install
* Easy to operate/maintain
* Light weight

AGAINST

* Initial equipment cost may be higher than conventional equipment

In specifying a u.p.s. system, two main decisions have to be made:
– whether to incorporate a static system or a rotary system,
– on-line system or off-line system. The difference is that in an on-line system, power conversion to the load is via the inverter in the u.p.s. system, whereas in an off-line system power is supplied to the load via mains bypass facility and is only transferred to the u.p.s. system on mains failure.

Rectifier and charger. The supply from the mains is converted to a regulated d.c. output to supply the inverter and to charge the battery.

Inverter. The direct voltage from the rectifier or battery is converted to an alternating voltage. Inverter voltage is filtered to reduce the harmonic content and provide final shaping of the output voltage waveform.

Batteries can be regarded as the easiest way of supplying d.c. standby power. The battery is connected between the rectifier and the inverter. In most applications the battery is in circuit at all times, connected to the d.c. link, however, in other applications it may be separately charged and be connected to the d.c. link only when the mains supply fails. In either case the battery will immediately supply power to the inverter. Hold-up time of the battery can vary for different applications but is typically 5 to 15 minutes, providing sufficient time for an auxiliary source to be brought into service.

By-pass facility. This allows the load to be transferred to an alternative mains supply while system maintenance is being carried out or should the u.p.s. fail.

In transfer of the load from the u.p.s. output to the bypass, the load should experience no break in the power. To achieve this, the inverter is normally synchronized with the bypass mains supply. the fast transfer action is accomplished by means of an electronic switch, referred to as a static switch. The switch typically comprises a pair of back to back thyristors.

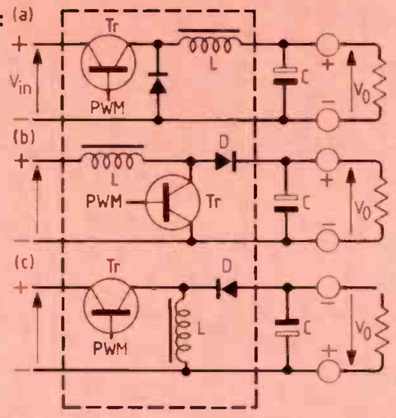
A rotary u.p.s. provides all the basic requirements of a static system; the main differences are: d.c.-to-a.c. inversion method and the type of switch used for transfer of load to the bypass supply. In a rotary system the inverter can comprise a d.c. motor with shunt field control and a separately excited alternator mounted on a common bedplate. The d.c. motor is capable of operation from either the rectifier or battery, and drives the alternator. The alternator speed is closely regulated to maintain a constant-frequency output. The output voltage from the alternator is a low distortion a.c. voltage which is regulated by an automatic voltage regulator. The alternator output is synchronized with the bypass supply.

As far as performance is concerned, there is little to choose between a static and a rotary u.p.s. Financial considerations and previous experience can be considered as the determining factors on u.p.s. selection.

SMPS CLASSIFICATION

There are two classifications associated with switched-mode power supplies. The first classification refers to the type of output voltage required, below, and the second to the topology used to implement the conversion. Using the three basic elements, an inductor, diode and transistor switch:

9:



(a) Step-down circuit (buck), (b) step-up circuit (boost), (c) inverting buck-boost circuit.

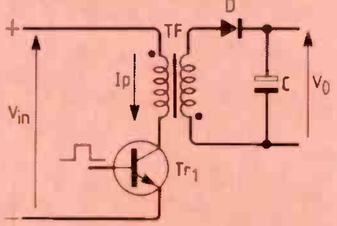
The second classification includes the following circuit configurations or topologies:

- ★ flyback
- ★ forward
- ★ push-pull
- ★ half-bridge
- ★ full-bridge
- ★ resonant.

10: Flyback topology

When the transistor is turned on current flows through the transformer primary. The diide is reversed biased owing to winding notation. When the transistor is turned off, the voltage induced in the secondary winding causes the diode to conduct therefore power is transferred to the output. The cycle is repeated.

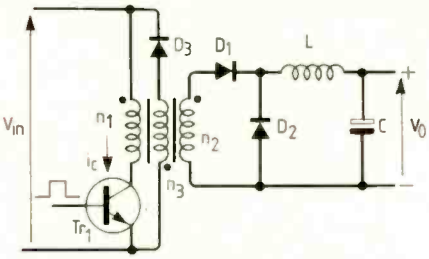
This topology can be used in continuous or discontinuous mode, the main difference being that the device current will rise from zero in discontinuous mode, but will have an initial value in continuous mode of operation. The consequences are that in continuous mode of operation, rectifier diodes will have to be faster and transformer size will be larger than that used in discontinuous mode. Output capacitor size will be smaller, almost by a factor of two, than that of a discontinous mode operation.



FOR
- ★ Low cost
- ★ Multiple outputs possible. Good tracking between outputs
- ★ No inductor needed In Secondary

AGAINST
- ★ High peak current
- ★ Difficult to stabilize the loop in contınous mode.

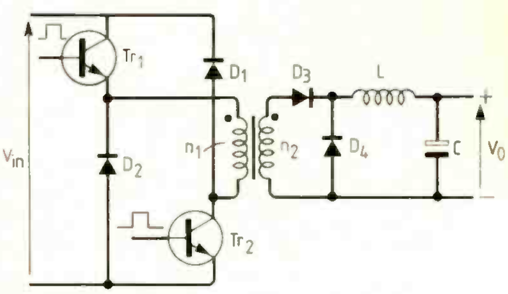
11: Forward topology



In a forward converter energy is supplied to the output during the conduction period of the transistor. To avoid destruction of the transistor, the magnetizing energy stored in the primary inductance of the transformer during conduction period of the transitor, must be recovered. This is accomplished using a magnetizing winding (n_3) and diode (D_3) which allows the stored energy to return to the supply. Assuming a ratio of 1:1 between primary winding and the magnetizing winding, the maximum voltage across the transistor will be limited to $2V_{in}$ and the maximum duty cycle must be limited to 50% for total demagnetization.

For high supply voltages, two transistors can be used in what is known as asymmetrical half-bridge forward converter, below, where the maximum voltage seen by each transsitor is limited to V_{in} and demagnetization is accomplished by the primary winding and free-wheeling diodes D_3 and D_2. Again maximum duty cycle is limited to 50% since magnetizing and demagnetizing times are equal.

12: Half-bridge forward converter



FOR

Single transistor topology
- ★ Only one high voltage fast diode
- ★ Simplicity

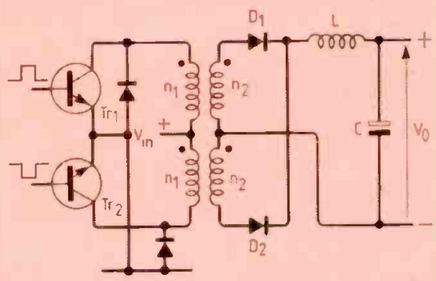
Two transistor topology
- ★ Simple transformer
- ★ $V_{CE\,max} = V_{in}$

AGAINST

Single transistor topology
- ★ Poor transformer utilization, compared to full and half-bridge circuits
- ★ $V_{CE\,max} = 2V_{in}$

Two transistor topology
- ★ Two high voltage fast diodes
- ★ Two transistors used
- ★ Tr_1. requires floating drive

13: Push-pull topology



The transistors alternately turn on and the voltage across the secondary will be V_{in} multiplied by the turns ratio of the transformer. Frequency of the secondary waveform will be twice the switching frequency which means simple filtering on the output can be designed for. Each device must be rated for twice the supply voltage as this is the voltage seen by one transistor when the other is conducting.

Like other bridge circuits, end stop (dead time) must be allowed for to avoid conduction of both transistors at the same time. This topology is prone to flux assymetry in the transformer, but is well suited in applications with low supply voltage. Simple drive circuits can be used as the two device emitters are at the same potential.

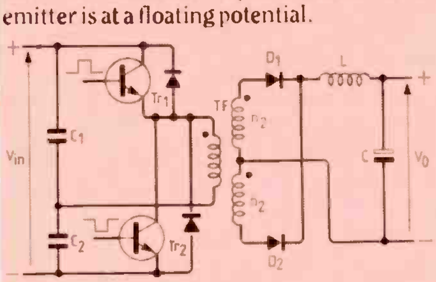
FOR
- ★ Efficient design
- ★ Easier drive circuit

AGAINST
- ★ $V_{CEmax} = 2V_{in}$
- ★ Possible flux asymmetry in the transformer could be corrected with current mode p.w.m. circuits.

14: Half-bridge topology

Half and full-bridge topologies are mandatory for higher power applications, whereas flyback or forward converters are used at lower power rating. Each transistor is turned on alternatively, connecting one side of the transformer to either the positive or the negative rail. The other side is connected to the midpoint of the two capacitors in series at $V_{in}/2$. This enables an alternating voltage to appear at the transformer primary, which is transferred to the output.

As the transistors are connected in series, the maximum voltage that each will be subjected to is equal to V_{in}. Isolated base drive for transistor Tr_1 is required as its emitter is at a floating potential.

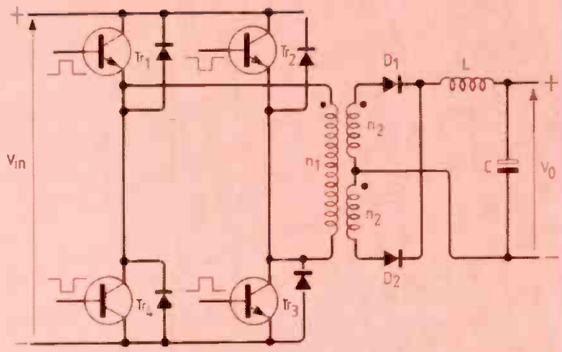


FOR
- ★ $V_{CEmax} = V_{in}$
- ★ Good transformer utilization

AGAINST
- ★ Tr_1 requires floating drive
- ★ Transistor storage times must be within close tolerance to avoid flux imbalance.

15: Full-bridge topology

This topology is used for higher power applications. Each pair of transistors are turned on alternatively. Transistors Tr_1, and Tr_3 are switched on for a period goverened by the control circuit. Transistors Tr_2 and Tr_4 are switched on only when Tr_1 and Tr_3 have ceased to conduct. To avoid simultaneous conduction of the two transistor pairs, end stop (dead band) must be accommodated for. Tr_1 & Tr_2 have floating emitters and this makes the drive circuit more difficult.

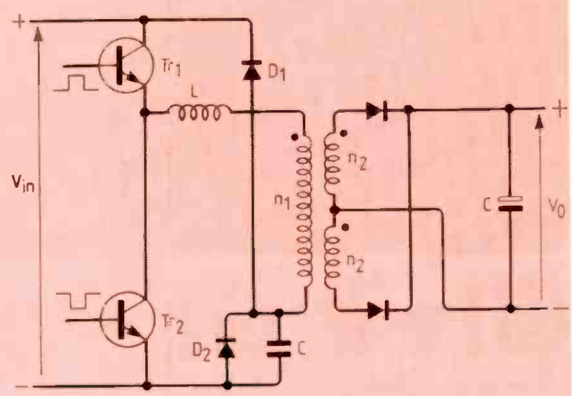


FOR
- ★ Simple transformer
- ★ High power application
- ★ $V_{CEmax} = V_{in}$

AGAINST
- ★ Requires four transistors and four high voltage fast diodes
- ★ Complex drive circuitry

16: Resonant converter

When Tr_1 is switched on, energy is delivered from the supply to the output and capacitor C. When Tr_2 is switched on, the energy stored in capacitor C is transferred to the output load. Diodes D_2 and D_1 clamp the voltage across the capacitor to the positive and negative rails respectively.



When Tr_1 is on, the input voltage is applied across the series combination of L, transformer primary and capacitor C. The primary winding current increases in a sinusoidal manner and the voltage across the capacitor begins to rise. The inductor voltage decreases and when it reaches zero, the current in the resonant network will have reached its peak. Reversal of the inductor voltage causes the current to decrease towards zero. At the instant of zero current Tr_1 is turned off and Tr_2 turned on. The current in the primary winding increases as energy is transferred from the capacitor to the output load. Once Tr_2 has ceased to conduct, the cycle is repeated with Tr_1 turning on again.

Resonant converters can be designed using variable frequency or p.w.m. mode of control to provide a stable output voltage.

FOR
- ★ Higher overall efficiency
- ★ No switch on losses
- ★ Reduction in e.m.i.
- ★ Increased reliability
- ★ Smaller weight and volume

AGAINST
- ★ Switch rating is higher than that of a conventional regulator
- ★ Requires additional LC network if compared to a flyback converter

TAIL PIECE

Of the three power conversion methods presented, the thyristor-controlled regulator provides the most economical answer for high power application (>100 to 200kVA). For lower power application (<40VA) a linear regulator is the cheapest solution but by no means the best. The switched-mode supply shows many advantages over its rivals, making it the best method of conversion for low-medium power. The techniques used in s.m.p.s. design provide high power to weight and volume ratios. One of their most interesting aspects is the suitability for use as a modular system.

The suitability and selection of any power supply depends greatly on the nature of the load. In some cases, user's particular preference or experience can override all other matters.

One of the main objectives of power supply designers in the future will be to reduce cost and achieve higher power/weight and volume ratios. It is ideal to increase the switching frequency so that the size of the magnetic and filtering components can be reduced, but of course this will cause an increase in radio frequency interference generated within the power supply, particularly at higher power ratings.

With recent advancement in integrated circuit design and manufacture, leading to commercial availability of high-voltage mosfets, current-mode controller i.cs, bimos devices and surface mount technology, designers can move toward designing future power supplies with higher efficiency, increased reliability, reduced interference and more customer interface facilities.

ADVANCES IN SOLID-STATE POWER SUPPLIES FOR RF HEATING

continued from page 1015

A prototype 3.3MHz, 100W output class E amplifier has also been constructed and its suitability assessed for high frequency heating applications. The amplifier was based on two IRF450 power mosfets in parallel as its switching elements. This design illustrates the high power possibilities of this type of power source and an alternative design using push-pull circuitry is also under consideration.

Microprocessor control of class E amplifier

Design of class E waveform shaping circuits is based on constant load impedances. Any variation of the load can lead to a loss of efficiency or possibly damage to the active device.

Another prototype device has been constructed which includes monitoring circuitry incorporated in a class E amplifier supplying a variable impedance load and uses a computer to control the parameters of the amplifier so that it operates as efficiently as possible and never allows active device failure. The amplifier was designed to operate between 1 and 5MHz and be capable of delivering 100W into a load which varied between 2 and 12 ohms.

The control computer receives signals from the outputs of both the rectifier and the class E sections. These first pass through an isolation and interface section before being processed. In return the computer provides input signals for the rectifier and component selection for the class E sections, providing overall control of the system.

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Professor Hobson and co-authors P.W. Tebb and S. Hinchliffe are at the department of electrical and electronic engineering, Brighton Polytechnic. *This article is based on material presented at the IEE's April conference of Power Electronics.* *Much of the work described was sponsored by SERC and Stanelco Products Co.*

Magnetic heading sensor

A compact circuit to provide a 0-5V analogue of heading for telemetry

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The scheme is based on the Humphrey pendulous magnetic flux valve detector type FD 09-0101-1, wound for 1 degree accuracy. The pendulous nature of the sensor avoids errors in measurement due to aircraft attitude within 20 degrees of the vertical, since only the horizontal component of the earth's magnetic field is sensed.

The design of an electronic compass using a Fluxgate sensor described in reference 1 explains in brief the operation of the fluxgate sensor. The circuit used suffers from the limitations that a portion has to be co-located with the sensor coil, operates with a square-wave excitation leading to e.m.i. and is not compact.

The Humphrey flux valve detector is recommended for use with a sine-wave excitation at a nominal frequency of 3kHz. The outputs when filtered show a resolver type of output at double the excitation frequency. When using this sensor with a Type 5 harmonic oscillator resolver to d.c. converter[2], it is necessary first to generate a reference at double the excitation frequency, filter and phase-sensitive-detect the sensor outputs using this reference to obtain direct voltages proportional to the sin and cosine of the heading angle. These voltages are to be set as initial conditions on the two integrators which, along with an inverter, form the harmonic oscillator loop. If the oscillator is now permitted to start, the quadrature outputs begin at the initial conditions set, at a frequency determined independently by the integrator time constants. The time between the start of the oscillations and an event such as the first negative zero crossing of one of the oscillator outputs is a function of heading angle.

The present circuit, while using the Type 5 harmonic oscillator resolver to d.c. converter, employs a triangular-wave excitation which is easier to generate, a novel scheme for deriving the frequency-doubled reference, half-wave phase-sensitive detection on the unfiltered sensor outputs and a method of time-sharing components between the phase-sensitive detector and harmonic oscillator, leading to a compact circuit.

CIRCUIT

The details of the Humphrey sensor and the circuit diagram are shown in Figs 1 and 2. The Burr-Brown universal active filter UAF 41 (IC_1 and IC_3) shown in Fig.3, containing two integrators, an inverter and an uncommitted op-amp, lends itself directly to the implementation of the functions required. IC_1 is used for the generation of the triangu-

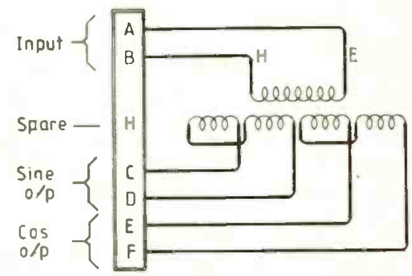
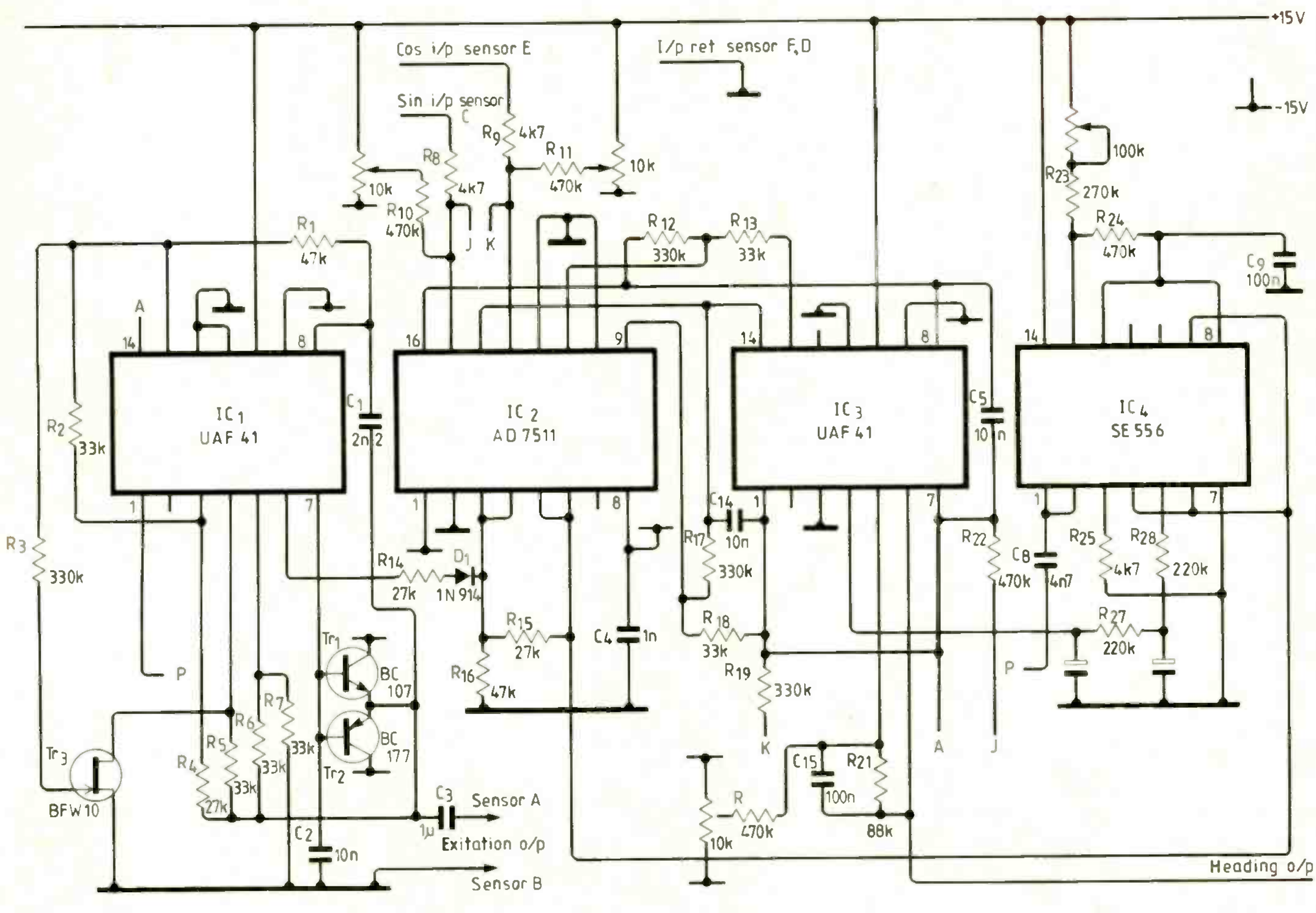


Fig. 1. Humphrey magnetic flux detector

Fig. 2. Heading sensor circuit diagram



lar wave excitation, using a standard integrator comparator loop, as the frequency-doubled reference and as a comparator for the harmonic oscillator output. The frequency-doubled reference required for the phase-sensitive detectors is derived on the square and triangular-wave outputs of the excitation circuit. Figures 4 and 5 show how the reference, bearing the necessary phase relationship to the excitation, and independent of frequency and component drifts with temperature is derived. This method is superior to frequency doubling by differentiation and rectification of the square wave, or rectification and shift of the triangle wave.

Figure 6 shows how a single op-amp is used for both the functions of a phase-sensitive detector and as an integrator. With S_2 closed and S_1 operated at the reference frequency the circuit acts as a half-wave, phase-sensitive detector, the rectified and filtered signal input being held on capaciter C_5. If both S_1 and S_2 are now opened, the circuit changes to an integrator with the initial condition set on C_5. In IC_3, two such circuit elements are interconnected along with an inverter to form a harmonic oscillator loop. The fourth op-amp is used as an output buffer. IC_4 is a SE 556 used for timing the overall circuit operation, and as a flip-flop to derive a pulse whose width is proportional to heading angle.

Heading angle ψ is evaluated by first obtaining K sin ψ and K cos ψ by half-wave phase-sensitive detecting the sensor outputs, setting these as initial conditions for the two integrators forming part of the harmonic oscillator loop, and initiating the oscillations. The flip-flop is set at the start of the oscillation and reset by the first negative-going zero crossing of the oscillator output. The flip-flop output width, which is proportional to heading, is averaged, offset and buffered to give the d.c. value of heading. Figures 7 and 8 show the typical waveforms.

PERFORMANCE

To calibrate the system, the sensor is placed on a non-magnetic stand capable of being rotated 360 degrees in the horizontal plane and graduated every 1 degree with an accuracy of 0.1 degree. The gain of the phase-sensitive detector has been set to obtain a K value of about 4 volts. R_{28} and R_{29} are used to offset-null K sin ψ and K cos ψ, such that the positive and negative maximum magnitudes obtained by variation of ψ are equal. Adjustments of R_{30} sets the clock

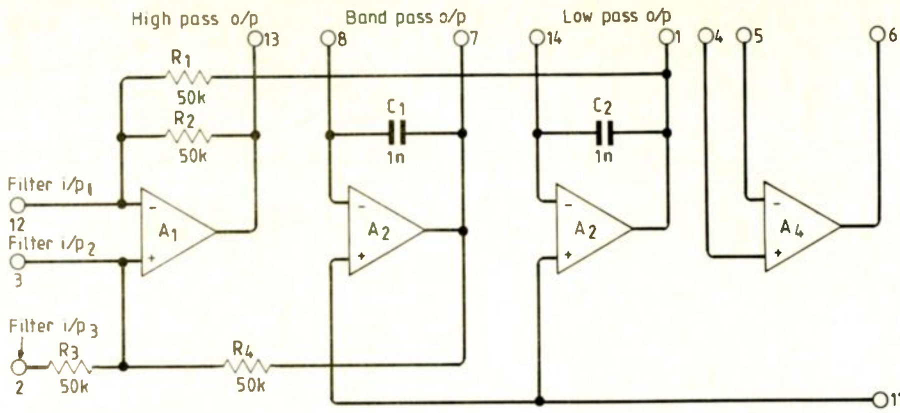


Fig. 3. Burr-Brown UAF41 schematic

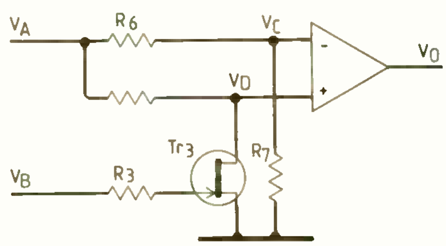


Fig. 4. Frequency-doubled reference circuit schematic

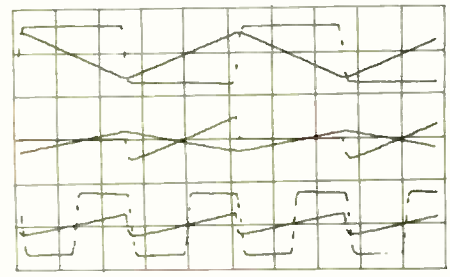


Fig. 5. Upper trace: triangle wave and square wave at frequency f. Middle trace: triangle and fet drain wave-form. Lower trace: sawtooth and comparator output at 2f. (All traces vertical scale 20V/div. and horizontal scale 0.1ms/div.)

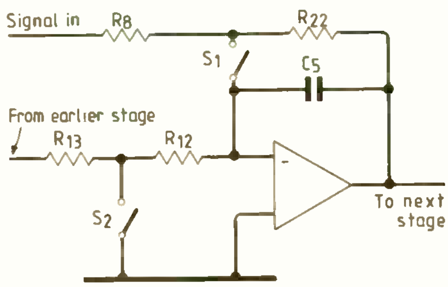


Fig. 6. Op-amp time shared between phase-sensitive detector and integrator schematic.

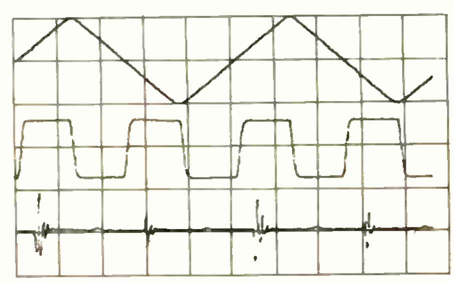


Fig. 7. Upper trace: sensor excitation (Tr_1, Tr_2 emmitters, 10V/div.) Middle trace: phase-sensitive detector reference (IC_1, Pin6, 20V/div.) Lower trace: typical sensor output (500 mV/div.) (Horizontal scale 0.1ms/div.)

frequency and indirectly the gain of the output. With the clock frequency set as one third of the harmonic oscillator frequency, the maximum variation of the final output is 5 volts. R_{31} is used to offset-null the output and, along with R_{30}, to obtain 0 to 5 volts for variation of heading 0 to 358 degrees.

A 2-degree changeover zone of uncertain heading exists. Accuracy depends primarily on the windings within the FD 09-0101-1 flux detector. Overall system accuracy is better than 1 deg. Table 1 shows the typical output variation with heading and change with temperature.

A count obtained by gating a crystal-derived pulse train by the flip-flop output may be used to get a digital indication of heading if desired.

Copies of printed-board layout and component placement diagram may be obtained from this office by sending an A4, addressed and stamped envelope, marked 'HEADING'.

Table 1, showing output variation with heading and change with temperature

Angle in degrees	Heading output in volts as a function of temperature 25°C	0°C	60 C
000	0.008	0.004	0.004
030	0.443	0.426	0.428
060	0.840	0.835	0.836
090	1.242	1.237	1.237
120	1.649	1.644	1.644
150	2.075	2.071	2.069
180	2.508	2.506	2.503
210	2.930	2.930	2.925
240	3.338	3.341	3.336
270	3.740	3.744	3.737
300	4.147	4.159	4.147
330	4.573	4.588	4.570
358	4.988	5.009	4.999

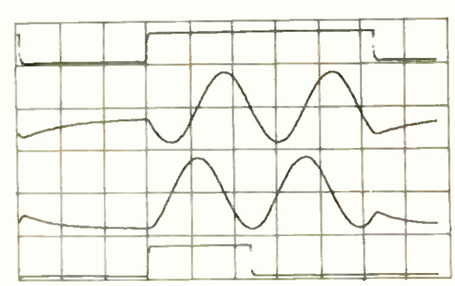


Fig. 8. Upper trace: clock output (IC_4, Pin 9, 20V/div.) Second trace: phase-sensitive detector (sin)/harmonic oscillator output (IC_3, Pin 7, 5V/div.) Third trace: phase-sensitive detector (cos)/quadrature output (IC_3, Pin 1, 5V/div.) Lower trace: flip-flop output (IC_4, Pin 5, 20V/div.) (Horizontal scale 10ms/div.)

References

1. Neil Pollock. Electronic compass using a fluxgate sensor. *Wireless World*, October, 1982.
2. Electronic Design – practical guide for synchro to digital converters. *Electronic Design* 9 April, 1970.

Demonstrating spectra and radiation

It is becoming increasingly important for engineers to understand how and why a circuit radiates. York University has been looking into the problem of demonstrating r.f.i. end electromagnetic compatibility.

PETER TURNER

Electromagnetic compatibility, e.m.c., and radio-frequency interference, r.f.i., have in the past been something of a dark art. Increasingly, however, e.m.c./r.f.i. theory and problem-solving techniques become more widely disseminated as more universities offer courses to undergraduates, service engineers and teachers.

Recently Dr Andy Marvin at the University of York had the idea for the demonstration circuit described here, which he uses to illustrate lectures in e.m.c. and r.f.i. As a research technician working in the department of electronics I designed, built and tested the circuit. When used with a suitable spectrum analyser, it shows some of the basic concepts of waveforms in the frequency domain – which many people have difficulty visualizing – as well as illustrating some of the problems of e.m.c. and r.f.i.

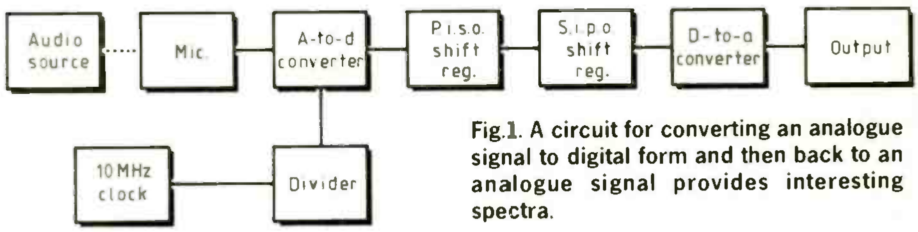


Fig.1. A circuit for converting an analogue signal to digital form and then back to an analogue signal provides interesting spectra.

DESIGN CONSIDERATIONS

My initial brief was for a 'typical' electronic circuit which would produce interesting spectra for display on a spectrum analyser. In the hope that the design would radiate a good spread of frequencies, ordinary circuit board was used and little attention was paid to layout. In other words I produced what would generally be regarded as a bad layout; with long loopy ground tracks, minimum decoupling, long transmission lines, mixed analogue and digital grounds, no ground plane etc.

Figure 1 is a block diagram of the circuit.

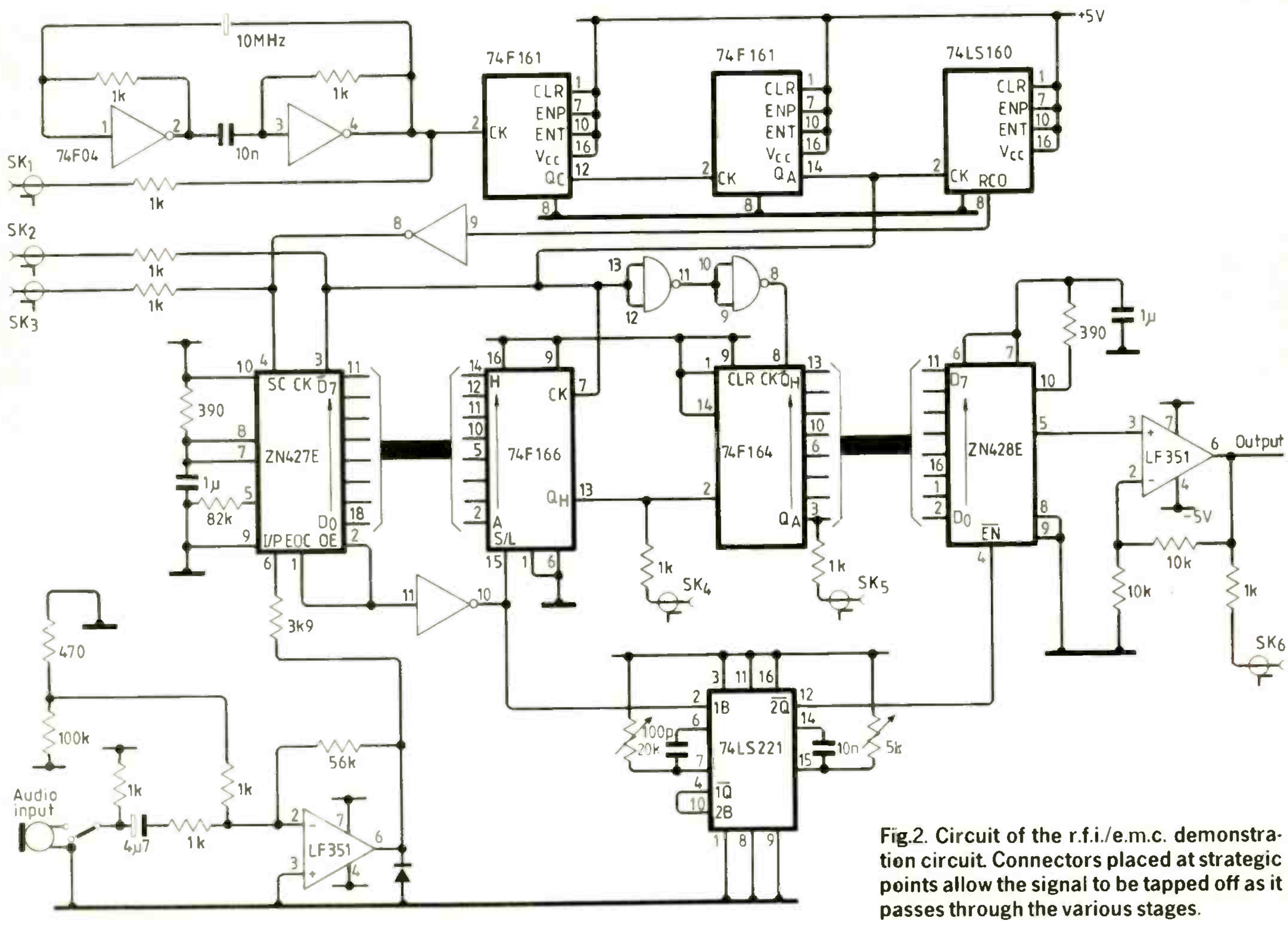


Fig.2. Circuit of the r.f.i./e.m.c. demonstration circuit. Connectors placed at strategic points allow the signal to be tapped off as it passes through the various stages.

Audio input is amplified and fed to an eight-bit analogue-to-digital converter. Parallel output from the converter is loaded into a parallel-in-serial-out (p.i.s.o.) shift register producing a serial data stream. Serial data is then fed, one bit at a time, into a serial-in-parallel-out shift register and subsequently reconverted by a d-to-a converter back into an analogue signal. After buffering, this analogue signal may be fed to a power amplifier for audio output or simply displayed on an oscilloscope.

Wherever possible, 74F series t.t.l. i.cs were used, since they have fast edges and hence provide more interesting spectra.

CIRCUIT DESCRIPTION

At the top left of the complete diagram, Fig.2, is a 10MHz crystal oscillator, whose output is divided in frequency to provide a 625kHz system clock on pin 14 of the second 74F161. To produce an 8bit conversion, the ZN427E a-to-d converter requires nine clock cycles. It also requires a negative-going pulse to start the conversion, which is provided by the inverted ripple-carry output (RCO) of a 74LS161 b.c.d. counter. This produces a pulse at a repetition rate of 62.5kHz and with a width of 1.6μs ($1/625\times10^3$).

Audio input comes from an electret microphone insert obtainable from Maplin, which contains a fet and produces an output in the region of tens of millivolts for a normal speaking voice. Amplification is provided by an LF351 and an offset of 1.25V is added to take the a-to-d converter to half full scale when there is no audio input (microphone switched out). A normal speaking voice a few inches away from the microphone produces a 0-2.5V signal for the a-to-d converter. To prevent the signal going too far below ground, a diode is included.

On completion of a conversion, the a-to-d converter produces an end-of-conversion pulse, EOC. After inversion, this pulse is fed to the converter's own output-enable pin, OE, to ensure that only valid data is presented to the 74F166 parallel-in-serial-out register. Valid data is then clocked out of the parallel-in-serial-out register into the serial-in-parallel-out register by the system's 625kHz clock. A small clock delay from a couple of 74LS00 gates ensures that there is sufficient time for the data to be set up on the output of the p.i.s.o. register.

Also derived from the a-to-d converter EOC pulse is the enable signal for the ZN428E d-to-a converter (EN), which occurs when eight parallel data bits are correctly assembled at the output of the s.i.p.o. register, i.e. after eight clock cycles. For the operation, one half of a 74LS221 dual monostable i.c. produces a delay for EOC and the other half is

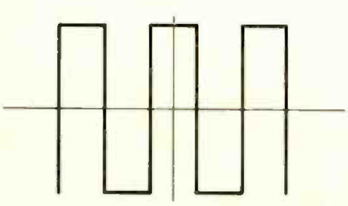
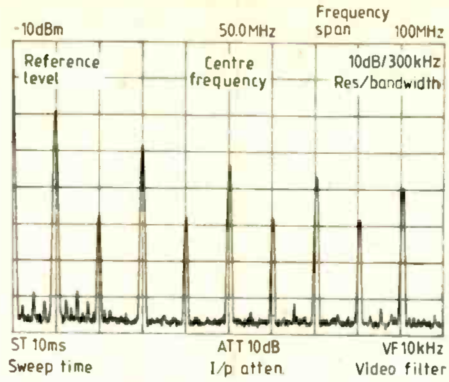
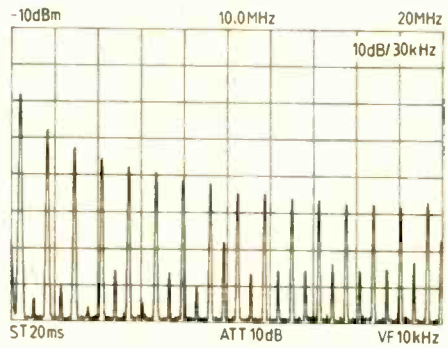


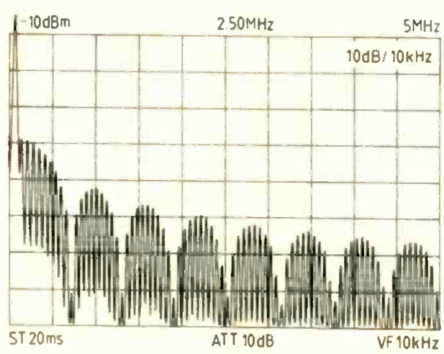
Fig.3. A square wave symmetrical about t=0 has no even-order harmonics.



Plot 1. Spectrum of the 10MHz crystal oscillator reveals many harmonics.



Plot 2. At the 625kHz oscillator, the spectrum shows far fewer even-order harmonics than at the 10MHz oscillator, as you would expect.



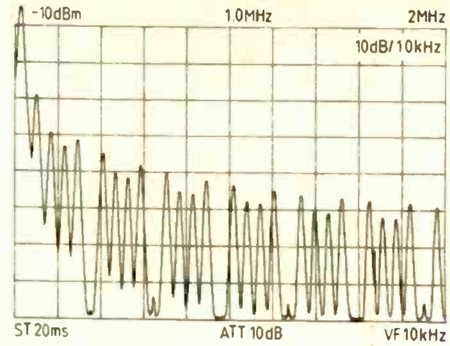
Plot 3. Spectrum of the analogue-to-digital converter start-conversion pulse-train.

triggered by the delayed EOC pulse to produce a pulse of suitable duration. Output is then buffered and amplified slightly by a second LF351 to produce an output of 0-5V.

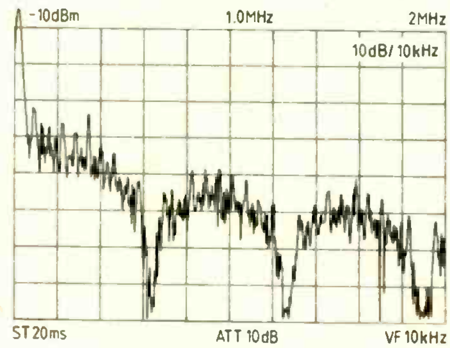
Six BNC connectors at strategic points around the circuit allow the signal to be examined as it passes through the various stages (series 1kΩ resistors make sure that the spectrum analyser loading does not affect the circuit's performance), Table 1.

CIRCUIT PERFORMANCE

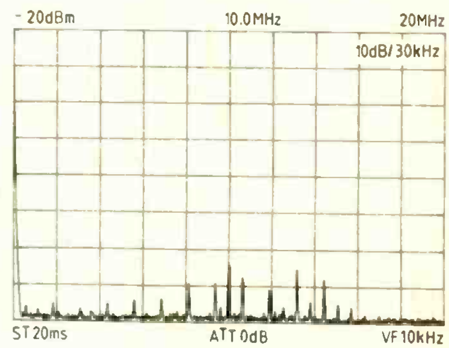
Performance of the circuit was assessed using an Advantest TR4131 spectrum analyser with a maximum bandwidth of 4GHz and plots of the traces obtained at the various points in the circuit were made by a Hewlett-Packard 7470A plotter. You might find this spectrum analyser prohibitively expensive; if so, equally useful results should



Plot 4. In the spectrum of the sampled serial data stream with the microphone switched off, regularity is caused by the constant direct voltage at the data converter's input.



Plot 5. With a 'random' input at the microphone, the serial data-stream spectrum shows rapidly changing data.



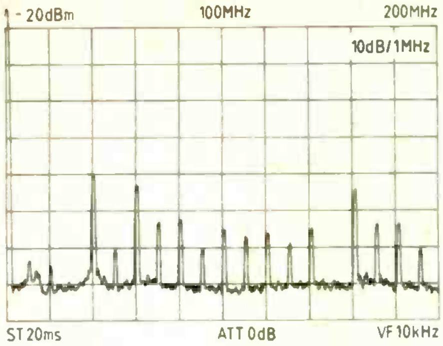
Plot 6. A simple dipole placed near the circuit shows that there is little radiation at low frequencies.

be obtainable from instruments with much lower specifications. I have annotated the first plot to show what all the numbers mean.

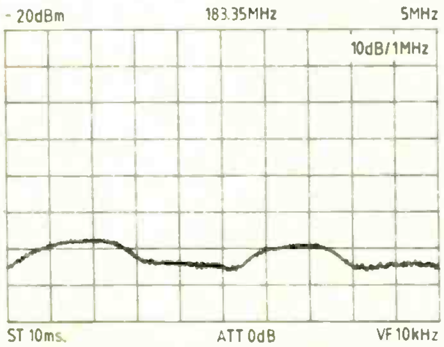
Plot 1 shows the spectrum of the 10MHz crystal frequency which is supposed to be a square wave but the spectrum clearly shows the presence of even order harmonics at 20, 40, 60MHz, etc., indicating a rather imperfect squarewave. This dominance of the spectrum by the odd-order harmonics ties in nicely with what we would expect from the

Table 1. Location of BNC connectors

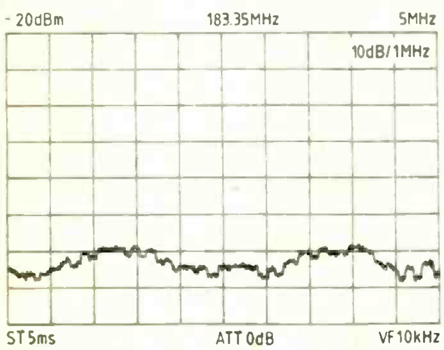
Connector	Location
1	10MHz crystal oscillator
2	625kHz system clock
3	Start-conversion pulse train
4	Serial data stream
5	Least-significant bit of converted data
6	Output



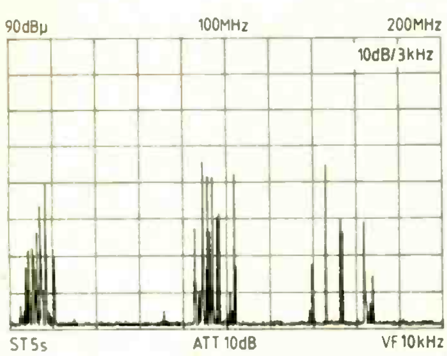
Plot 7. At higher frequencies, the p.c.b. tracks radiate.



Plot 8. A closer look at one of the spectral peaks from Plot 7 with no audio input.



Plot 9. With audio input, the 183MHz spectral peak from Plot 7 reveals the effects of data.

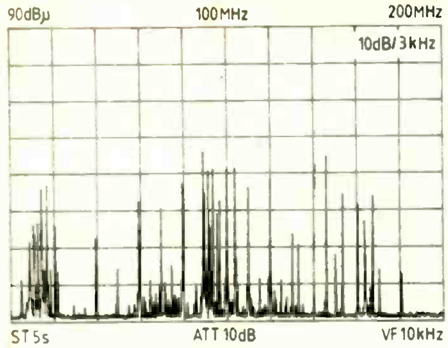


Plot 10. In open air, well away from radiating circuits, a vertically-mounted biconical antenna connected to the spectrum analyser picks up radio broadcasts.

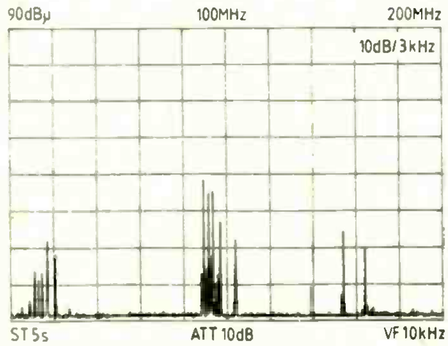
theory. For example, for a square wave such as Fig.3 an even function, symmetrical about t=0, would have a Fourier Series description:

$$f(t)=4(\cos\omega t-\tfrac{1}{3}\cos3\omega t+\tfrac{1}{5}\cos5\omega t+\ldots)$$

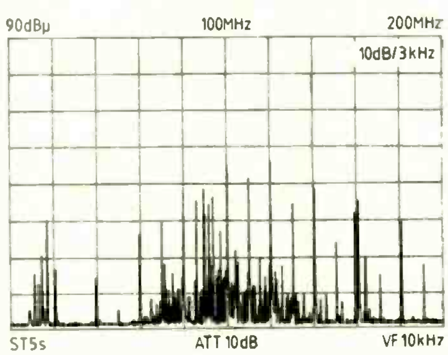
with no even order harmonics present.



Plot 11. Under the same circumstances as those of Plot 10, but with the demonstration circuit switched on.



Plot 12. Again in open air with the circuit switched off, but now with the antenna mounted horizontally, the spectrum analyser shows broadcast radiation.



Plot 13. Switching the circuit on with the antenna mounted horizontally shows a slightly different radiation spectrum to that obtained with a vertically-mounted antenna, Plot 11.

Plot 2 shows the spectrum of the 625kHz system clock, again a square wave. This time there are far fewer even-order harmonics present, only detectable at higher frequences, showing that we have a much better square wave at 625kHz than at 10MHz, which is not surprising.

An interesting spectrum is of the start-conversion pulse train, Plot 3, which shows the characteristics sinx/x spectral envelope associated with a pulse-train signal. The periodic lows of the spectrum occur at one over the pulse-width frequency, and the spectral peaks between the lows at one over the pulse repetition frequency, as you would expect. This spectrum ties in quite nicely with that of the first two plots. Imagine the pulse width gradually increasing, causing the lows to move closer together, until eventually you have a square wave with the lows occurring directly on top of each even harmonic – hence the spectra of Plots 1 and 2.

Plot 4 is the spectrum of the sampled serial-data stream with the microphone switched off showing the regular spectrum due to a constant d.c. voltage at the input to the a-to-d converter.

Output from BNC connector 4 provided Plot 5, which shows the spectrum of the same serial-data stream with a "random" audio signal applied to the microphone (a song from Radio 1 actually) showing the rapidly changing data. In this plot, the overall sinx/x envelope can still be seen, and the rapidly changing spectrum of changing data is clearly visible. Similar spectra could be obtained from BNC connector 5, the l.s.b. of the converted data.

A different set up was used for the next two plots, with the spectrum analyser decoupled from the circuit. I connected 4mm long leads acting as a rudimentary dipole to the spectrum analyser and laid them alongside the circuit. Plot 6 shows only small amounts of radiation from the circuit at relatively low frequencies. At higher frequencies, the tracks of the p.c.b. begin to approach fractions of wavelengths of the dipole and radiate more efficiently, as Plot 7 clearly shows.

For Plots 8 and 9 I zoomed in on a couple of the spectral peaks from Plot 7. No audio input is applied with Plot 8 so it has a clean rounded peak. Exactly the same point of the spectrum is used for Plot 9, but with audio input. It clearly shows the data being reflected at higher frequencies.

This raises an interesting question. Could this sort of data be picked up and demodulated from its high-frequency radiation? If so, then with a sensitive, tuned antenna any computer system which is not effectively screened could have its security breached from a distance, and with no direct connection.

Finally, I did some open field tests on the circuit board. These were carried out on a 3m test site with the aid of the York Electronics Centre, which carries out e.m.c. tests for industry at the University of York.

A biconical antenna was used, placed 3m from the circuit board and well away from any other potentially radiating equipment. This type of antenna has a flat response over a wide band of about 30 to 250MHz. Two basic tests were carried out, one with the antenna mounted vertically and the other with it mounted horizontally.

Plots 10 and 11 show results with the vertically-mounted antenna and plots 12 and 13 show results with a horizontal antenna. In each case, the first plot shows the spectrum first with power off, and then with power on. Large peaks present with the circuit switched off are due to radiation from radio broadcasts, the largest at around 100MHz being from local radio I would guess. With the circuit switched on, radiation at regular 10MHz intervals appears; these intervals are harmonics of the crystal clock frequency.

Peter Turner is a research technician in the Department of Electronics at the University of York.

SIDEBANDS BY MIXER

Lost in thought

Now wait a minute – you don't know what I'm going to say yet. No good moaning until you've read the page. When you've done that, moan away as much as you like: I don't care.

As you can see, any ideas that I had gone for good, having fallen into a number-cruncher, were splendidly optimistic: I was merely thinking. If you consider six years a long time to spend just thinking, you should see the state of our kitchen. I've been thinking about doing that up for a long time now because I think you have to have a plan before tackling major engineering works of that kind, although you can't expect a woman to understand.

One of the things, apart from kitchens, that I was thinking about was the state of education. "Well, hooray for you!" You might think, with some justification, because I know little about the trade of educating young people. What I do know is the result of the education process, as manifested by university entrants and youngsters I meet in the ordinary course of events: it seems to me that thirteen years of schooling has left very little impression on the average eighteen year old and that what is discernible is misguided.

Having reached the age at which policemen seem like adolescents, I have to be careful not to sound like an old curmudgeon – I am one, but I try to keep it quiet. But I'm not alone in thinking that the young chaps turning up at university to be taught engineering are pretty innocent of the sort of stuff they ought to know. I was talking to a friend who lectures in elec. eng. at a redbrick and who gets so fed up about their extremely unsteady grounding in maths and physics and their almost total lack of interest in the subject beyond the passing of exams and "getting a good job" that he is often in despair.

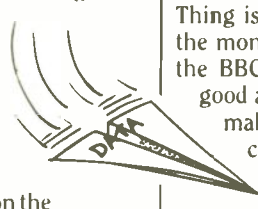
I don't think it is the fault of universities that there is a shortage of good graduates, but that of secondary schools, where the kids are evidently not having their imaginations fired by any kind of excitement in learning. To arrive at university to read electronic engineering without the foggiest notion of what it's all about, being totally unable to say what an electrolytic capacitor is or to differentiate $y=x^2$ indicates that the youngsters have been directed towards the subject, with little regard to the obvious fact that they don't give a hoot about it. And it's no good saying they're not like that. I know at least some of them are because I once sat in on a tutorial in which those very questions could not be answered.

I haven't any instant solutions to offer – I'm merely pointing out, perhaps superfluously, what the problem is. I suppose it comes down to the old shortage of science teachers in the end, and I'm blowed if I know what to do about that.

Data flow

What I want to know is – what exactly is all this data that's being fired round the world at some impossible speed? I keep seeing news of new networks and fast modems and data terminals and optical fibres and stuff, but no one ever explains what it is that needs to be sent from here to there so urgently and in such volume.

What I think is happening is that, now it has become possible to send masses of information to anywhere you like whenever you like at the speed of light, people are sending great gobbets of totally useless information to anyone they think might like it.



Having had the new gizmo installed, it seems a crying shame not to use it, so why not ask for all the holiday records from the branch offices from Huddersfield to Hong Kong? Call for reports on the consumption of A4 envelopes, if any are left in service. Send weekly pep talks from the m.d. to all offices.

I tell you – it's a mercy all this high-tech gear came along when it did because we quite clearly couldn't have carried on much longer with bits of paper and telephones.

Jungle Jargon

It's getting to the point now where it can be quite hard to understand the press hand-outs, let alone the equipment itself. It isn't all those Greek names ending in OS I mean (you know the ones: MSDOS and the others) but way the p.r. people seem to be able to string perfectly ordinary words together in a way that almost defies interpretation.

I'm sitting here looking at a hand-out from a company making workstations which, according to the publicity that comes into the office, can be anything from a computer-aided design terminal to a soldering iron in a stand. "Designed with a high degree of integration at both the system and component level, the hardware architecture of the workstation provides a superior price/performance advantage over similarly configured machines". Well... er... yes.

The "high degree of integration" bit seems to mean that it's all on one board and the rest means that it's better value than the others. Fine, but why do they need to hide this information under a thick coat of coagulated porridge? Is it because they think if you can understand it it can't be posh enough?

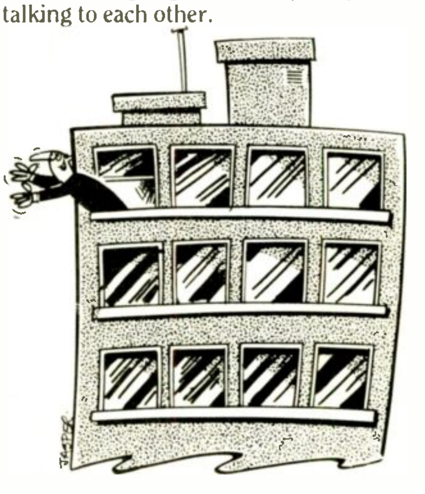
I think that might be it, because they change the meaning of words, as well. For instance, the thing has a "single 32-Kbyte static cache memory". I always thought a cache was where you hide things, but it now seems to be a store. "Interconnect" is turned into a noun so your eye shoots off, fruitlessly seeking an object for a non-existent verb.

One could go on, but you see what I mean? I simply can't see why people feel they have to use this funny code when writing. They don't speak like that – why write like it? Modern electronics is hard enough without having to cope with gobbledegook as well.

Never mind the quality...

Well, isn't it exciting that all those new television channels are on the way? Imagine, all that time that they can now devote to wonderful new kinds of entertainment and mind-broadening visual experience. Yes. Thing is, I expect they won't, or can't. It's the money, you see: the stuff coming from the BBC and independents is nowhere as good as it was a few years ago, because to make a good television drama or comedy series or wildlife programme is so hair-raisingly, ruinously expensive that it can only be done in small doses. Obviously, there is some excellent stuff being shown, but the number of repeats and imported American tripe seems to be growing all the time.

So what on earth will we be getting from all the extra channels? Well, it's no good asking me, but maybe it will all be such a waste of time and money that people will start reading again and, perhaps, even talking to each other.



TELECOMMS TOPICS

Mercury expands Centrex services

Mercury has expanded the capacity of its London Centrex switch from 10 000 to 28 000 lines. It also plans to provide Centrex services in other major cities.

Centrex, in which the local telephone exchange provides facilities equivalent to those of a p.a.b.x. has proved to be ideal for many businesses and provides a real alternative to a traditional company network. It is well suited to companies with several separate locations, all of which need the benefits that the latest technology can provide, and also to those that quickly need to alter their internal communications system in response to company growth or relocation. Benefits to the customer include eliminating the need for major capital expenditure.

Mercury is the first digital Centrex service in Europe and has been available for customers on Mercury's London Cable Scheme since April 1987. Charges for the service consist of a one-off connection fee per service line plus monthly rentals. External calls are charged but calls between extensions are free.

Line cards for System X

GPT (GEC Plessey Telecommunications) is testing adaptive line balance (ALB) interface cards aimed at eliminating mismatching problems experienced on subscriber lines.

One of the most difficult problems for telecom administrations worldwide is having to adjust the exchange equipment to match the widely differing characteristics of individual subscribers' lines.

Even on modern digital exchanges where the adjustments are software controlled, the result has until now been a mismatch because the characteristics of the lines are known only approximately and there are usually only three or four line card 'settings'.

Effects of mis-match are a loss of signal, increased noise and the audible 'hollow tunnel' effect sometimes encountered on telephone conversations. Mis-match also impairs data transmission.

The new System X ALB line card will automatically measure the characteristics of the line it is connected to and set itself to match the line exactly. The result is perfect balance, no reflections back into the network and no hollow tunnel effect. Neither is there any need for the administration to measure lines manually and program thousands of different settings.

Data access for schools

The Department of Trade and Industry and British Telecom are jointly offering over £500 000 to help all secondary schools install telephone lines to access data services.

Local education authorities will be offered £100 towards the cost of installing a new line in every secondary school. These lines must be used only in connection with value-added data services for the first 12 months. The current total cost of installation is £115. If local educational authorities have already equipped some of their schools with lines, they may use the money for lines in middle or primary schools.

In recent years schools have made increasing use of the information services offered by Prestel, NERIS (National Educational Resources Information Service) and The Times Network Systems to find information and curriculum materials and also to communicate by electronic mail.

DTI has supplied micros and modems which enable schools to connect to data services, but many schools make only intermittent use of the equipment because they have no suitably-located telephone line. The DTI/BT offer aims to correct this.

Easier access to international networks

Eight major organizations in worldwide computing and telecommunications have banded together to accelerate the introduction of Open Systems Interconnection network management products capable of operating with each other. Their aim is to apply OSI standards in a consistent manner that will benefit businesses by improving their ability to manage their voice and data networks. By simplifying network management, customers can devote more of their resources to their true business activities.

Known as the OSI Network Management Forum (OSI/NM Forum), it will initially consist of eight voting members – each of which is providing $40 000 per annum and two engineers. They are Amdahl Corporation, AT&T, BT, Hewlett-Packard, Northern Telecom, Telecom Canada, STC and Unisys Networks. Nixdorf, which is one of a number of other companies that have expressed an interest in becoming early members of the Forum, is likely to sign up shortly.

The group encompasses suppliers of service and products in virtually all sectors of the industry, including telecommunications service providers, voice and data switching system manufacturers as well as suppliers of computers and data networks. It does not expect users to meet the high costs of becoming voting members – instead the vendor community has to invest in order to meet customers' needs.

The objective is that the Forum should be "facilitator" in the evolution of actual working standards because, as Brian Hewat, director of Telecom Canada and spokesman for the Forum, said: "many aspects of OSI still need to be worked out". It is not intended that membership of the Forum should inhibit competition. Anyway, "no single manufacturer can provide a complete solution", he said.

In addition to the voting members there will also be associate members who, for their annual fee of $5000, will be able to influence the directions being taken and have access to results obtained.

The concept of OSI, aimed at standardizing protocols, originated in 1978 when the International Standards Organisation (ISO) became dedicated to developing a new architecture and family of protocols for the emerging distributed information and telecommunications systems.

Then, computer and telecommunications suppliers were still developing products and services using many different protocols. In most cases these systems could not interconnect. The only way to add incompatible equipment to an existing system was to make it emulate the first manufacturer's equipment, or to establish protocol converters – analogous to an interpreter in human dialogue.

These major constraints severely limited the ability to create distributed applications freely, and led to the concept of OSI. This, in turn, led to the publication in 1986 of the OSI specification, which defined each of OSI's seven layers in detail.

However, although OSI has become the computer communications standard worldwide, and virtually all major computer and telecommunications companies have publicly stated their support for OSI and the development of OSI applications, it is no simple task to create multi-vendor operations. Major reason for this is the large number of available protocol options and the need to identify common message sets.

While many companies with common interests have formed associations over the past two years to define specifications for their particular applications, such as in the motor, aviation, manufacturing and service sectors, the OSI/NM Forum represents the first time that computer and telecommunications suppliers have formed an alliance to develop and promote an OSI application – in this case, for network management systems.

The forum is devoted to achieving multi-vendor network management inter-operability in the shortest possible time: and it expects to be able to demonstrate this is around 18 months.

The protocol group will agree on a common implementation of the seven-layer OSI protocol stack. It will select appropriate OSI subsets or "profiles" of features to be used in each layer. In this way it will create a single protocol stack, to ensure inter-operability between different management products and systems.

Within the first three layers, for example, the Forum expects to adopt the CCITT X. 25 wide-area network standard and the IEEE 802.3 local area network standard. It could examine other transport methods later.

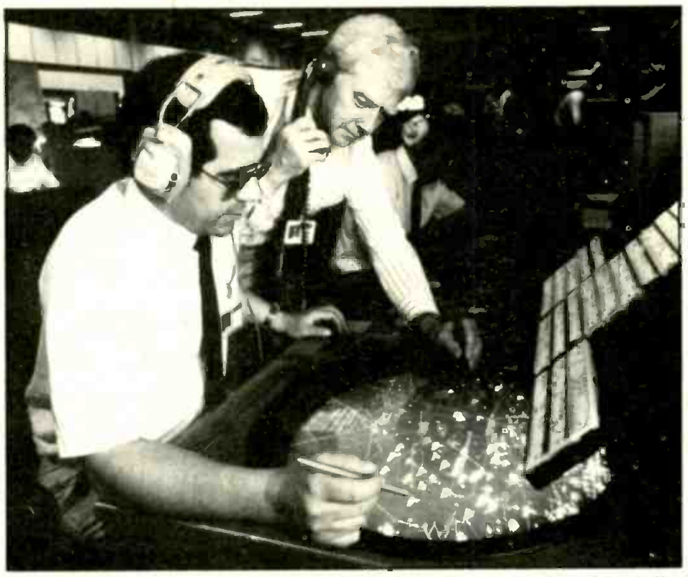
As an example of upper layer activity, the Forum is planning to adopt the draft OSI proposal for Common Management Information Services and Protocol (CMIS/P), which specifies the format of network management messages.

Profiles for OSI layers 1 to 6 and for the first three sub-layers at the seventh layer – up to and including CMIS/P – should be determined by the end of this year.

The second group will select high-priority application areas to define message content. It expects to make an early start on event and configuration reporting. It will establish the messages and services required within a network for management purposes; and it will select, as the area of first priority, messages and services related specifically to configuring the elements of a network and their topology and to event reporting and management. These are the messages and services which flow across the interoperable interface between products and systems supplied by different vendors. Event information will include items such as status changes of the managed objects, additions or deletions of managed objects, collections of alarms, etc.

Currently the list of management objects will include voice and data switches, multiplexers, computer systems and applications, modems, terminal concentrators, local and wide area network equipment, transmission systems and information services.

Additional work will be undertaken to determine processes and guidelines for defining network management objects and messages. For example, it will adopt naming and addressing plans and a directory of structures.



A private communication network designed, supplied and installed in less than three weeks by British Telecom International is helping to cut delays for British holidaymakers. It links air traffic flow control centres in London, Madrid, Paris, Frankfurt and Rome. Supervisors at each centre can now contact one another, either individually or in conference immediately to discuss overall traffic management and flight movements.

Network upgrade for academics

Northern Telecom has agreed to provide equipment and know-how to help establish an advanced data communications network using international packet switching standards to link universities and academic research centres throughout Europe.

The European Academic Research Network (EARN), which currently uses leased lines to connect over 550 computers of member establishments in 24 countries, has decided to upgrade its communications systems to conform to OSI standards using the X.25 packet switching protocols defined by CCITT.

EARN has accepted Northern Telecom's offer to provide at least four network nodes based on its latest DPN-100 packet switching systems. These nodes will be strategically located at universities across Europe and will form an international X.25 switching network connecting the national academic networks of each member state.

Northern Telecom will also provide a network management capability which will allow EARN to analyse traffic on the network and provide a more efficient service to the academic users.

The equipment will be installed and maintained by Northern Telecom, and the company will give operational support to EARN for an initial period.

Dr Dennis Jennings, president of EARN, based at University College, Dublin, said: "The translation of EARN to OSI standards is one of our key objectives. We appreciate the support of Northern Telecom, which we know is committed to open systems. This is the first step in establishing highly effective data communications facilities for the academic research community throughout Europe. EARN will work with other networking interests in Europe towards a common, shared infrastructure for r&d."

The move to X.25 will enable EARN to implement new features which will progressively enhance the services available. Once the new international network is in place, EARN will introduce X.400 messaging. At a later date, full 2Mbit/s links will be introduced (the present leased line network runs at 64kbit/s).

Northern Telecom's packet switches will interface with Digital Equipment Corporation (DEC) VAX systems connected to the international network and also with various equipment, including DEC and IBM systems, used in the national networks.

GCHQ approves secure processor

The Government's computer security authority, Communications Electronic Security Group (CESG) based at GCHQ Cheltenham, has formally certified GPT's Secure Communications Processor. The approval follows a three-year programme to design a trusted processor which will form the heart of highly secure computer networks. The programme was sponsored by the Royal Signals and Radar Establishment at Malvern and was implemented by GPT Data Systems.

GPT Data Systems claims that this processor is the first in the world to be designed specifically for secure applications in data networks. Users with highly sensitive information which needs to be kept completely secure will be able to use the processor to reap all the benefits of linking computers with networks, without many of the attendant risks.

The CESG report states that "the certification process included a range of investigations into various aspects of the secure communications processor and confirmed the high development standards. It is a major contribution to the field of computer security, and a suitable basis for the development of secure systems."

The first application for which the GPT secure communications processor is being offered is the Ministry of Defence CHOTS (Corporate Headquarters Office Technology) programme which will provide a multi-level secure network of 24 000 terminals in the MoD.

As more and more computers are linked together, so the dangers of information being stolen, corrupted or leaking out are growing. Particular areas for concern are in financial institutions, where there have already been examples of poor computer security resulting in substantial financial loss, and in government, where national security is constantly under threat and can only be effectively protected by the latest networking and computing techniques.

Financial costs of losses arising from breaches in computer security are difficult to quantify. However, a survey in France in 1986 found that some £700M has been lost in the one year, whilst a similar exercise by accountants Ernst and Whinney put the cost at $5G in the USA in a single year. A recent example of the problem was the announcement in August of an investigation into the attempted theft of £32M from a Swiss bank in London via the international banking computer network.

Telecomms Topics is compiled by Adrian Morant.

RADIO BROADCAST

A louder 'Voice'

The largest-ever contract for high-power broadcast transmitters has been placed by the United States Information Agency with the GEC group of British and American companies. The contract covers the first phase of a major modernization of Voice of America relay sites. The initial contract, worth $57 million, includes ten transmitters for the VOA base in Morocco, with provision for further contracts for 22 high-power transmitters for bases in Sri Lanka, Thailand and Botswana. Together these would increase the value of the contracts to over $150 million.

The 500kW h.f. transmitters, using high-efficiency pulse-duration-modulation ("Pulsam"), have been designed at Chelmsford by Marconi Communication Systems, where initial production and testing will take place, but under a technology transfer agreement follow-on production will be at GEC's American subsidiary Cincinnati Electronics Corporation, with ancilliaries provided by Dielectric Communications and Andrew Corporation.

Voice of America programmes were first transmitted on 24 February, 1942, just over two months after Pearl Harbor had resulted in the US entry into the second world war. The early transmissions went out on 13 h.f. transmitters leased by the US government from six private broadcasting companies. The pre-VOA history of American short-wave broadcasting dates back to the 1924 experiments by Dr Frank Conrad of Westinghouse, including some Spanish-language programmes; but the USA soon fell far behind European countries such as the USSR (Radio Moscow), Germany (Zeesen) and Italy (Radio Roma) in using h.f. for external broadcasting for propaganda or to expatriates.

In 1929, the Federal Radio Commission (superseded by the FCC in 1934) adopted regulations for a class of h.f. stations called "experimental relay broadcasting stations" intended primarily to relay programmes over long distances from one station to another, rather like the "distribution satellites" of some 50 years later. But it was soon evident that direct reception of such transmissions was increasing with the introduction of "all-wave" receivers, much though these suffered from frequency drift, image reception and difficult tuning.

By 1934 NBC was providing international programming from Bound Brook, New Jersey (W3XAL) and also on the Westinghouse (W8XK, Pittsburgh) and General Electric (W2XAD, Schenectady,) facilities. Powel Crosley of Cincinnati was authorized to use 10kW on W8XAL in 1931.

In May 1939 the FCC removed the "experimental" designation. The former amateur-type callsigns, with an X following the 'district' number, were replaced by standard four-letter broadcast callsigns. As someone who recalls listening to W8XK, W2XAD etc. in the mid-thirties as a schoolboy, most of the programmes I heard were based on popular domestic broadcasts, including items from the NBC 'Red' and 'Blue' networks. In 1939, following the outbreak of war in Europe, there was a daily round-up of news commentaries from London, Berlin and Paris that made particularly interesting listening and set the agenda for foreign radio correspondents that has lasted down the years.

In December 1939, the United Fruit Company sponsored an NBC 15-minute news broadcast and helped to launch 'commercial' broadcasting from the USA on h.f. In the period to the founding of VOA, h.f. broadcasting to South America attracted sponsors, particularly to the NBC and Crosley (WLWO) stations. Crosley also organized re-broadcasting of their transmissions by a string of medium-wave stations in Central America.

Various attempts were made in 1937-38 to legislate for the setting up of a US government-operated international broadcasting facility but these fell by the wayside until Pearl Harbor. In the postwar period there have been a few privately-owned h.f. stations in the USA, supported primarily by religious organizations, but VOA has remained the "official" h.f. service of the USA with its string of relay bases and with transmitters leased from other broadcasters including the BBC (Woofferton).

Serving East Africa

The new BBC relay base on the Seychelles is due to be taken into service on 25 September following a period of test transmissions. The base, equipped with two automated 250kW Marconi h.f. transmitters is expected to provide strong signals throughout the target area of East Africa. It will carry programmes from Bush House, including the World Service in English, "English by radio" lessons and broadcasts in a variety of African languages.

Although one-hop coverage results in very strong signals it does not overcome one of the main bugbears of h.f. broadcasting: bad distortion of double-sideband signals due to selective fading. Indeed, such distortion tends to be more severe than on long-distance, multi-hop weaker signals. Trials in Japan and other countries have shown that a significant reduction of distortion due to selective fading is possible by the use of single-sideband transmissions with reduced carrier, but most h.f. broadcasters still seem reluctant to use s.s.b.

Paradoxically, one result of the increasing use of h.f. 'all-band' receivers with low-cost digital frequency synthesizers is that the resulting ability of listeners to tune accurately to any specific channel is tending to take the excitement out of the hobby of short-wave listening. Increasingly, h.f. broadcasters are atempting to build up audiences with a real interest in programmes rather than in logging "dx" stations.

It seems insensitive, however, for the BBC in its *Waveguide* programme to recommend listeners on the west coast of North America to listen to World Service from the BBC's Hong Kong relay on 7180kHz, ignoring the fact that this frequency is within Region 2's exclusive amateur band, although shared between broadcasters and amateurs in Regions 1 and 3. A recent Californian visitor to London complained bitterly that throughout the evenings the band between 7100 and 7300kHz is virtually unusable by radio amateurs.

Fade-free surface waves?

The current development of h.f. ground-wave radars seems to be leading to confusion between conventional 'ground-wave' and true 'surface-wave' propagation of radio waves. Medium-wave broadcasting has traditionally depended primarily on the radiation of vertically polarized ground-waves plus sky-wave reception after dark, resulting in zones of severe fading. Surface waves are different, being electromagnetic waves propagating virtually without radiation along an interface between two different media, as in the G-line single-wire transmission line occasionally used at u.h.f. as a low-cost waveguide. Energy is launched along a dielectric-coated wire by means of a cylindrical horn. In practice, there is some limited radiation within a few feet of a straight G-line and rather more from any bends.

In 1967, the late Professor H.M.Barlow proposed a ferrite-loaded half-horn form of antenna with an aperture of about 20ft and a ferrite taper, for the launching of 1.5MHz surface waves along the interface between earth and air (*Electronics Letters*, July 1967, vol.3, No 7, p304). Attenuation would, in some circumstances, be of the order of 1.83dB/mile. BBC engineers at Kingswood Warren noted that, at least in theory, such a system would be attractive for local broadcasting, although the range would be more limited than with free radiation (*Electronics Letters*, September 1967). Professor Barlow (4 September, 1967) conceded the limited range but suggested that a combination of surface wave and conventional transmission might give an improved overall performance, reducing fading but maintaining a reasonable field strength out to about 100km. But, 21 years later, it would appear that nobody has attempted to try a Barlow surface-wave launcher, even though it might not only reduce fading but conceivably permit closer re-use of channels.

Radio Broadcast is written by Pat Hawker.

TELEVISION BROADCAST

Format rivalries

Not so many years ago there was just one universal videotape format, the two-inch quadruplex format developed by Ampex and used on broadcast machines from 1956 to the mid-1970s. Since then, despite the efforts of broadcasters and industry to hammer out, through EBU and SMPTE, universal international standards, the scene is dominated by market forces, commercial rivalries and a degree of chauvinism. The number of formats proposed or used for broadcast application has proliferated, approaching 20 for tape widths of 2, 1, ¾, ½ and ¼ inch. For studio applications, the one-inch helical-scan machines, after more than a decade of use, are still divided between B and C formats. For the new all-digital machines, the composite D-2 format is currently making significantly more impact than the component D-1 format endorsed by EBU/SMPTE as a "universal" standard. At IBC88, Sony is showing for the first time in Europe its new DVR-10P PAL composite D-2 machine alongside its original DVR/DVPC-1000 component machines, claiming that its small size and ease of integration into existing studios make it an attractive option. Ampex, which devised the D-2 format, is featuring its VPR-300 digital machines for PAL.

But currently the prime battle is between the two half-inch metal-particle component tape cassette formats – M.II and Betacam-SP. Sony has recently announced important recruits for Betacam-SP. ITN has just introduced this format for news gathering and will progressively convert to it for all purposes when it moves to its new home in Gray's Inn Road. This brings to 31 the number of European broadcasters who have so far invested in this format, although NBC remains committed to M.II. The ITN decision follows closely on the commitment of Bayerischer Rundfunk of Bavaria to use Betacam-SP for electronic news gathering and portable single camera (p.s.c.) production in parallel with their studio one-inch BCN (B-format) machines.

IBC88 also underlines the rapid advance of c.c.d. solid-state cameras. These are now almost an automatic choice for electronic news gathering and seem set to make a significant impact on production cameras, except perhaps for h.d.tv.

Thermionic displays

The cathode-ray tube, with a history that dates back to the end of the 19th century, increasingly looks like being the only thermionic device (except possibly for high-power transmitters) that will remain in common use into the 21st century. The large, flat, solid-state displays at consumer prices, so often promised, so often deferred, still await appropriate technologies to bring them into homes.

Small, active matrix l.c.d. displays, on the other hand, are already available up to six-inch diagonal. Driven by commercial and military needs, because of their ruggedness and low power-consumption, they will – according to Werner F. Wedam of the David Sarnoff Research Center ("Future Trends in Television", *IEEE Trans. on Consumer Electronics*, May 1988) – make a major impact on the consumer market in the early 1990s: "Even at a higher price, they will achieve a substantial market share of c.r.t.-type displays up to 12-in diagonal, because the weight and form factor is ideal for portable products".

For large pictures, he notes that direct-view tubes with 35-inch and 43-inch diagonals are becoming available, and rear projectors with increasingly good quality are commonly found in US homes. "Unfortunately, since consumers view these large displays from approximately the same distance as smaller ones, the artifacts associated with the existing standards are more noticeable: thus, there is no real benefit in the larger screen unless the picture resolution is improved. With the introduction of new standards, better pictures will be possible, and therefore, large screens will look more attractive."

But Werner Wedam warns: "Higher performance picture tubes for wide aspect ratio must still be developed. The experimental kinescopes (picture tubes) which are presently used to demonstrate the various advanced television systems are quite expensive small quantity h.d.tv prototypes with fine dot pitch and very low brightness. Such tubes will not be satisfactory for consumer use because of their cost and lack of brightness. With present technology large kinescopes for the e.d.tv consumer market will be possible but a substantial amount of development is still needed until similar tubes for h.d.tv will be available."

Planning the audio digits

While there has been much discussion about the planning of television studio complexes for analogue-component and all-digital video, the more immediate problem for most broadcasters – radio as well as television – is the progressive conversion to digital stereo sound. In practice, sound facilities for either radio or television comprise a number of functional blocks: a master control room, production studios, a post-production suite for assembling and editing the sound recordings, programme continuity suites, a short- and long-term library of recordings, field production facilities and the like.

An article "Principles of building digital audio facilities for television and radio broadcasting" by Gosteleradio (USSR) engineers, B.V. Nekrasov and V.I. Scherbina (OIRT's *Radio & Television*, 1988/3) notes that digital audio provides an opportunity to base a sound complex on a line-up of unified systems, devices and blocks of equipment with their functions defined by the software package.

The authors conclude that digital complexes will lead to improved techniques and quality of sound programme production, post-production and transmission: "The application of software-based systems of control and processing of sound signals all facilitate the modular build-up of equipment and will allow it to be up-graded without developing new hardware. The utilization of local transmission networks for remote control will lend greater functional flexibility to the individual blocks of the complexes."

They outline principles for implementing unified digital audio equipment that enables the working load of equipment to be distributed rationally, its performance potential to be fully utilized and "the number of technically complex units limited and the cost, weight, size and power-consumption of the complete audio equipment of a radio or television centre reduced".

RTS marks Tony's 80th

The July Fellows' Dinner of the Royal Television Society brought many well-known names in television to the Caledonian Club to mark the 80th birthday of T.H. ("Tony") Bridgewater OBE, a former BBC chief engineer and one of the few surviving engineers whose career in television began with the Baird Company as early as 1928. He became one of the original trio of "BBC" television engineers – Birkinshaw, Bridgewater and Campbell. In the early days of the "Ally Pally" era he pioneered outside broadcasts including that of the Coronation of George VI in May 1937. After wartime service with the RAF, working on radar, he returned to the BBC to become involved with the ambitious (for those days) coverage of the 1948 Olympics and, in conjunction with M.J.L. Pulling, the first television exchanges between Paris and London in July 1952 – involving a five-hop microwave link across the English Channel to Lille and conversion between the French 819-line and the British 405-line systems. Tony Bridgewater retired in 1968 but his unique knowledge of British television spanning sixty years has remained much in demand. There can be few who can equal his membership of the Television Society, of which he is a past chairman. He joined while with the Baird Company despite the lowly regard in which the society was then held by his colleagues, who saw it as a "bunch of amateurs". But then I find a "T. Bridgewater of Sutton" in the list of new members of the R.S.G.B. for November 1930.

Television Broadcast is written by Pat Hawker.

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RADIO COMMUNICATIONS

Radio science at King's

The two-day fifth National Radio Science Colloquium (URSI) attracted about 80 participants to King's College, London. In its two days the colloquium included some 50 presentations on a wide span of radio science topics currently being researched at British universities and polytechnics, the Rutherford Appleton Laboratory, British Antarctic Survey, British Geological Survey, Meteorological Office and elsewhere.

Professor E.H. Grant (King's College) reviewed the evidence for thermal and non-thermal **biological effects** of low-level, non-ionized radiation at frequencies from e.l.f. to 300GHz. He showed how the known thermal effects have resulted in established protection levels, such as the ANSI standard, but it has generally proved impossible to replicate non-thermal biological effects frequently reported at lower radiation levels. He quoted Clerk Maxwell's dictum that the most absurd claims may become current provided they are expressed in scientific language.

Dr A.C.L. Lee (Meteorological Office) described their new v.l.f. "arrival time difference" (a.t.d.) technique for accurately detecting and locating **lightning** strikes. Early results show that, after systematic biases have been removed, the new 9.8kHz UK network can provide a relative location accuracy better than 650m (1.3μs) and that 1.5μs a.t.d. scatter should prove realistic in operational use. The system thus compares favourably with the high-cost systems developed in North America. Operating at long or medium range, it implies that lightning flashes appear as "point images" of typical horizontal dimension of 10 to 100m.

Later, Dr Laura Scott (Electricity Council Research Centre) described an alternative approach. Its new and improved e.l.f. lightning location system is intended to permit the CEGB to check the effectiveness of lightning protection systems fitted to power lines, radio and television masts etc. Lightning costs the industry millions of pounds annually, yet has remained a relatively unquantified phenomenon. An improved network of automatic d.f. stations is now in operation; these largely overcome the problem of polarization errors (which limited the accuracy of an earlier v.l.f. system) by reducing the frequency from 10kHz first to 2kHz and more recently to 1kHz. Each station provides a bearing free from 180° ambiguity using three vertical loops at relative angles of 120° plus one horizontal loop to reduce still further any polarization error.

Dr W.F. Stuart (British Geological Survey) made a strong plea for continued funding of **solar-terrestrial monitoring** which is currently under severe financial pressure. Maintenance of the vital data bases is in direct competition for funding with new "exciting" projects. As he wrote in a letter to *The Times* (15 June, 1988), there is imminent danger that an accurate magnetic reference may no longer be available for air and sea navigation in the British Isles and their coastal waters. Charts, Ordnance Survey maps, air traffic lanes, beacons, and runway approach plates [pilots' diagrams] would be affected and this is giving rise to serious concern for air and sea safety. Similar problems face ionospheric and solar flare monitoring, with staff not being replaced when they retire and NERC proposing 150 compulsory redundancies among government scientists. He pointed out that long-term, solar-terrestrial monitoring has led to such important discoveries as the greenhouse effect, the 'ozone hole', solar cycle, solar winds, fluid core, etc. Radio physicists, communication engineers and others make use of data from the national and world data centres now at risk.

Radio systems outlined at NRSC5 included the application of zero-crossing analysis to real-time evaluation of channels to provide automatic adaption of error-control power (Warwick and Hull universities); "QNBFAM" techniques to provide an integrated voice and data transmission, quadrature-multiplex system for v.h.f. mobiles based on narrowband angle modulation with 12.5kHz channelling (Polytechnic of Wales); measurement of intermodulation interference generated by metallic structures at radio sites (University of Kent); diffraction and scatter of microwaves by buildings and vegetation (Polytechnic of Wales).

Dr R.J. Cohen (NRAL, Jocrell Bank) highlighted the difficulties encountered by **radio astronomers** having to share frequencies with other services. He warned that interference can be particularly acute in a small island like the UK and that "the survival of radio astronomy depends on a wider awareness of these problems". He was particularly concerned about the amount of 1610MHz data being ruined by the Russian Glonass navigational satellite, although there are hopes that future satellites in this series will use a different frequency. He noted wryly that a newly-found maser line of methanol at 12.2GHz falls in the satellite d.b.s television band.

Dr W.R. Piggott took the opportunity to present for the first time a new application of stochastic methods to the distribution in Europe of **sporadic E** propagation. He believes that previously used distributions of SpE have proved seriously misleading. His new model produces the observed distributions of strong and intense SpE as functions of a mean probability which varies slowly with position over Europe. It is independent of what ever model, such as gravity-wave wind-shear, is held to cause the formation of SpE. Dr Piggott believes his stochastic model will provide a powerful tool for predicting the probability of SpE for any part of Europe, any time of day, from a single observed parameter. It is not a tool for predicting in advance when SpE will occur.

A number of participants reported the progress of current research projects concerned with **microwave propagation** through the troposphere, including over-the-horizon propagation due to rain scatter. A Home Office/Essex university study is based on reflecting layer rather than ducting models.

Professor E.D.R. Shearman (University of Birmingham) and his team are continuing work on the use of ground-wave **h.f. radar** for remote sensing of ocean-wave and surface-current vectors (the technique has also been shown to be useful for tracking ships over the horizon) at distances up to 150-200km from two coastal sites on opposite sides of the Bristol Channel. Recent work has used frequencies of the order of 6 to 9MHz using narrow-band c.w. systems with shaped pulses to minimize interference to other services.

Theoretical work by Oxford Computer Services is based on the belief that "what is hidden shall be revealed" by using **microwave scatter** to detect surface roughness changes which occur when surface currents – such as those induced by internal waves in the sea – interact with the ambient surface wave field. Whether this active interest in how internal waves are patterned stems entirely from a desire to locate natural navigational hazards such as sandbanks, or man-made submersible objects, was not revealed, but there seems little doubt that OCS's hydrodynamic interaction model (OCSHIM), in conjunction with airborne microwave radar, seems likely to provide an ability to peer deep below the surface of the oceans.

Modern radio science

Eleven tutorial papers from the 1987 General Assembly of URSI at Tel Aviv have been brought together in book form as "Modern Radio Science" (editor Professor A.L. Cullen, published by Oxford University Press for URSI and ICSU Press, 166+x pages, hard covers, £25). Valuable to both specialist and non-specialist readers they provide up-to-date reviews by 13 international scientists on laser measurements, waves, spectra and plasmas, ionospheric physics, coherent optical fibre communications and digital switching techniques, radio astronomy, packet communications networks, etc., each with useful lists of references. Each section is reprinted directly from the Assembly papers, although OUP standards seem to be slipping with "propogation" (*sic*) in the running heads of two chapters!

Radio Communications is written by Pat Hawker.

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7440	0.60		
7441	0.90		
7442A	0.70		
7443A	1.00		
7444	1.10		
7445	0.70		
7446A	1.00		
7447A	1.00		
7448	1.00		
7450	0.36		
7451	0.35		
7453	0.38		
7454	0.38		
7460	0.55		
7470	0.50		
7472	0.45		
7473	0.45		
7474	0.50		
7475	0.60		
7476	0.45		
7480	0.65		
7481	1.80		
7483A	1.05		
7484A	1.25		
7485	1.10		
7486	0.42		
7489	2.10		
7490A	0.55		
7491	0.70		
7492A	0.70		
7493A	0.55		
7494	1.10		
7495A	0.60		
7496	0.80		
7497	2.90		
74100	1.90		
74107	0.50		
74109	0.75		
74110	0.75		
74111	0.55		
74116	1.70		
74118	1.10		
74119	1.70		
74120	1.00		
74121	0.55		
74122	0.70		
74123	0.80		
74125	0.65		
74126	0.55		
74128	0.55		
74132	0.75		
74136	0.70		
74141	0.90		
74142	2.50		
74143	3.30		
74144	2.70		
74145	1.00		
74147	1.10		
74148	1.40		
74150	1.75		
74151A	0.70		
74153	0.80		
74154	1.40		
74155	0.80		
74156	0.80		
74157	0.70		
74159	2.25		
74160	1.10		
74161	0.80		
74162	1.10		
74163	1.10		
74164	1.20		
74165	1.10		
74166	1.40		
74167	4.00		
74170	2.00		
74172	4.20		
74173	1.40		
74174	1.10		
74175	1.05		
74176	1.00		
74178	1.50		
74179	1.50		
74180	1.00		
74181	3.40		
74182	1.40		
74184	1.80		
74185A	1.30		
74190	1.30		
74191	1.30		
74192	1.30		
74193	1.15		
74194	1.80		
74195	0.80		
74196	1.30		
74197	1.30		
74198	2.20		
74199	2.20		
74221	1.10		
74251	1.00		
74259	1.50		
74265	0.80		
74273	2.00		
74276	1.70		
74278	1.70		

74LS SERIES

74LS00	0.24	74LS273	1.25
74LS01	0.24	74LS279	0.70
74LS02	0.24	74LS280	1.90
74LS03	0.24	74LS283	0.80
74LS04	0.24	74LS290	0.80
74LS05	0.24	74LS292	14.00
74LS08	0.24	74LS293	0.80
74LS09	0.24	74LS295	1.40
74LS10	0.24	74LS297	14.00
74LS11	0.24	74LS298	1.00
74LS13	0.34	74LS299	2.20
74LS14	0.50	74LS321	3.70
74LS15	0.24	74LS322A	3.90
74LS20	0.24	74LS323	3.00
74LS21	0.24	74LS324	3.20
74LS22	0.24	74LS348	2.00
74LS24	0.50	74LS352	1.20
74LS26	0.26	74LS353	1.20
74LS27	0.24	74LS356	2.10
74LS28	0.24	74LS363	1.80
74LS30	0.24	74LS364	1.80
74LS32	0.24	74LS365	0.50
74LS33	0.24	74LS366	0.50
74LS37	0.24	74LS367	0.52
74LS38	0.24	74LS368	0.50
74LS40	0.24	74LS373	0.70
74LS42	0.50	74LS374	0.70
74LS43	1.50	74LS375	0.75
74LS48	0.90	74LS377	1.30
74LS49	1.00	74LS378	0.95
74LS51	0.24	74LS379	1.30
74LS54	0.24	74LS381	4.50
74LS55	0.24	74LS385	3.25
74LS73A	0.30	74LS390	0.60
74LS74A	0.35	74LS393	1.00
74LS75	0.45	74LS395A	1.00
74LS76A	0.36	74LS399	1.40
74LS78	0.42	74LS445	1.80
74LS83A	0.70	74LS465	1.20
74LS85	0.75	74LS467	1.20
74LS86	0.35	74LS490	1.50
74LS90	0.48	74LS540	1.00
74LS92	0.35	74LS541	1.00
74LS93	0.54	74LS608	7.00
74LS95B	0.75	74LS610	25.00
74LS96	0.90	74LS612	25.00
74LS107	0.40	74LS624	3.50
74LS109	0.40	74LS626	2.25
74LS112	0.45	74LS628	2.25
74LS113	0.45	74LS629	1.25
74LS114	0.45	74LS640	2.00
74LS122	0.70	74LS640-1	3.00
74LS123	0.80	74LS641	1.80
74LS125	0.50	74LS642	2.50
74LS126	0.50	74LS642-1	3.00
74LS132	0.65	74LS643	2.50
74LS133	0.55	74LS643-1	3.00
74LS136	0.45	74LS644	3.50
74LS138	0.55	74LS645	2.00
74LS139	0.55	74LS645-1	4.00
74LS145	0.95	74LS668	0.90
74LS147	1.75	74LS669	0.90
74LS148	1.40	74LS670	1.70
74LS151	0.65	74LS682	2.50
74LS152	2.00	74LS683	3.00
74LS153	0.65	74LS684	3.50
74LS154	1.60	74LS687	3.50
74LS155	0.65	74LS688	3.50
74LS156	0.65	74LS783	16.00
74LS157	0.50		
74LS158	0.55		
74LS160A	0.65		
74LS161A	0.65		
74LS162A	0.75		
74LS163A	0.75		
74LS164	0.75		
74LS165A	0.75		
74LS166A	1.50		
74LS168	1.30		
74LS169	1.30		
74LS170	1.40		
74LS173A	1.00		
74LS174	0.75		
74LS175	0.75		
74LS181	2.00		
74LS183	1.90		
74LS190	0.75		
74LS191	0.75		
74LS192	0.75		
74LS193	0.75		
74LS194A	0.75		
74LS195A	0.75		
74LS196	0.80		
74LS197	0.80		
74LS221	0.90		
74LS240	0.80		
74LS241	0.80		
74LS242	0.90		
74LS243	0.90		
74LS244	0.70		
74LS245	0.90		
74LS247	1.10		
74LS248	1.10		
74LS249	1.10		
74LS251	0.75		
74LS253	0.75		
74LS256	0.90		
74LS2457A	0.70		
74LS258A	0.70		
74LS259	1.20		
74LS260	0.75		
74LS266	0.60		

74S SERIES

74S00	0.50
74S02	0.50
74S04	0.50
74S05	0.50
74S08	0.50
74S10	0.50
74S11	0.75
74S20	0.50
74S22	0.50
74S30	0.50
74S32	0.60
74S37	0.60
74S38	0.60
74S40	0.50
74S51	0.60
74S64	0.45
74S74	0.70
74S85	5.50
74S86	1.00
74S112	0.90
74S113	1.20
74S114	1.20
74S124	3.00
74S132	1.00
74S133	0.60
74S138	1.80
74S139	1.80
74S140	1.00
74S151	1.50
74S153	1.50
74S157	2.00
74S158	2.00
74S163	3.00
74S169	5.50
74S174	3.00
74S175	3.00
74S188	1.80
74S189	1.80
74S194	3.00
74S195	3.00
74S196	3.50
74S200	4.50
74S201	3.20
74S225	5.20
74S240	4.00
74S241	4.00
74S244	4.00
74S251	2.50
74S257	2.50
74S258	2.50
74S260	1.00
74S261	3.00
74S283	2.70
74S287	2.25
74S288	2.00
74S289	2.25
74S299	4.50
74S373	4.00
74S374	4.00
74S387	2.25

Special offer to PE readers only – 10% off on all TTLS and CMOS

74ALS SERIES

74ALS00	0.45
74ALS02	0.45
74ALS04	0.50
74ALS08	0.50
74ALS10	0.45
74ALS20	0.45
74ALS32	0.45
74ALS74	0.70
74ALS138	1.50
74ALS139	1.50
74ALS244	4.00
74ALS245	4.75
74ALS573	2.60
74ALS574	4.50
74ALS580	2.60

4000 SERIES

4000	0.20	4076	0.65
4001	0.24	4077	0.25
4002	0.25	4078	0.25
4006	0.70	4081	0.24
4007	0.25	4082	0.25
4008	0.60	4085	0.60
4009	0.45	4086	0.75
4010	0.60	4089	1.20
4011	0.24	4093	0.35
4012	0.25	4094	0.90
4013	0.36	4095	0.95
4014	0.60	4096	0.90
4015	0.70	4097	2.70
4016	0.36	4098	0.75
4017	0.55	4099	0.99
4018	0.60	4501	0.36
4019	0.60	4502	0.55
4020	0.80	4503	0.36
4021	0.60	4504	0.95
4022	0.70	4505	3.80
4023	0.30	4506	0.80
4024	0.48	4507	0.35
4025	0.24	4508	1.20
4026	0.90	4510	0.55
4027	0.40	4511	0.55
4028	0.60	4512	0.55
4029	0.75	4513	1.50
4030	0.35	4514	1.10
4031	1.25	4515	1.10
4032	1.00	4516	0.55
4033	1.25	4517	2.20
4034	2.50	4518	0.48
4034	2.50	4519	0.32
4035	0.70	4520	0.60
4036	2.50	4521	1.15
4037	1.10	4522	0.80
4038	1.00	4526	0.70
4040	0.60	4527	0.80
4041	0.55	4528	0.65
4042	0.50	4529	1.00
4043	0.60	4531	0.75
4044	0.60	4532	0.65
4045	1.00	4534	3.80
4046	0.60	4536	2.50
4047	0.60	4538	0.75
4048	0.55	4539	0.75
4049	0.36	4541	0.90
4050	0.35	4543	0.70
4051	0.65	4551	1.00
4052	0.60	4553	2.40
4053	0.60	4555	0.38
4054	0.80	4556	0.50
4055	0.80	4557	2.40
4056	0.85	4560	1.40
4060	0.70	4566	1.40
4063	0.85	4568	2.40
4066	0.40	4569	1.70
4067	2.30	4572	0.45
4068	0.25	4583	0.90
4069	0.24	4584	0.48
4070	0.24	4585	0.60
4071	0.24	4724	1.50
4072	0.24	14411	7.50
4073	0.24	14412	7.50
4075	0.24	14416	3.00
		14419	2.60
		14490	4.20
		14495	4.50
		145000	6.50
		14599	2.00
		22100	3.50
		22101	7.00
		22102	7.00
		40014	0.48
		40085	1.20
		40097	0.36
		40098	0.40
		40100	1.50
		40101	1.25
		40102	1.30
		40103	2.00
		40104	1.20
		40105	1.50
		40106	0.48
		40107	0.55
		40108	3.20
		40109	0.80
		40110	2.25
		40114	2.25
		40107	2.80
		40163	1.00
		40173	1.20
		40174	1.00
		40175	1.00
		40192	1.00
		40193	1.00
		40194	1.00
		40244	1.50
		40245	1.50
		40257	1.80
		40373	1.80
		40374	1.80
		80C95	0.75
		80C97	0.75
		80C98	0.75

LINEAR ICs

ADC0808	11.90	LM710	0.48	TBA231	1.20
AM7910DC	25.00	LM711	1.00	TBA800	0.80
AN103	2.00	LM723	0.60	TBA810	0.90
AN 1-5050	1.00	LM725CN	3.00	TBA20	0.80
AY 3 1350	5.00	LM733	0.65	TBA820M	0.75
AY-3-8910	4.90	LM741	0.22	TBA920	2.00
AY-3-8912	5.00	LM7747	0.70	TBA950	2.25
CA3019A	1.00	LM748	0.30	TC9109	5.00
CA3020	3.50	LM1011	4.80	TCA270	3.50
CA3028A	1.10	LM1014	1.50	TCA940	1.75
CA3046	0.70	LM1801	3.00	TDA1010	2.25
CA3059	3.25	LM1830	2.50	TDA1022	4.50
CA3060	3.50	LM1871	3.00	TDA1024	1.10
CA3080E	0.70	LM1872	3.00	TDA1170S	3.00
CA3085	1.50	LM1886	6.00	TDA2002	3.25
CA3086	0.60	LM1889	4.50	TDA2003	1.90
CA3089E	2.50	LM2917	3.00	TDA2004	2.40
CA3090AD	3.75	LM3302	0.90	TDA2006	3.20
CA3130E	0.90	LM3900	0.80	TDA2030	2.50
CA3130T	1.30	LM3909	1.40	TDA2593	5.00
CA3140E	0.45	LM3911	1.80	TDA2653	7.00
CA3140T	1.00	LM3914	3.50	TDA3560	7.50
CA3146	2.25	LM3915	3.40	TDA3810	7.50
CA3160E	1.50	LM3916	3.40	TDA7000	3.50
CA3161E	2.00	LM13600	1.50	TEA1002	7.00
CA3162E	6.00	M51513L	2.30	TL061CP	0.40
CA3189E	2.70	M51516L	4.50	TL062	0.60
CA3240E	1.50	MB3712	2.00	TL064	0.90
CA3280G	3.00	MC1310P	1.50	TL071	0.40
D7002	6.00	1413	0.75	TL072	0.70
DAC1408 8	3.00	MC1458	0.45	TL074	1.10
DAC0800	3.00	MC1495	3.00	TL081	0.35
DAC0808	3.00	MC1496	0.70	TL082	0.55
DG308	3.00	MC3340P	2.00	TL083	0.75
HA1366	1.90	MC3401	0.70	TL084	1.00
ICL7106	6.75	MC3404	0.65	TL094	2.00
ICL7611	0.95	MF10CN	4.10	TL430C	1.20
ICL8038	4.00	MK50240	9.00	UA759	3.20
ICM7555	0.90	ML902	5.00	UA2240	1.20
ICM7556	1.40	ML922	4.00	UCN5801A	6.00
LC7120	3.00	MM6221A	3.00	ULN2001A	0.75
LC7130	3.00	NE529	2.20	ULN2002A	0.75
LC7131	3.50	NE531	1.20	ULN2003A	0.75
LC7137	3.50	NE544	1.90	ULN2004A	0.75
LF347	1.20	NE555	0.22	ULN2068	2.90
LF351	0.60	NE556	0.60	ULN2802	1.90
LF353	0.90	NE564	4.00	ULN2803	1.80
LF355	0.90	NE565	1.20	ULN2804	1.90
LF356N	1.70	NE566	1.50	UPC575	2.75
LF357	1.00	NE567	1.25	UPC592H	2.00
LF398	4.00	NE570	4.00	UPC1156H	3.00
LM10CLH	4.50	NE571	3.00	UPC1185H	5.00
LM301A	0.30	NE592	0.90	XR210	4.00
LM307	0.45	NE5532P	1.50	XR2206	4.50
LM308CN	0.75	NE5533P	1.60	XR2207	3.75
LM310	2.25	NE5534P	1.20	XR2211	5.75
LM311	0.60	NE5534AP	1.50	XR2216	6.75
LM318	1.50	OP-07EP	3.50	XR2249	1.20
LM319	1.80	PLL02A	5.00	ZN404	1.00
LM324	0.45	RC4136	0.55	ZN414	0.80
LM334Z	1.15	RC4151	2.00	ZN419P	1.75
LM335Z	1.30	RC4195	1.50	ZN423E	1.30
LM336	1.60	RC4558	0.55	ZN424E	1.30
LM339	0.40	S50240	9.00	ZN425E8	3.50
LM348	0.60	SFF96364	8.00	ZN426E8	3.00
LM358P	0.50	SL490	3.00	ZN427E8	8.00
LM377	3.40	SN76013N	5.00	ZN428E8	4.50
LM380N 8	1.50	SN76033N	5.00	ZN429E8	2.25
LM380N	1.50	SN76115N	2.15	ZN447E	9.00
LM383	3.20	SN76489	4.00	ZN448	7.50
LM384	2.20	SN76495	4.00	ZN449E	3.00
LM386N 1	1.00	SN76660	1.20	ZN450E	7.50
LM387	2.70	SP0256AL2	7.00	ZN459CP	3.00
LM391	1.80	SP8515	7.50	ZN1034E	2.00
LM392N	1.10	TA7120	1.20	ZNA1040	8.60
LM393	0.85	TA7130	1.40	ZNA134H	23.00
LM394CH	4.30	TA7204	1.50	ZNA234E	9.50
LM709	0.35	TA7205	0.90		
		TA7222	1.50		
		TA7310	1.50		

VOLTAGE REGULATORS

1A FIXED VOLTAGE PLASTIC TP220

+ VE		− VE	
5V 7805	0.45	7905	0.50
6V 7806	0.50	7906	0.50
8V 7808	0.50	7908	0.50
12V 7812	0.45	7912	0.50
15V 7815	0.50	7915	0.50
18V 7818	0.50	7918	0.50
24V 7824	0.50	7924	0.50

1A FIXED VOLTAGE PLASTIC TO92

5V 78L05	0.30	5V 79L05	0.45
6V 78L06	0.30	12V 79L12	0.50
8V 78L08	0.30	15V 79L15	0.50
12V 78L12	0.30		
15V 78L15	0.30		

OTHER REGULATORS

FIXED REGULATORS

LM309K	1A 5V	1.40
LM323K	3A 5V	3.50
L78H05KC	5A 5V	7.50

VARIABLE REGULATORS

LM305AH		2.50
LM317T	TO-224	1.20
LM317K	TO3	2.40
LM337T		2.25
LM350T		4.00
LM723N		0.50

SWITCHING REGULATORS

ICL7660	2.50
SG3524	3.00
TL494	3.00
TL497	2.25
78S40	2.50
RC4195	1.50

COMPUTER COMPONENTS

CPUs

1802CE	6.50	TMS4500	14.00
2650A	10.50	TMS9901	5.00
6502	4.50	TMS9902	5.00
65C02-2MHz	12.00	TMS9914	14.00
6502A	6.50	Z80PIO	2.50
6502B	8.00	Z80APIO	2.75
6800	3.50	Z80CTC	2.50
6802	3.50	Z80ACTC	2.75
6809	6.50	Z80DART	6.50
6809E	10.00	Z80ADART	7.00
68B09	10.00	Z80DMA	7.00
68B09E	12.00	Z80ADMA	7.50
68000 LB	38.00	Z80ASIO-0-2/9	7.00
8035	3.50	Z80BPIO	5.00
80C35	8.00	Z80BPIO	5.00
8039	4.20	Z80BCTC	5.00
80C39	7.00	Z80BDART	9.00
8080A	9.50		
8085A	3.00		
80C85A	7.50		
8086	22.00		
8087-5	£120		
8087-8	£160		
8088	17.50		
8741	15.00		
8748	18.00		
TMS1601	12.00		
TMS9980	14.50		
TMS9995	18.00		
V20 8	12.00		
V30 8	12.00		
Z80	2.50		
Z80A	2.90		
Z80B	5.50		
Z80H	7.50		

SUPPORT DEVICES

2651	12.00
3242	8.00
3245	4.50
6520	3.00
6522	3.50
6522A	5.50
6532	4.80
6551A	6.00
6821	1.60
68B21	2.50
68040	3.75
68B40	6.00
6850	1.80
68B50	2.50
6852	2.50
6854	6.50
68B54	8.00
8154	8.50
8155	3.80
8156	3.80
8205	2.25
8212	2.00
8216	1.60
8224	POA
8226	4.25
8228	5.50
8237	6.50
8243	2.60
8250	12.00
8251A	3.25
8253C-5	3.50
8255AC-5	3.20
8256	18.00
8257C-5	54.00
8259C-5	4.00
8275	29.00
8279C-5	4.80
8282	4.00
8284	4.60
8287	3.80
8288D	6.50
8755A	16.00

MEMORIES

2114-3	1.00
4116-2	1.50
4164-15	2.50
41256-15	7.00
41464-15	8.00
4416-15	3.00
5101-3	5.00
6116LP-15	2.80
62256	12.00
6810	2.50

PROMS

28L22	4.00
74S188	1.80
74S287	2.25
74S288	1.80
74S487	2.25
82S123	1.50
82S123	1.50
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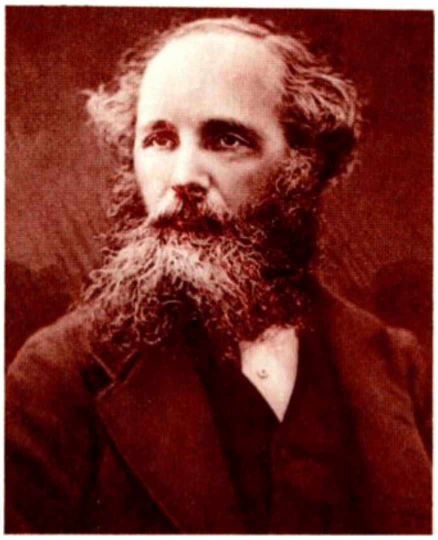
22. James Clerk Maxwell (1831-1879): Scottish laird and scientific genius.

But what is the little man there for? That was the question William Thomson, Lord Kelvin, asked as he peered into the eyepiece of one of Maxwell's optical experiments. The physical phenomenon described by Maxwell was evident, but so too was the figure of a little man – dancing. Baffled, Kelvin peered again. Why was he there? Maxwell's eyes twinkled as he answered, "Just for fun, Thomson".

Maxwell's sense of fun ran through his life, from his childhood paddling of a tub across a duck pond and tripping up the maid when she was carrying the tea tray, to spoofing his inaugural lecture as Cavendish Professor at Cambridge University. An inaugural professorial lecture is usually an affair of pomp and circumstance conducted before the university hierarchy. Maxwell so arranged the publicity for his lecture that it took place in an obscure lecture room before an audience of twenty or so undergraduates. A few days later, after a formal announcement, he gave the first of his undergraduate lectures. There in the front row were assembled the senior members of staff. To them and to his undergraduates, again with that



Institution of Electrical Engineers

mischievous twinkle in his eye, he very carefully explained the differences between the centigrade and Fahrenheit temperature scales.

Love him or hate him, Maxwell was a genius. Fully comprehend his electromagnetic theory and those famous equations or run a mile from them, they changed the world. They are at the foundation of modern physics and they are a major part of his legacy to us. From electromagnetic theory, paths can be traced to relativity and quantum theory as well as the more obvious path to radio. From quantum theory a path leads to semiconductors and so to modern electronics.

Though electromagnetic theory was Maxwell's supreme achievement, his other accomplishments were enough to secure him an important place in the history of science: colour perception, kinetic theory of gases and statistical mechanics, the theory of Saturn's rings, geometrical optics, photoelasticity and other topics. He wrote many elegant papers and a few books, including a two-volume "Treatise on Electricity and Magnetism" (1873) which the Encyclopaedia Britannica has described as "one of the most splendid monuments ever raised by the genius of a single individual".

SHY AND DULL!

Maxwell belonged to the Scottish gentry, being descended from the Clerks of Penicuik, a family noted in Edinburgh from the seventeenth century. He was a skilled horseman and a good swimmer, and loved to read and write poetry. The Clerks had intermarried with the Maxwell family which owned a large estate at Glenlair in south-west Scotland. Maxwell's father, John Clerk, inherited that estate and took the name Maxwell to overcome a legal difficulty. Though a lawyer, he was interested in mechanics and attended meetings of the Royal Society of Edinburgh. Maxwell's mother, Frances Cay, died when he was eight. Both his parents were religious and Maxwell himself held a strong Christian faith.

Born in Edinburgh on 13 June, 1831, just eleven weeks after Faraday discovered electromagnetic induction, Maxwell spent his childhood at the family estate of Glenlair. At the age of ten he went to school at the Edinburgh Academy where he was at first regarded as shy and dull! Four years later, whilst still at school, he wrote his first published paper which duly appeared in the *Proceedings of the Royal Society of Edinburgh*.

After three years at Edinburgh University he moved to Cambridge, where he spent most of his time at Trinity College studying mathematics. Like the rest of us he faced trial by examination. In a letter written during his last term he expressed his attitude towards revision: "I am busy arranging everything so as to be able to express all distinctly so that examiners may be satisfied now and pupils edified hereafter. It is pleasant work and very strengthening but not nearly finished." Evidently his revision went well, for he sat his Tripos in January 1854 and came second. One wonders about the man who came first, E.J. Routh.

In 1856 Maxwell was appointed to the chair of natural philosophy at Marischal College, Aberdeen, where he spent three years before losing the position when the two colleges there were combined into one. As the junior of the two professors of natural philosophy, Maxwell was redundant.

Still, his three years at Aberdeen were notable for two achievements. Maxwell married the boss's daughter, Katherine Mary Dewar, whose father was principal of the college, and he won the Adams Prize of the University of Cambridge. This important prize was awarded every two years for the best essay on a given subject. The subject for 1857 was the motion of Saturn's rings, and a decision was sought between three hypotheses for the composition of the rings: solid, liquid/gas, or loose particles. Maxwell's mathematics led him to conclude that only the third possibility could yield the stability evident in the rings. This major contribution to astronomy set him amongst the leading researchers in mathematical physics.

With such a reputation he was not redundant for long. Soon he was appointed as a professor at King's College, London, but

Fig.1. Maxwell, aged about 10, paddling across the duck pond at the Glenlair estate (sketched by his cousin Isabella Wedderburn).

after five strenuous years there, whilst at the pinnacle of his career, Maxwell resigned and retreated to his country seat in Scotland.

Having suffered a severe illness, he adopted the relatively quiet life of a minor laird and took seriously the responsibilities of his position towards those whose welfare depended on his estate. However, he also continued his own studies, wrote his "Treatise on Electricity and Magnetism" and was an examiner for the Cambridge University examinations.

It was Cambridge University which lured him out of his "retirement" in March 1871 (when he was still not quite 40). The tempting offer was the newly established post of Professor of Experimental Physics, with the task of setting up from scratch a physics laboratory to be known as the Cavendish Laboratory. It was to be his final appointment. He tackled the job with relish and set that new teaching laboratory on its road to world renown as a research centre of the first rank. He even helped to design the building.

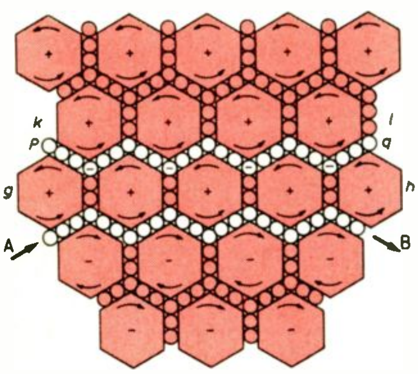
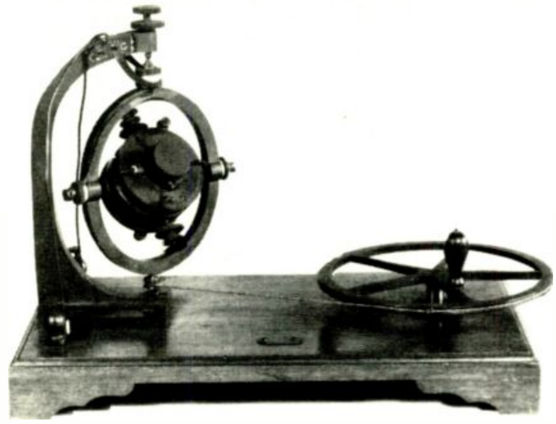


Fig.2. Part of the model of the ether. AB are idle-wheel particles of electricity between the vortices (shown hexagonal). Lines of magnetic force enter and leave the plane of the paper. The kinetic energy of the vortex motion represents magnetic energy, and the force of the vortices on the particles represents electromotive force.

ELECTROMAGNETISM

To electrical engineers, Maxwell's greatest accomplishment was his electromagnetic theory. He was 24 years old, and had graduated about a year before, when his first paper on the subject, "On Faraday's Lines of Force", was published in 1855-56. He stated his intentions quite clearly, explaining that he was not trying to establish a physical theory but to show that "by a strict application of the ideas and methods of Faraday, the connexion of the very different orders of phenomena which he has discovered may be clearly placed before the mathematical mind". His "paper" contained about 25 000 words, almost half the length of a short novel today. To those who wanted a physical theory of electrodynamics he suggested the work of Wilhelm Weber.

His next publication on the subject came in a series of four parts issued from 1861-62, a mere 18 000 words this time. He assumed that magnetism depended on the existence of a tension in the direction of Faraday's lines of force and that the pressure was greater in the "equatorial than in the axial direction". This inequality of pressure was



explained as arising from "the centrifugal force of vortices or eddies in the medium having their axes in directions parallel to the lines of force". Since each vortex revolved in the same direction as its neighbours, a particle like an idle wheel was needed between them so as to avoid clashes at the edges of the vortices (Fig.2).

Whilst these ideas may seem unrelated to electromagnetic theory as we know it, Maxwell used them to construct a mathematical model of the ether using ideas from mechanics. Extending the model to electrostatics yielded the famous displacement current.

The mathematical analysis indicated that the electric and magnetic vectors are at right angles to one another and are propagated in air or vacuum with a velocity almost equal to the then known value for the velocity of light. "We can scarcely avoid the inference", Maxwell wrote, "that light consists in the transverse undulations of the same medium which is the cause of electric and magnetic phenomena."

A third paper, in 1864, added a further 20 000 or so words to his publications. It presented his theory of the ether and its relationship with electric and magnetic fields, stripped of the mechanical scaffolding with which it had been constructed. It introduced the terms "electromagnetic field" and "electromagnetic theory of light". In it he showed that a plane wave propagates with a velocity equal to the number of electrostatic units in one electromagnetic unit. Experimental values for this number, he said, agreed "sufficiently well" with the known value for the velocity of light. In a charming statement he noted that neither electricity nor magnetism had been used to measure the velocity of light, and that in the only known measurement of the ratio of the two systems of units "The only use made of light in the experiment was to see the instrument".

Obviously in the space available here a full account cannot be given of Maxwell's great work on electromagnetism. If you read his papers you may even have some difficulty in spotting those famous equations. The terminology is different from modern usage; and they were given in component form, not in the now commonly used vector calculus form. A full account of his work is given by Whittaker[1] and many shorter accounts are available. A glance through the pages of this magazine over the last couple of years reveals that his work on electromagnetism can still spark a lively debate[2].

FIRST COLOUR PHOTOGRAPH

Less well known is Maxwell's work in other areas of science. Maxwell-Boltzmann statistics, for example, were derived to explain the kinetic theory of gases but are now frequently used in semiconductor theory.

Another major contribution to physics was his work on colour perception. It spanned about 20 years and was roughly contemporary with his electrical research. Whilst a student at Edinburgh, he and J.D. Forbes revived Thomas Young's idea that colour is a physiological effect of the eye and that there are three receptors. This ran contrary to the Newtonian belief in seven primary colours. (We all remember the Richard of York who gave battle in vain, don't we?)

Using spinning discs with coloured segments, Forbes and Maxwell showed experimentally that there are only three primary colours: red, blue and green. Maxwell also explained why the three primary colours and the three primary pigments are different, and he explained colour blindness. All that was great enough but, being a mathematician, Maxwell (now at Cambridge) went on to express his findings algebraically and created the science of quantitative colorimetry. He also probably projected the first colour photograph.

The last five years of Maxwell's life were partly devoted to editing the papers of Henry Cavendish. It was a period during which his wife endured a long and serious illness through which he nursed her whilst continuing to fulfil his professional duties. Eventually it became clear that he also was seriously ill. In June 1879 he left Cambridge for Scotland hoping the rest would help, but in October he was told he had only a month to live. Still caring for his bedridden wife, he returned to Cambridge to be under the care of his favourite doctor. He died of cancer on 5 November, 1879, aged 48.

References

1. E.T. Whittaker, A History of the Theories of Aether and Electricity, Nelson, London, 1951.
2. 'Joules Watt', Maxwell's e.m. theory revisited, *Electronics & Wireless World*, July 1987 page 697.

Next in this series of pioneers of electrical communication: Walter Bruch, inventor of the PAL colour television system.

Dr Tony Atherton is on the staff of the IBA Harman Engineering Training College at Seaton in Devon. His book, from Compass to Computer, a history of electrical and electronics engineering, is published by Macmillan.

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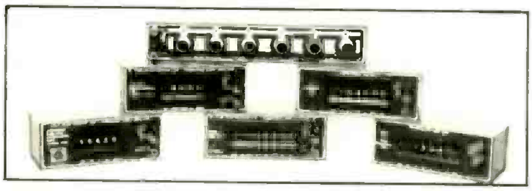

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Tektronix FET Probe 6045 **£90**
Tektronix S3A Sampling Head **£120**
Tektronix 7403N Rackmount O'scope Mainframe, no guarantee tube OK **£200**
Tektronix D11 Storage O'scope Mainframe, no guarantee tube OK. **£200**
Tektronix 7S11 Sampling Amp P/in **£450**.
Tektronix 7B92 Dual time base P/in **£450**.
Tektronix 1A4.4 Trace Plug in **£75**
Tektronix 1A5 Comparator Plug in **£45**
Exact Model 337 Digital phase gen 4μHz/100MHz **£300**.
Keithley Inst 610C Solid State Electrometer measure V,I,R,Q and is a current source **£850**.
Bell & Howell Datatest Calibration Unit for FM systems **£175**.
Marconi Sanders Microwave Osc. c/w 26-40GHz Plug in **£1.000**.
Marconi Inst. 0.1% universal bridge TF 1313A **£260**
HHL 411 Capacitor Charger 20KV new c/with manual **£1.000**.
Feedback Ltd. variable phase oscillator type VSO 230 1Hz to 100KHz **£150.00**

All listed cards ½ shown price this month. Card No. 1: 1×Z80A CPU, 1×D8255 AC5 in holders, 1×5MHz Xtal, 8×MB8264 15, 1×SN74198N +53 various chips, new ex-equipment. **£16.50** Card No. 2: 1×WD1933B-01 in holder +16 various new ex-equip **£12.25** Card No 3: 2×D8255 AC 5, 2×HLCD0437P in holders +10 various **£4.95** Card No 4 LCD 6 digit display, 12 momentary plain keyboard rocker switches 4 bar LEDs. Green, yellow, red. Flat top type. **£6.95** Card No 5: Peripheral Comms Controller. 8×MC68661. 8×MC14891 8×MC1488P 13 various chips all in holders, new ex-equipment. **£18.95** Card No. 6: S100 Backplane 20×100 pin connectors, new. **£29.95** Card No. 7: Hard disk, floppy disk controller S100 type, inc: D765AC D8237 AC5. 8253 8085A 2764 64K Eprom SN74L240N. 224N, 373 etc inc. block dia, new ex-equipment **£26.50** Card No. 8: Infra-red Remote Controller 1AY-3-8470A Encoder IC 1 Infra-Red Emitter. 16 membrane keyboard **£3.50** Card No. 9: 1×MC68000L12 Motorola ceramic CPU. 1×16MHz Xtal + various chips inc block dia chips in holders, new ex equipment **£29.95** Card No. 10 IO Master Board **£7.50** Card No. 11 IO-M Board **£7.50** Card No 12 MC68451L8 Motorola Ceramic **£12** + various chips.

Full height MFE tape streamer, 30 IPS 24 KBPS, SCSI interface streamer tape cassette **£65.00** c/p 1.50

1.2V 1.8Ah Ni Cad new, 42×25mm **£2.00**. 1.2V 1.2Ah Ni Cad new, 41×22 **£2.00** inc c/p.

Vacuum Pump Assembly 240V AC, 2 vacuum pumps by Gast model 1531 714 1/12 HP 2800 RPM c/with limit switch filter etc. **£30** c/p 8.00.

We would like the opportunity to tender for surplus equipment

Official Orders/Overseas Enquiries Welcome/Order by phone or post. Open 6 days, Postal rates apply U.K. mainland only. All test equipment carries warranty. All prices include 15% VAT unless stated. Phone your order for quick delivery. Access, Amex, Diners. Visa accepted. We can supply telephone and some audio equipment, electrical and aerial equipment, much more than is shown in our ad. Please ring.

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16" Decca, 80 series budget range, colour monitors, features include: PIL tube, attractive teak style case, **guaranteed 80 column resolution**, only seen on monitors costing 3 times our price, ready to connect to a host of computer or video outputs. Manufacturers fully tested surplus, sold in little or hardly used condition with 90 day full RTB guarantee. 1000's Sold to date.
DECCA 80 RGB - TTL + SYNC input for BBC type interface etc.
DECCA 80 COMP 75 Ω composite video input with integral audio amp & speaker ideal for use with video recorder or TELEBOX ST or any other audio visual use. **Only £99.00 (E)**

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BRAND NEW **CENTRONIC 14"** monitors in attractive style moulded case featuring **hi res** Mitsubishi 0.42 dot pitch tube with 669 x 507 pixels, 28Mhz bandwidth. Full 90 day guarantee.
Order as 1004-N2 for TTL + sync RGB for BBC etc £159.00 (E)
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Superbly made, UK manufacture, PIL tube, all solid state colour monitors, complete with composite video and sound inputs, attractive teak style case. Ideal for a host of applications including Schools, Shops, Disco's, Clubs etc. Supplied in EXCELLENT little used condition with 90 day guarantee.
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MOTOROLA M1000-100 5" CRT black & white compact chassis monitor measuring only cm 11.6h, 12w, 22d, ideal for CCTV or computer applications. Accepts standard Composite video or individual H & V syncs. Operates from 12v DC at apprx 0.8a. Some units may have minor screen marks, but still in very usable condition. Fully tested with 30 day guarantee & full data Only £29.00 (C)
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KGM 324 9" Green Screen, Little used fully cased, mains powered high res monitors with standard composite video input. Fully tested and in excellent condition £49.00 (E)
20" Black & White monitors by **AZTEK, COTRON & NATIONAL**. All solid state, fully cased monitors, ideal for all types of AV or CCTV applications. Units have standard composite video inputs with integral audio amp and speaker. Sold in good, used condition- fully tested with 90 day guarantee. Only £85.00 (F)

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A MASSIVE purchase of standard 5.25" disk drives enables us to offer you prime product at all time super low prices. All units unless stated are removed from often **BRAND NEW** equipment, **fully tested** and shipped to you with a **full 120 day guarantee**. All units offered operate from +5 and +12 volts DC, are of standard size and accept the common standard 34 way interface connector.
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TEAC FD55-F 40-80 track double sided Half Height Brand New £115.00 (B)

DISK DRIVE ACCESSORIES

34 Way Interface cable and connector single £5.50, Dual £8.50 (A)
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SUGART 800/801 single sided refurbished £175.00 (E)
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TATUNG PC2000. Big brother of the famous **EINSTEIN**, the **TPC2000** professional 3 piece system comprises: Quality high res **GREEN** 12" monitor, Sculptured **92 key keyboard** and plinth unit containing the **Z80A** CPU and all control electronics **PLUS** 2 integral **TEAC 5.25" 80 track double sided disk drives.** Many other features include **Dual 8" IBM format** disk drive support, Serial and parallel outputs, full expansion port, 64k ram and ready to run software. Supplied complete with **CPM, WORDSTAR, BASIC** and accounts package. **BRAND NEW**
Full 90 day guarantee.
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LIMITED QUANTITY **Only £149 (D)**

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DATEL 2412 2780/3780 4 wire modem unit EX BT fully tested £199.00 (E)
MODEM 20-1 75-1200 BAUD for use with PRESTEL etc EX BT fully tested £49.00 (E)
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CONVER AC130-3001 High grade VDE spec compact 130 watt switch mode PSU. Outputs give +5v 15a, -5v 1a, +&-12v 6a. Dim 6.5 x 27 x 12.5 Current list price £190. Our price New £59.95.00 (C)
FARNELL G6/40A Compact 5v 40 amp switch mode fully enclosed New £140.00 (C)
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Special Offer EXPERIMENTORS PSU — ONLY £16.95 (C)

Made to the highest spec for **BT** this unit gives several fully protected DC outputs most suited to the **Electronics Hobbyist.** +5v 2a, +&-12v 1a, -+24v 1a and +5v fully floating at 50ma. Ideal for school labs etc. Quantity discount available.
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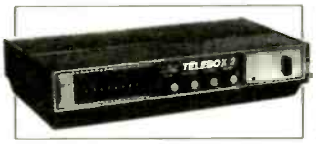

TV SOUND & VIDEO TUNER ONLY **£29.95**

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Full particulars and application forms are available from:
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RFA

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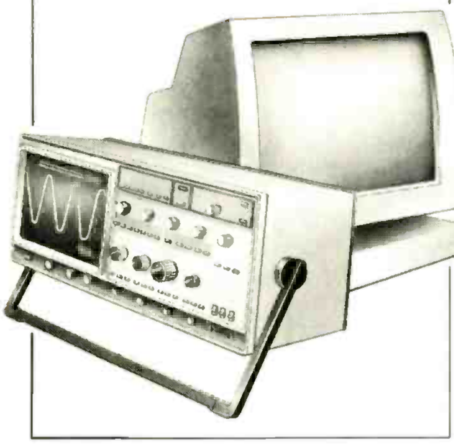

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Your electronics experience should cover repair and test in any of the following fields: Electrical Generation and Control Equipment, Communications, Navigation and Radar, Electrical and Electronic Equipment, and Automatic Test Equipment. You will also need a flair for fault diagnosis.

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£9,000 - £25,000

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STS Recruitment

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