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IN OUR NEXT ISSUE

Shortwave broadcasting efficiency. System developed by Radio Canada International to measure how successful a s.w. broadcasting service is in reaching its intended listeners.

Distortion in audio amplifiers analyses the mechanism of distortion resulting from transistor non-linearities in low-noise circuits. A design example follows later.

Amateur radio equipment. A survey outlining design and performance trends in commercial transmitters, receivers and transceivers at present available for amateur operators.

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Elektor Electronics
Magazine No. 8, Dec. 1975

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**Details**

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<tr>
<th>No.</th>
<th>Impedance (OHMS) Input</th>
<th>Output</th>
<th>Turns Ratio</th>
<th>Operating Level</th>
<th>Frequency</th>
<th>Response</th>
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<tr>
<td>MU 7501</td>
<td>0.3/15</td>
<td>100Ω</td>
<td>200Ω</td>
<td>6.5</td>
<td>50Hz-&gt;10kHz</td>
<td></td>
</tr>
<tr>
<td>MU 7503</td>
<td>0.3/100</td>
<td>100Ω</td>
<td>600Ω</td>
<td>1:1</td>
<td>50Hz-&gt;10kHz</td>
<td></td>
</tr>
<tr>
<td>MU 7510</td>
<td>1.5/20</td>
<td>10Ω</td>
<td>10Ω</td>
<td>1:1</td>
<td>50Hz-&gt;10kHz</td>
<td></td>
</tr>
<tr>
<td>MU 7512</td>
<td>3.7/15</td>
<td>10Ω</td>
<td>600Ω</td>
<td>2:1</td>
<td>50Hz-&gt;10kHz</td>
<td></td>
</tr>
<tr>
<td>MU 7514</td>
<td>5.0/20</td>
<td>10Ω</td>
<td>600Ω</td>
<td>3:1</td>
<td>50Hz-&gt;10kHz</td>
<td></td>
</tr>
<tr>
<td>MU 7522</td>
<td>10/25</td>
<td>10Ω</td>
<td>600Ω</td>
<td>5:1</td>
<td>50Hz-&gt;10kHz</td>
<td></td>
</tr>
<tr>
<td>MU 7524</td>
<td>15/50</td>
<td>600Ω</td>
<td>600Ω</td>
<td>1:1</td>
<td>50Hz-&gt;10kHz</td>
<td></td>
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<tr>
<td>MU 7528</td>
<td>30/100</td>
<td>600Ω</td>
<td>600Ω</td>
<td>1:1</td>
<td>50Hz-&gt;10kHz</td>
<td></td>
</tr>
<tr>
<td>MU 7530</td>
<td>10k</td>
<td>600Ω</td>
<td>600Ω</td>
<td>1:1</td>
<td>50Hz-&gt;10kHz</td>
<td></td>
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<tr>
<td>MU 7534</td>
<td>50k</td>
<td>600Ω</td>
<td>600Ω</td>
<td>1:1</td>
<td>50Hz-&gt;10kHz</td>
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<tr>
<td>MU 7535</td>
<td>100k</td>
<td>600Ω</td>
<td>600Ω</td>
<td>1:1</td>
<td>50Hz-&gt;10kHz</td>
<td></td>
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<td>MU 7538</td>
<td>1M</td>
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<td>MU 7539</td>
<td>0.5M</td>
<td>600Ω</td>
<td>600Ω</td>
<td>1:1</td>
<td>50Hz-&gt;10kHz</td>
<td></td>
</tr>
</tbody>
</table>

We would emphasise that the above is a representative selection only. Send for Brochure GTS for complete listings. All units described are normally AVAILABLE FROM STOCK.

**SPECIAL DESIGN SERVICE**

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Micropower down to 1.5 mW | Strobability | CA3160, CA3130
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**Power Bandwidth**
- DC 20kHz: 150 watts + 1db. - 0db
- 500 watts RMS into 2.5 ohms
- +0. – 15: DC to 20kHz, 1 watt: 8Ω
- Harmonic Distortion: Below 0.05% DC to 20kHz
- Intermod. Distortion: Below 0.05% 0.01 watt to 150 watts
- Greater than 200 DC to 1kHz at 8Ω: At least 110dB below 150 watts

**Slowing Rate**
- 8 volts per microsecond

**Load Impedance**
- 1 ohm to infinity

**Input Sensitivity**
- 1.75 V for 150 watts into 8Ω

**Input Impedance**
- 10K ohms to 100K ohms

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**Power Supply**
- 120-256V, 50-400Hz

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- 19' Rackmount. 7' High. 9½' Deep: At least 110dB below 150 watts

**Harmonic Distortion**
- Below 0.05%

**Intermodulation Distortion**
- Below 0.05%

**Damping Factor**
- Greater than 200 DC to 1kHz at 8Ω

**Dimensions**
- D150A – 150 watts per channel

**Other models**
- D60 – 60 watts per channel
- D150A – 150 watts per channel

**Other models available from 100 watts to 3000 watts**

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Wireless World, July 1977
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Tuner Kit

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M1 KIT

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M6 MODULE ONLY £44.40

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<tr>
<th>Module</th>
<th>Kit Price</th>
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<tr>
<td>M2 Stereo decoder</td>
<td>£7.60</td>
<td>£6.22</td>
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<td>M3 Push button M5</td>
<td>£15.95</td>
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<td>SU1310 decode IC</td>
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<td>LP1196 front-end</td>
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<td>Filter, SFJ10 7MA</td>
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<td>7 segment L.E.D. (c/a)</td>
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WW—034 FOR FURTHER DETAILS

Detecknowledge

Detecknowledge?

Not a spelling mistake, but a new publication from AMBIT that sets out to explain some of the basic theory that surrounds metal location techniques. It is an explanation, that builds up from first principles, why iron sometimes reacts like a non-ferrous metal, what determines detector range, what the shortcomings are, how to avoid them. In fact, it explains about BFO, IB, VCO and Pulse Induction techniques, as a result of research carried out to produce our range of locators, and why we chose the methods we used. As a general purpose reference work for designers, constructors, users etc., we think you will find it unique. £1.00 inc. postage.

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<tr>
<td>EF5600 6 oct varicap head</td>
<td>12.95</td>
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<tr>
<td>EC3302 3 oct varicap head</td>
<td>7.50</td>
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<tr>
<td>7030 linear phase FM if 100Hz</td>
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<td>91196 high spec mx decoder</td>
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FEATURES: Complete pre-amplifier in single pack — Multi-function equalization — Low noise — Low distortion — High overload — Low simply combined for stereo

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FEATURES: Complete kit — Line Distortion — Short. Open and Thermal Protection — Easy to Build

APPLICATIONS: Uploading audio equipment — Guitar practice amplifier — Test amplifier — Audio recorder

SPECIFICATIONS:
- OUTPUT POWER: 16W R.M.S. into 8Ω input SENSITIVITY: 500mv FREQUENCY RESPONSE: 1kHz-45kHz — 3dB
- SUPPLY VOLTAGE: 24v SIZE: 100 X 25mm

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FEATURES: Low Distortion — Integral Heatsink — Only five connections — 3 Amp output transistors

APPLICATIONS: Medium Power H.F. systems — Low power disco — Guitar amplifier

SPECIFICATIONS: INPUT SENSITIVITY 500mv.
- OUTPUT POWER 250w R.M.S. into 8Ω
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60 Watts into 8Ω

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FEATURES: Very low distortion — Integral Heatsink — Load line protection — Thermal protection — Five connections — No external components

APPLICATIONS: H.F. — High quality disco — Public address — Monaural amplifier — Guitar and Organ

SPECIFICATIONS: INPUT SENSITIVITY 500mv
- OUTPUT POWER 600w R.M.S. into 8Ω LOAD IMPEDANCE 4:16Ω DISTORTION 0.04% at 600w at 1kHz
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- SIZE: 114 X 100 X 85mm

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120 Watts into 8Ω

The HY200 now improved to give an output of 120watts, has been designed to stand the most exacting conditions, such as direct or group while retaining true H.F. performance.

FEATURES: Thermal shutdown — Very low distortion — Load line protection — Integral Heatsink — No external components

APPLICATIONS: Hi-fi — Disco — Monitor — Power Slave — Industrial — Public address

SPECIFICATIONS: INPUT SENSITIVITY 500mv
- OUTPUT POWER 1200w R.M.S. into 8Ω LOAD IMPEDANCE 4:16Ω DISTORTION 0.05% at 1200w at 1kHz
- SIGNAL/NOISE RATIO 96dB FREQUENCY RESPONSE 1kHz-45kHz — 3dB SUPPLY VOLTAGE: 45v
- SIZE: 114 X 100 X 85mm

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HY400

240 Watts into 4Ω

The HY400 is a Little Big Daddy of the range producing 240W into 4Ω. It has been designed for high power disco or public address applications. If the amplifier is to be used in continuous high power levels a cooling fan is recommended. The amplifier includes all the qualities of the rest of the family including true high power fidelity, high efficiency power module.

FEATURES: Thermal shutdown — Very low distortion — Load line protection — No external components

APPLICATIONS: Public address — Disco — Power Slave — Industrial

SPECIFICATIONS: INPUT POWER 2400w R.M.S. into 4Ω LOAD IMPEDANCE 4:16Ω DISTORTION 0.1% at 2400w at 1kHz
- SIGNAL/NOISE RATIO 94dB FREQUENCY RESPONSE 1kHz-45kHz — 3dB SUPPLY VOLTAGE: 45v
- INPUT SENSITIVITY 500mv SIZE: 114 X 100 X 85mm

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The Ernie and Arnie show?

Mr Ernest Harrison, chairman and managing director of Racal Electronics, has been calling for further rationalization of the British electronics industry. It is "bound to come" he declared at a press lunch. And "it won't be too long in coming, I believe". Asked if he had had any discussions with the National Enterprise Board, he replied "Yes, we've all been involved, not just Racal but all the other companies as well". Mr Harrison's main concern is to improve Britain's chances of obtaining big overseas orders. He feels that the present system, of several UK companies bidding competitively, without Government support, fares badly against that of other countries which have their governments assisting one or two large groups. Mr Harrison made it clear what he had in mind, at least for Racal. "We want another group matching GEC" he said. "A bit of competition might be good for Arnold Weinstock, good for his company and good for the country".

In principle rationalization is a good thing. Its purpose is to eliminate wasteful duplication of resources, the splitting in too many ways of capital investment, materials, labour and other factors of production inevitable in normal business competition. It should mean that whatever resources are available in an industry they will all be used continuously and efficiently. And the government, which has to be seen to be even-handed, is much more likely to give diplomatic and financial support to a single large group tendering for an overseas contract than it is to favour invidiously one of several companies in a freely competitive situation.

In practice, however, rationalization means take-overs. These can be achieved by agreement, when the willing "victim" is in a weak financial state, or covertly, by secret buying of shares on the stock market (as Racal started to do with Ultra some months ago). Now one immediate effect of rationalization for merger purposes is loss of jobs, as happened in GEC, for the improved efficiency required can seldom be achieved without this shedding of labour. With unemployment as serious as it now is in Britain, those considering rationalization of the electronics industry will have to weigh very carefully the certain social consequences against the expected economic benefits.

Another problem inherent in rationalization is that it can create a business monopoly. One could argue that if we had two big groups in electronics, say GEC and Racal, there would be competition between them. Well, there is competition between ICI and Unilever, but no sign that these two giants are fighting each other to the death. Between them they dominate the market for a wide range of household products in Britain. Experience shows that when a small group of companies holds a captive market there is a tendency towards price fixing — remember the telephone equipment "ring" of the 1950s — and the people who work for them feel they are in a safe job, so there is no need to labour hard but just keep one's nose clean. Both of these facts of life are against the interests of the public.

Finally, if an industry is concentrated into one or two big groups that industry is ripe for nationalization. We have just seen the British Aircraft Corporation and Hawker Siddeley Aviation being merged and nationalized into British Aerospace. This will achieve remains to be seen. But a recent French parliamentary report on their aircraft industry considers that the possible nationalization of Dassault and merging with the already nationalized Aerospatiale to form a single national group would do more harm than good. It would eliminate competition which, the report says, is essential and "exerts a decisive influence on export sales".

Maybe there are some experiences here for our electronics industry chiefs to ponder on.
Microwave intruder alarm

Construction of Doppler radar to detect movement

by M. W. Hosking, M.Sc., M.I.E.E., British Aircraft Corporation

Based on the Doppler frequency shift principle, this domestic intruder alarm system uses straightforward and simple techniques, together with materials that are readily available to everyone and brings what has hitherto been a costly and professional system within the reach of a domestic budget. Most of the components can also be used to make a simple voice communications link, with the main addition of an audio modulator. Construction of a voice link, including the microwave transmitter and receiver will be described in a later article.

The microwave transmitter and detector circuits are constructed in waveguide. But, for those who do not wish to go to the lengths of building these components, a complete intruder alarm kit is available with these items already built and set to the correct frequency. This complete system has been given type approval by the British Home Office as satisfying their transmission regulations.

General principles

The microwave intruder alarm operates on the principles of a small radar system. It transmits a signal at the appropriate frequency which travels outward as a radio wave until it meets an object, whereupon a portion of the signal is reflected back again toward the receiver. If this returned signal can be detected and suitably processed, then information can be extracted about the reflecting object.

With the advent of solid-state sources of microwave signals ("Realm of microwaves" Wireless World Feb. 1973) the way has opened for very small, cheap, low-power transmitters operating from low-voltage, d.c. power supplies. In this instance, the transmitter is a Gunn diode operating from a 7V rail. The device is encapsulated in a package about the size of a match head, but to control the frequency spectrum and to extract power efficiently, it is mounted in a waveguide resonant cavity. The detector, a Schottky barrier diode, is also waveguide-mounted. Further details, including a method of fabrication for those who wish to build their own will be given in a later article.

If the reflecting object shown in the schematic arrangement of Fig. 1 is moving toward or away from the receiver then, in similar fashion to the train-whistle example usually cited at school, the receiver frequency will differ from that transmitted. The difference between the two is the Doppler frequency. In addition to the directly transmitted signal, a small portion is arranged to couple directly into the receiver and acts as a local oscillator drive. The returning frequency-shifted signal at frequency \( f_a \pm f_d \) is thus mixed with this local oscillator at frequency \( f_o \) and the output circuit bandwidth adjusted to extract the beat frequency difference, \( f_b \).

The creation of a Doppler shift in frequency can be visualized by considering the two waveforms in a little more detail. As the transmitted signal moves out, with its amplitude varying sinusoidally, its phase angle relative to the starting point will change by \( 2\pi \) radians (360 degrees) every time the distance increases by a wavelength. In this case, the wavelength is about 28mm. Exactly the same thing is happening to both the returning signal and to that forming the local oscillator. These two are mixed together in the diode to form the beat or difference frequency.

The amplitude at this i.f. is a phase function of the two input signals. If the path, 2R, traced by the reflected signal was half a wavelength different than that taken by the direct local oscillator wave, then the two would subtract at the receiver. The output would not actually go to zero, as the two signals are not normally comparable in amplitude, but would be a minimum. Conversely, when both inputs had traversed an integral number of whole wavelengths, they would combine in phase to produce an i.f. output of maximum amplitude. If the reflecting object happens to be moving, then the relative phase of the two inputs is also changing. The local oscillator path remains constant, but the path taken by the radar signal is varying at twice the reflector speed, 2Vm/s.

Back at the mixer, the effect is as if the two wavetrains were sliding past each other at 2V/\( \lambda \) wavelengths per second to produce an alternating output voltage at this rate as they reinforced or subtracted from each other. This is the Doppler frequency \( f_d = 2V/\lambda \).

To comply with the regulations, the transmitter must operate at 10.687GHz i.e. \( \lambda = 28.07\text{mm} \). Thus, the Doppler frequency is 71.25Hz for each m/s of reflector speed, or 31.85Hz per mile/h. Fig. 2 shows this relationship in graphical form.
Extraction of this Doppler signal can be used as an efficient means of detecting a moving object against a stationary background. For use as in intruder alarm, the reflections from walls and furniture will all be stationary in phase difference and so will produce no alternating beat frequency, whereas a moving object will generate an if, typically in the low audio range. This signal can then be amplified and used to trigger an alarm. This type of system thus gives the type of selectivity that is required and, operating as it does in this relatively uncluttered area of the frequency spectrum, is not so vulnerable to interference. There are no beams to break, as in some systems, as the signal fills the whole room and movement anywhere can trigger the alarm. Nor is it sensitive to spurious acoustic noises as are another class of alarm systems. A gain control on the alarm allows the triggering threshold to be adjusted to suit the size of room and the reflecting target, i.e. to choose the larger reflection from a human as opposed to that from the the domestic pet.

Transmitter and receiver
The general design of the transmitter and receiver cavities for the ready-made Mullard CL8960 unit are shown in Fig. 3(a) and Fig. 3(b) the schematic electrical connections. The operating frequency is controlled by the length of the transmitter waveguide between the Gunn device and the back wall. However, insertion of the tuning screw perturbs the field within the cavity in such a way as to appear initially as an inductance and to lower the resonant frequency. The side-by-side arrangement is to allow coupling of the local oscillator signal which occurs by direct leakage into the receiver waveguide. However, the level of signal is very low, at about 10 µW and a small amount (30.35 µA) of forward bias is necessary on the mixer diode.

Some precautions are necessary when making the electrical connections to avoid damage to the microwave semiconductor devices. The mixer diode is easily damaged by voltage transients on the mains supplies, so it is recommended that soldering appliances be disconnected from the mains just prior to making the mixer connection and during any subsequent contact with this component. Forward bias should not be allowed to exceed 1 mA. The Gunn device will not tolerate a reversed supply voltage, so check before connecting. As supplied, the mixer is fitted with a shorting wire to the case and this should be left in place until assembly is completed and then removed. The Gunn device appears as a dynamic negative resistance and it is possible for oscillations to be induced in the supply circuit. To avoid this, connect a small 10 nF capacitor directly across the terminals as shown in Fig. 3(b).

General conditions of operation for the assembly are:
- Frequency 10,687 ± 12 MHz (preset)
- Gunn device supply voltage + 7.0 ± 0.1V (+7.5V max.)
- Gunn device supply current 130 to 163 mA (140 mA typ.)
- Mixer diode forward bias 30 to 34 µA
- Power output 80mW typ. (100mW max.)

The microwave module is supplied with a small, 5-dB gain antenna, constructional details of a 20dB gain horn will be given later. The magnitude of the Doppler output at the mixer terminals is a function of the size of the reflecting object and its range. Typically, however, a man would have a radar cross section of 1 m² and, using the 5 dB antenna, the received signal would be 100 dB down on that transmitted at a range of 15 m. This will produce about 40 V of Doppler signal for signal-plus-noise ratio of 18 dB.

Fitted with the 5 dB gain antenna, the Doppler module is reasonably matched to free space and has a polar pattern of the form shown in Fig. 4. The widebeam coverage together with the filling-in effect from multiple reflections means that comprehensive coverage of a room is effectively achieved.

An interesting game has evolved at home: in a room about 30 ft long, children endeavour to creep and crawl up on the intruder alarm without being detected. No matter how subtle the approach, this has not so far been achieved without triggering the alarm.

Receiver and alarm
It is necessary to selectively amplify the Doppler signal to a level sufficiently high to trigger an alarm, whilst at the same time rejecting false alarms from spurious noise levels (Fig. 5).
More conventional circuits could be used for the amplifier, but the intruder system has been developed side-by-side with a voice link and as much commonality as possible has been built into the two systems.

Sensitivity of the Doppler receiver is a function of the i.f. amplifier input noise figure and bandwidth. The narrower the bandwidth, the less the contribution of thermal noise power. Thus, the first section of the circuit is an RC filter having the measured bandpass characteristic of Fig. 6. The combination of Tr1 and IC1 provide a first stage voltage gain of about 1000, together with a reasonable input noise figure. The slightly unusual connections to the operational amplifier are mainly for the benefit of the voice link receiver, as they provide a means of achieving a high slew rate from a normal 748 op-amp by by-passing the input stages.

Fig. 5 (top) Amplifier and alarm trigger circuit with power supply (bottom) to p.c.b and transmitter.
Components marked with an asterisk may have different values in the kit design.
The second amplifier provides a good voltage gain which can be varied with the potentiometer R26. The diode pump and clamping circuit of C1, C2, D3 and D5 defines the voltage threshold and time constant necessary to switch on the Tw; Tr, Darlington drive to fire the s.c.r. Potentiometer R26 provides additional control of the drive level and the l.e.d. gives a visual indication of each time that a trigger signal is generated. It is also used for initially setting the maximum gain that can be obtained from IC5 before any instability occurs.

The prototype, the alarm itself is an 18V audible warning device which emits a penetrating, modulated wail at about 3kHz. However, as the alarm trigger takes place through a relay, it would be a straightforward matter to connect up to other warning devices such as a door bell, or to add an extra feature such as camera and flash unit.

Assuming that the intruder alarm will be fitted in a room or hallway of domestic premises, it is obviously necessary that the circuit should be activated when everybody is out of the way, otherwise one's own movement would trigger the alarm. Two options are provided in Fig. 5 for achieving this. Firstly, the positive supply rail for the s.c.r. and relay is routed via the Tr3, Tr5 combination, so that sufficient current to operate the relay can only flow when Tr3 and Tr5 are switched on. This can only occur when C22 has charged through the high resistance path of R38. Thus, when the overall system is switched on, the Doppler module, amplifiers and supply rails are all activated, but the relay will not operate to trigger the alarm until after a short delay. This delay is set by the timeconstant of R3 and C22 which, in this case, has been chosen as 45-60 seconds: ample time to leave the room and close the door. Using this method, the alarm will be triggered on re-entering the room, say the next morning. If this was acceptable, then it could be looked upon as providing a daily check on the system.

An alternative uses the jack plug and socket arrangement. Inserting the plug by-passes the delay circuit and allows the alarm to be set by a remote switch taken out of the room and located at some convenient point. The circuit has been tested with over 100ft of flex between alarm and switch. Whichever method is used once fired the s.c.r. and hence the alarm will remain on until reset by the appropriate switch.

To be concluded

An end to listen-only answering machines

The proliferation of telephone answering machines is likely to advance even more rapidly if a device made by LMG Electronics gains wide acceptance. Normally the user of one of these hideously unsociable devices has to travel back to his office in order to hear the rude things people have shouted into it, but the LMG system enables an accredited caller to dial into the machine from a distant telephone and hear the messages over the phone. According to an article by the company’s founder, Mr Graham Bent, in NRDC Bulletin number 45 the idea is not new “but operation hitherto has been cumbersome, and only a single rewind could be initiated.” The LMG device controls stop, start, rewind, playback and erase on the answering machine by means of coded pulses of tone generated by the user on a distant phone. The audible tone pulses are produced by an audio unit, the interro-gator holds against the mouthpiece of the telephone he is using. One control button provides an operating code of five trains of pulses. Only this pulse can open the machine to remote operation. “There are over 40,000 possible combinations,” the device manufacturer says. Once the recognition code has been established, the machine receives short common pulse trains enabling control of the machine from four buttons. The unit is powered from a 9V battery which should last 12 months.

When LGM approached the National Research and Development Council they asked for £3,000 repayable over 12 years but the NRDC thought they were being optimistic and lent them £4,000 repayable over three years. The loan was unsecured at 20% instead of the more usual royalty on sales. In addition the firm had £5,000 of Bent’s money and a similar amount from the bank. That was in 1972. The NRDC loan was repaid “A few months ago,” according to Graham Bent.
Kinetic images from sound

American developments in a modern art form

by Thomas E. Mintner, University of Iowa

With the advent of certain technologies such as video, lasers and integrated electronic circuitry the contemporary artist or composer has resources available which allow forms of expression unheard of as little as fifteen years ago. One obvious example is the field of electronic music, where the proliferation of synthesizers and similar devices has resulted in a deluge of electronic music studios, compositions, live performances and commercial applications. A related area is concerned with devices and compositions designed to take advantage of simultaneous presentation of music with light and images.

Historically, this area ranges from essays on "colour music" dating from the early part of this century to devices utilizing the latest technology. Now, as in the past, efforts in this area come not from any one discipline, but from composers, artists and sculptors, engineers, dancers and architects. Technologically, there is a wide span from simple colour light boxes to video or laser devices incorporating advanced combinations of electronic and electro-optical techniques. This article is not intended to be a comprehensive listing of all such aural/visual devices or works, but rather an overall view with detailed information on some projects with which the author has been associated.

If there can be one conclusion drawn from most of the artistic attempts at correlation of audible and visual information, it is that effective and natural co-ordination is difficult to achieve.

Although some early attempts were severely hampered by a lack of suitable technology, there is a still more basic problem. The fundamental differences in the two sensory systems involved are many. Since our senses of sight and hearing tend to complement each other in day-to-day activities, we may tend to overlook the many perceptual differences which must be confronted when we attempt to create a set of stimuli (a composition) that will utilize both senses together. Investigation of these two sensory systems is still at the level of basic research and modelling for even relatively simple stimuli. Complex signals such as music or visual arts can also be analysed in terms of their content, both from the point of view of their respective disciplines (e.g. music theory) and from the more general basis of information theory.

Given these facts, it is not hard to understand the limited success of early "colour organ" type efforts at music-light correlation. Generally, it was assumed that there would be some sort of fixed relation between the colour spectrum and the musical scale (12 note), with perhaps differences in colour intensity used to represent octave displacement of pitches. There were also numerous other schemes, all with similar problems. However, it should be noted that at least one major composer wrote an orchestral work, still performed and recorded, with a noted part in the score for "tastiera per luce" or keyboard of light. This is A. N. Scriabin's Prometheus, The Poem of Fire (1909-10). Scriabin's correlation theories are somewhat more interesting than those above, and in fact a modern realization of his composition has been performed.

Colour organs, along with the pioneering work of artists such as Thomas Wilfred, who was the originator of the Lumia (or light box) in art, are part of a broad range of efforts relating more to colour than image. With the development of the cathode-ray tube it became relatively simple to generate visual image analogues to sound and music through the use of X-Y display techniques. This involves routing two sets of signal information or two similar components of the same information (e.g. left and right stereo channels of recorded music) to the vertical and horizontal inputs respectively of a cathode-ray tube. As early as 1953 an American artist exhibited his Oscillons - images created by photographing specially generated signals fed to a c.r.t.

In the mid and late 1960s there was increased development of new techniques. Lowell Cross described his experiments and compositions with
Wireless World, July 1977

X-Y display art as a kinetic form with music in articles for Source magazine. The use of this type of display as an adjunct to electronic music allowed for another level of interest in a live or taped performance. Although the analogues produced with these methods are not necessarily the only way to interface the elements of sound and visual information, they are generally effective, and have been used in many works in recent years. Cross progressed from oscilloscopes to specially modified television sets and eventually to laser deflection systems, as we shall see later.

During the same period, various artists and composers began experimenting with video imagery. One technique which was “discovered” for artistic purposes was video feedback. In its simplest form, a camera is pointed at the video monitor that it is feeding. As in the famous situation in audio, oscillations are set up because of the relatively uncontrolled feedback path. By controlling this path, it is possible to use feedback as a versatile method of image generation. Various limiting and processing devices may be inserted into the feedback loop to modify and control the images. The author’s introduction to this method was in 1969 in work with Glenn R. Sogge and Timothy Skelly, both composers and artists. At that time, considerable effort was sometimes necessary to convince studio supervisors that video feedback experimentation under controlled situations would not necessarily leave the video chain in flames! However, once this was done, it became possible to present a series of concerts/events with specially generated video imagery and electronic music.

Up to this point there was no actual electronic interface between the two domains. The initial attempt in this direction, which was moderately successful, was as follows. Oscillators being used in the generation of musical sounds were connected and mixed so that their outputs were fed to a balanced modulator as well as to their normal destinations. These oscillations were then modulated with a frequency high enough that the upper sidebands were in a video frequency range. The output of the modulator was then sent through an encoder to produce a composite video signal. In the intervening years various video processors and “synthesizers” have been developed using i.c. technology and methods borrowed from electronic music. Composers, film-makers, and video artists are continuing to experiment in this area.

One example of such experimentation from the Center for New Performing Arts of the University of Iowa is the Video Colour Quantizer System. The basic system is a modification of a standard unit manufactured by Colorado Video, Inc., an American firm. Franklin Miller, a film-maker at the university, started the experimentation with this unit. Basically the quantizer is a device which accepts a monochrome video signal and has sixteen adjustable signal comparator thresholds relating to the amplitude of the video signal. At these various levels from black to white along the grey scale, sixteen points can be set to trigger production of sixteen different pre-assigned, synthetically generated colours. With the colour mixing unit incorporated in this version any combination of colours may be set to allow modifications such as synthetic colour generation, grey scale reversal and other effects.

A recent grant has allowed the design and construction by the author of a voltage control interface for the quantizer system. With this interface the sixteen threshold points, or “slice levels,” can be determined by the application of a d.c. or a.c. control voltage. This means that a colour assigned to a given grey level range may be made to change with the applied voltage, or that a threshold can be shifted electrically to alter (by colour addition) several other colour areas in the image. In addition, the master outputs of red, green, and blue can each be gated with a control trigger. Signals routed to this total of nineteen control inputs may be used directly, as in the case of electronic music, or may be generated from other music through the use of an amplitude detector or a pitch-to-voltage converter. Another performance possibility is to use control signals derived from other than musical sources, or to split the allocation of control inputs, with some control voltages coming from musical material, and some from other sources, such as devices sampling video signals or sensors attached to dancers. As a part of the grant programme, two colour films are to be produced, one by the author, and one by Peter Tod Lewis, composer and director of electronic music at the University of Iowa. These films will have specially composed sound tracks to control the video colour quantizer interface.

Another interface project is a work realized by West Coast US artists and engineers Bob Watts, Bob Diamond and David Behrman. The work, called the Cloud Music, uses a video camera trained on the sky during daytime periods. As clouds pass into the field, the changing video signal, sampled at various cursor points on the screen, controls a system by composer David Behrman which produces electronic music “on the spot.” The piece functions as a kind of performing sound sculpture (depending, of course, on the weather). Shortly after small lasers became commercially available, artists began experimenting with them in a variety of ways. The laser light itself is the object of some of these investigations. The highly collimated beams lend themselves to a variety of illumination tasks, including large outdoor geometric constructs using the stationary beams of high power lasers. On the question of light and sound correlation, however, we find that most uses of lasers involve methods of scanning the beam. Various approaches have been tried, and the most sophisticated systems in use today use galvanometer mirror scanners to produce X-Y scanning. Thus we find that principles of music-light correlation applicable to oscilloscope type displays find a new and much larger scale medium in X-Y laser scanning.

In addition to this simple X-Y scanning there are other techniques which are sometimes combined with X-Y systems. By passing a laser beam through an uneven glass or plastic surface, for example, one can generate patterns of a “cellular” nature which results from the interference of the laser light with itself as it passes through the material. If the beam is deflected slightly as it passes through the material, kinetic images related to the deflection signal (e.g. music) may be generated. One of the deflection methods which

![Fig. 2. Method of laser beam deflection used in the Sonovision system.](image)
could be used in this application involves attaching a small first surface mirror to a loudspeaker (Fig.1). A signal fed into the speaker will cause the mirror to move and deflect the beam. Another experimenter in this area was Lloyd Cross (not to be confused with Lowell Cross), who developed a system called Sonovation\(^2\) using a loudspeaker covered with a reflective membrane (Fig. 2). In addition, the system, which was intended to be commercially available, had a rotating prism assembly for generating more complex multiple images. A slightly more useful version of this idea uses two loudspeakers (Fig. 3), each of which has a hinged mirror assembly connected to the cone. The hinges restrict the movement of each mirror to one axis. Thus a simple X-Y scanning system is formed. The deflection is limited to relatively low frequencies and the system response is not at all linear because of the many mechanical resonances. More sophisticated X-Y scanning systems use commercially available galvanometer mirror scanners. The first such system assembled for the artistic purpose of exploring kinetic inter-relationships between light and sound was Video/Laser 1, an experimental laser deflection system initiated by Lowell Cross, Carson Jeffries and David Tudor at Mills College, USA. This was in May 1969. Soon after, another such system was commissioned for use in the Pepsi-Cola Art and Technology Pavilion at the 1970 World Exhibition in Osaka, Japan. Both of these early systems have been dismantled. However, Video/Laser III, the latest system constructed by Cross and Jeffries for the Center for New Performing Arts at the University of Iowa had its premiere in a concert with orchestra on November 29, 1972.\(^3\) Improvements and additional electronic control devices are being added on a continual basis by Lowell Cross and the author.

The system used is as follows. The output beam of a 2-watt krypton-argon laser is split into its component beams. This is achieved by passing the initial greenish-white output beam through a direct vision prism. Any four of the approximately sixteen available colours may then be selected and routed to the four beam deflection systems. Each system contains a beam splitter and two mirror scanners for deflection (X and Y). Each deflection component of each channel has its own direct coupled amplifier, and any audio signal may be fed to the systems. The devices used have certain frequency response limitations because of necessary compromises between maximum scanning angle and frequency response.

The maker of the scanners, General Scanning Inc., through a subsidiary, is now involved in X-Y scanning systems for artistic purposes also. One such system, called Skywriter, is designed with X-Y inputs and an accompanying vector generator system to produce a variety of line images, including a kind of animation.

Multi-colour laser systems using large lasers are capable of creating extremely large images on any suitable projection surface, indoors or out, though generally the area must be in relative darkness for best results. The Video/Laser III system mentioned above is used in a variety of performance situations, often with electronic music as a sound source. It is conceived of as an experimental performance and research instrument.

One fairly recent performance with the Video/Laser III system may demonstrate how the original art of "colour music" has progressed to its current position. A performance of A. N. Scriabin's Prometheus was given on September 24, 1975, with the laser system functioning to realize fully, perhaps for the first time, Scriabin's wishes for the keyboard of light. A specially constructed keyboard interface was used, with a performer playing the written part as indicated in the orchestral score. The keyboard controlled the gating of the various colours, while the images were generated both directly from the orchestral sound and also by electronic means with auxiliary equipment. In addition to the lighting effects, fog and various scents were present in the hall at appropriate points in the performance.

This unusual meeting between the latest technology for realization of one type of kinetic music/light performance and the ideas of one of the earliest and most interesting proponents of this art form may serve as an appropriate point to conclude this brief survey. However, work involving video, lasers, and other systems for the realization of this very old dream of "music light" will undoubtedly be continuing for years to come.

References
4. Lowell Cross, "Musica Instrumentalis-Video (II), Video (III), Video (IV) Music of the Avant Garde, issue No. 9.

The front cover of this issue shows examples of projected multi-coloured images produced by the Video/Laser III equipment described by the author.

Teletext a permanent service?

Officials of the British Radio Equipment Manufacturers' Association estimate that there should be about 12,000 teletext receivers in operation by the end of this year. This figure will include purpose-built sets by British manufacturers, existing colour TV sets fitted with external teletext adaptors, and sets with external decoders similar to the Wireless World design. BREMA members are hoping to get the price of sets down to about £750 to £800.

The set makers are anxious for a statement from the government that teletext, at present an experimental service, will soon be established as a permanent public service. Unless this happens they seem unlikely to achieve any substantial sales to the public. Sources close to the Home Office hint that such an announcement could come in the autumn of this year.
Multi-system ambisonic decoder

1—Basic design philosophy

by Michael A. Gerzon, M.A., Mathematical Institute, Oxford

This series of articles describes a decoder capable of decoding all major existing and proposed two-channel surround-sound systems, including the Ambisonic System 4SJ, SQ, Regular Matrix, BMX and BBC Matrix H. For systems other than SQ, the decoder gives full psychoacoustically optimized results using NRDC Ambisonic decoding technology. In addition, Ambisonic playback of mono, stereo and of three-channel studio-format signals is provided. The decoder is suitable for three-amplifier/four-speaker, four-amplifier/four-speaker, and four-amplifier/six-speaker reproduction.

The NRDC Ambisonic project has developed a comprehensive technology for creating, encoding and decoding sound. While this ambisonic technology can give its best only with optimized programme material and encoding (i.e. the System 4SJ described in reference 1), the methods can be applied to getting improved results from nearly all existing surround-sound systems. Later articles in this series will give the detailed circuit and some constructional details for a decoder for all the above-listed two-channel systems. As this decoder does a great deal more than any previously-published decoder designs, it is necessary to describe its many facilities in some detail, as well as giving some idea of what the circuitry is intended to do.

The aim of any surround-sound decoder is to provide the listener with an illusion of sounds coming from all (horizontal) directions around him. Moreover, if the decoder is well designed, the directions should be those intended by the recording engineer, and should be heard by a listener through the usual listening area.

Conventional "quadraphonic" decoder designs give very poor images for sounds in inter-loudspeaker directions, especially at the sides, resulting in a rather gimmicky "ping-pang-pong" effect at the four corners.

The full theory used to design ambisonic decoders is mathematical, and computing facilities are required to carry out the extremely complex design calculations involved. It is clearly not possible to give full details here of why the various parts of the decoders have the exact values that they do, but some idea of what is going on can be given.

Two previous articles in Wireless World have described some, but not all, of the psychoacoustics lying behind ambisonic decoder design. Essentially, the ears use different methods of localizing sounds, not just one or two. The more of these hearing mechanisms that are satisfied the better the sound and accuracy of the result. In particular, if a decoder satisfies several different methods of hearing, the brain has to do far less work to unscramble the complex sound reaching the ears, and the result is particularly "relaxed" listening, with little listener fatigue. While the mathematics of the design is aimed at getting accurate sound localization for all directions, it is undoubtedly true that the biggest musical benefit comes from this consequent low listening fatigue, rather than from any ability to "shoot the pianist".

Some aspects of sound that ambisonic decoders are designed to optimize are now described. At low frequencies, below 500 or 700Hz, there are three important aspects of sound localization: the "Maikita" direction of a sound (the direction one turns to face the apparent sound direction), the "velocity magnitude" (the degree to which the sound stays in its correct localization as one turns to other directions), and the "phasiness" (the degree to which unwanted components of sound not in phase with the desired sound are heard). It turns out that for all systems other than SQ, it is possible to design a decoder matrix below 700Hz to get the Maikita localization correct for all encoded sound directions. In addition, a careful adjustment of the gain of the various signal components in the decoder permits the velocity magnitude to be made correct also. Thus, at low frequencies, a listener will hear all directions correctly reproduced in direction, no matter which way one faces.

Phasiness is more of a problem with two-channel systems, as it is not possible to design decoders that get rid of it altogether. The effect of phasiness is not only to blur the sound image, but also to create an unpleasant sensation often described as "pressure on the ears" that actually makes some people feel sick, although others don't seem to notice it much. Studies by the BBC and NHK have given a good indication of how much phasiness can be tolerated. In addition, it is found in practice that phasiness is more acceptable for sounds behind the listener than for sounds in front. Two-channel ambisonic decoders are therefore designed for very low phasiness in the front sector of sounds, while giving rather higher phasiness in the rear.

There is another reason why phase shifts cause poor directional reproduction that comes into action below 300Hz. In a real-world listening room, the loudspeakers are at a finite distance from the listener (often about 2.5 meters for British listening rooms), which means that the sound wave from each loudspeaker arrives at a curved wavefront at the listener, rather than as a plane wave. This curvature can be shown to cause the "phasiness" components of the reproduced directional sound to be converted into rotations of sound images around the listener at low frequencies. However, it is possible to remove these low-frequency errors by means of two high-pass filters in the "velocity signal" paths in the decoder. These speaker-distance compensation filters are RC types with –3dB points at about 20Hz for 2.7m speaker-to-listener distance. This may seem too low to worry about, but listening tests here confirmed the design theory and showed that image displacements of as much as 15 to 30° can occur for instruments such as double basses when situated behind the listener unless distance compensation is used. Distance compensation does not turn a bad decoder into a good one, but it does give a "tighter" and more well-defined sound to an already good decoder design.

The ears use different methods of locating sounds at higher frequencies say from 700Hz to 5kHz. However, a rather magical result emerges from the
Fig. 1. Block diagram of multi-system ambisonic decoder, switching arrangements omitted. Shelf filters, inoperative for SQ decoding, depend on system being decoded, as does the resistor matrix. Also not shown is switching for $C_H$ or $C_R$ output.

design theory that states that, in effect, the basic sound localization of a decoder will automatically be the same at low and higher frequencies provided that the loudspeaker outputs of the decoder are derived via a particular type of amplitude matrix, the matrix involved depending only on the loudspeaker layout being used by the listener.

Besides getting the basic high frequency localization correct, it is necessary to minimize phaseness in this frequency range also, and to ensure that the sound image does not move around as the listener faces other directions. To get this last requirement right, it turns out that the best decoder design at higher frequencies involves different relative signal gains from those apt at low frequencies, so that the decoder has to be made frequency-dependent. The effect of minimizing the image movement as the listener rotates his head is to avoid an unpleasant "in-the-head" sensation often, but incorrectly, described as "closeness" of sound by other authors.

There are numerous other detailed aspects of decoder design, particularly those involving the way reverberation is reproduced (where a careful choice of encoding system such as 453 can help), the effect heard by listeners seated away from the centre of the listening area, and the tone quality of the sound. It may seem strange that absolutely flat frequency response reproduction can sound coloured when reproduced through several speakers, the coloration depending on the precise speaker feeds used in the decoder. Many simple "matrix quadraphonic" decoders suffer from a tubby bass or harsh treble due to these effects. However, it is possible to account for most of these effects by the psychoacoustic design theory, and to minimize them in the decoder design. In practice, sounds encoded at the back are allowed to sound a little more colored than frontal sounds in ambisonic designs, because the ears appear to be more tolerant of marginal faults at the back, although one should assume that they are infinitely tolerant!

All decoder designs for two-channel encoding systems are a compromise between conflicting factors, and no design can achieve perfect performance in all ways. In this respect, the design of decoders is akin to loudspeaker design in being in the final analysis an art based on experience and listening. However, the science (i.e. the comprehensive psychoacoustic theory) is a very necessary part of reducing the almost infinitely complex design problem to a point where the designer can be sure of achieving his particular compromise as well as possible. The compromises inherent in these designs are based on the requirements:

- for front-stage material, the surround sound should be subjectively superior to stereo for musical listening (few existing designs meet this minimal requirement!),
- good results for listeners facing non-frontal directions and in non-central listening positions, especially behind-centre, and
- "musicality" of effect on both "ambient" and "surround" programme material, leading to low listening fatigue.

To some extent these requirements conflict with those based solely on the localization of direct sounds, such as in the experimental results quoted in ref. 10, where image sharpness for a forward-facing central listener has been achieved in a simple matrix decoder at the expense of "in-the-head" sound and severe image mislocation for non-forward-facing and non-central listeners. Good single-sound localization for most directions and listening positions can be achieved using a signal-actuated variable matrix decoder, but such decoders give a high level of listening fatigue on music due to the constant variation of signal parameters. Such decoders may be useful for surround-drama, where accuracy of localization becomes more important than "musicality" or low listening fatigue, and a fully-fledged ambisonic "variable matrix" design is under development for such specialist applications. However, there is no doubt that a non-variable decoder is going to remain the preferred method of serious listening to music despite its superficially less "impressive" performance.

The basic diagram of the ambisonic decoder to be described in detail in later parts is shown in Fig. 1. Left and right signal inputs are fed to a sum-and-difference matrix to derive the sum $\Sigma = L + R$ and difference $\Delta = L - R$, because this leads to simplification of the later parts of the decoder, as well as to a slightly greater tolerance to small component errors. These two signals are each fed to 0° and 90° phase shift networks, and the 90°-shifted signal is also phase inverted to yield a $-90°$ phase shifted signal in each case. The

Fig. 2. Phase-compensated shelf filter circuits allow frequency-dependent decoding. Conventional RC shelf filters would cause unwanted phase differences between signal paths.
Fig. 3. Methods of feeding four loudspeakers using four amplifiers (a), and three amplifiers (b). Speaker terminals marked + are the positive-phase terminals in each case.

Fig. 4. Compensation is provided for non-square layouts. Angle \( \phi \) is set on a layout control.

Fig. 5. Better results can be obtained from four-amplifier, six-speaker regular hexagon decoding. Connections are shown for two hexagon layouts with the angle \( \phi \) used in the equations of the output matrix.
phase-shifters used are high precision types, as the ears are capable of hearing very small errors in localization (as little as 1/2° in real life). Present "quadruphonic" decoders have not required such high precision mainly because they gave in any case a poor decoded effect due to sup-optimal design. The six signals are then fed to a resistor matrix, which derives the required combination of these signals to produce the correct pressure and velocity signals W', X', Y'. For the particular encoding system in use. (For a discussion of this aspect see ref. 1, in particular in connection with its Fig. 2). The resistor matrix used is different for different encoding systems, so that switching is provided for different matrix resistance values. The resistor matrix, which involves no active circuitry, also includes a switched three-channel input option suitable for use with three-channel ambisonic masters. In a later article we hope to describe live ambisonic recording for the keen tape enthusiast. These three channel inputs only cost a few resistors and input sockets in the present decoder, and so come virtually for free; in addition, they provide useful test signal inputs for setting-up purposes. We shall give the resistor matrix formulas for the various encoding systems for the signals W', X', Y' in part 2 of this series. An output -jW is provided for phasiness-control in some systems, as described in references 1 and 2.

The frequency-dependent aspects of the decoder are provided by the shelf filters which give one decoding matrix at low frequencies and a second at high frequencies, with the transition centred at 400Hz. Were conventional RC shelf filters to be used, there would be phase shifts in various signal paths, which would cause quite bad localization errors. For this reason, the shelf filters are designed to give phase shifts identical to one another by making them "all-pass" types. The basic circuit of the phase-compensated shelf filters is shown in Fig. 2. The particular arrangement shown has an input impedance of R at all frequencies, which means that it is seen by the resistor matrix as a resistive load, suitable for terminating a matrix circuit. The value of R/R controls the ratio of high-to-low-frequency gain of the shelf, and R provides extra h.f. gain to make up the losses of the preceding resistor matrix. Thus the shelf filters are made to do five different jobs: terminate the matrix circuit, provide gain, give a different matrix circuit at low and high frequencies, give matched phases over the transition frequency band, and give an overall flat frequency response to the decoder at all frequencies.

An additional complication arises because different methods of encoding require different shelf filters in the decoder. In practice, the shelf filters required for BMX, RM, 45J and BBC H differ only slightly, so that a compromise choice has been made to do all these systems. Decoding mono, stereo, and three-channel studio format requires, for best results, a different set of shelf filters, and SQ requires that no shelf filters be used. (SQ decoders cannot be designed to give full ambisonic results; there is a mathematical theorem to this effect. The decoder for SQ provided is, however, less phase in quality than the SQ designs on the market, and was designed specifically for incorporation into this design. It is not in accordance with CBS Laboratories' SQ specification, but in the author's opinion, it is better than decoders that are.)

The switching of the shelf filters involves equipping the op-amps of Fig. 2 with several filter circuits, which are switched in and out as required.

The outputs of shelf filters acting on Y' and -jW' (see Fig. 1) are added to reduce front-stage phasiness, and the velocity signals are then subjected to the RC high-pass distance compensation. This gives us three signals W'', X'' and Y'' representing respectively the signal pressure, forward component of acoustic velocity, and leftward component of acoustic velocity heard by the listener. These are fed to an output amplitude matrix, which includes a layout control adjustment to adjust the outputs of the decoder to match different shapes of rectangular loudspeaker arrangement.

The decoder provides six different outputs L_f (left back), L_p (left front), R_f (right front), R_p (right back), W' (pressure) and either C_p (due back) or C_f (due right), switched. The way these six outputs can be used is itself an interesting story, for they can be used to provide decoding with loudspeakers in a wide range of rectangle shapes using either four amplifiers, Fig. 3(a), or, remarkably, using just three power amplifiers as shown in Fig. 3(b). The three-amplifier-set-up in no way means that there is any compromise in the psychoacoustics of the decoded signal, as precisely the same speaker signals are produced as in Fig. 3(a).

To see this, we first remark that the outputs of the decoder are given by the formulae

\[ L_f = \frac{1}{2}(W'' - \sin \phi X' + \cos \phi Y') \]
\[ L_p = \frac{1}{2}(W'' + \sin \phi X' + \cos \phi Y') \]
\[ R_f = \frac{1}{2}(W'' + \sin \phi X' - \cos \phi Y') \]
\[ R_p = \frac{1}{2}(W'' - \sin \phi X' - \cos \phi Y') \]

where \( \phi \) depends on the setting of the layout control, being 45° for a square layout, and being equal to the angle \( \phi \) shown in Fig. 4 for a rectangle layout. From these formulae

\[ L_b + R_f = L_f + R_p = W' \]

so that

\[ L_b = W' - R_f \]
\[ R_p = W' - L_f \]

and it will be seen that the rear speakers of Fig. 3(b) indeed are connected so that the potentials of their "positive phase" terminals relative to their negative phase terminals are \( W'' - R_f \) and \( W'' - L_f \) respectively.

Even more remarkable however, are the four-amplifier six-loudspeaker arrangements possible with this decoder. It has been known for several years that decoders using six loudspeakers are capable of better results than is possible using four, no matter how well-designed the decoder may be. If properly used, the extra speakers give more solid image location over a larger area, with less tendency for the image to hug the loudspeakers than when using four, particularly on difficult waveforms such as audience applause. It has not been possible to market six-speaker equipment; few homes could properly accommodate it, and the market for such special equipment was thus too small to justify manufacture. However, the ambisonic decoding method permits the same decoder and the same four amplifiers to be used for six speakers for the few who can manage it, making this improved form of decoding domestically available for the first time. We emphasise that in no way does the use of four amplifiers imply substandard results: exactly the same speaker signals are given as one would design a psychoacoustically optimized six-amplifier decoder to give.

The six-speaker connections for two shapes of regular hexagon layout are shown in Fig. 5. The three speakers that are fed in a "simple" manner in each case form an equilateral triangle of speakers; this helps minimize the subjective effects of slight mismatches of amplifier gain. The signals \( C_p \) and \( C_f \) are

\[ C_p = \frac{1}{2}(W'' - \sqrt{2}X') \]
\[ C_f = \frac{1}{2}(W'' + \sqrt{2}Y'). \]

Although detailed instructions for calibrating and using the decoder will be given at the end of this series of articles, it is worth emphasizing now that all amplifiers and loudspeakers

Fig. 6. Approximate listening area for ambisonic decoding (shaded) with a rectangle speaker layout obtained for BMX, 45J, Matrix H and RM systems as well as stereo. Optimal listening is at the centre (X).
must be accurately matched for correct ambisonic results. Unlike "quadra-
phonic" decoders, both front and rear loudspeakers co-operate to produce sounds in any direction. Thus, for
example, the rear speakers provide outputs that help to reinforce the localisation of sounds that are repro-
duced in front of the listener. Thus one cannot try turning the rear speakers up or down in the mistaken idea that the front and rear are independent of one another. When the outputs are not matched, the sound field tends to "fall apart"; in fact turning down the rear speakers often makes them much more audible (as distracting noises at the back) in a correct balance.

While it is not absolutely necessary to have all power amplifiers of the same make, they should be adjusted for identical gains and phases, and one should check (e.g. by using an X-Y oscilloscope display) that they have substantially identical phase responses over the audio band. If in doubt, identical amplifiers should be used. While identical speakers should be used, a small number of speaker manu-
facturers (e.g. IMF Electronics) have taken the trouble to test different models in their range carefully, and in such cases different models can be used at front and rear. Again, if in doubt, use identical speakers for best results.

The decoder not only reproduces surround sound from a variety of existing systems, but also handles mono and stereo, using ambisonic techniques to get the most natural possible repro-
duction (using four or six speakers) from existing records and broadcasts. Except for exceptional stereo material, the decoder does not create "pseudo surround sound", but reproduces stereo over a conventional frontal stage with a subtle enhancement over two-speaker stereo, and without any gimmickry. The mono decode mode reproduces a mono source from straight in front, but the

Fig. 7. Most stable front images are provided by arrangement (a), most stable side images by (c), while (b) is a compromise between these extremes.

rear speakers help to lock the image solidly in space behind the front loudspeakers. Neither mono or stereo decode modes enhance badly recorded material, but neither do they degrade it any further. In practice, many ambient SQ classical recordings, such as those released by EMI, will be found to reproduce better in the stereo decode mode than via SQ decode mode, owing to the inherent limitations of the SQ system.

Fig. 6 shows the approximate usable listening area for most decoding modes (excluding SQ) in a typical domestic room using a rectangle layout. The listening area will in practice depend on the loudspeakers used, the room acous-
tics, the layout shape used, the pro-
grame material, and also on the system being decoded. The type of
listening area shown has been obtained both with ambisonic recordings made in concert halls, and with commercial "easy listening" (sic) music in the BMX, 45J, Matrix H and RM systems, as well as with stereo material played in stereo decode mode.

It is found that a longer-than-wide layout of four speakers as in Fig. 7(a) gives the most stable front images for non-central listener and the least stable side images. A wider-than-long layout as in Fig. 7(c) gives excellent stable side images for most listeners, although the front stage tends to be drawn over to the nearest speaker. A square layout,

supplied by Mullard. To accommodate satellite drift provision was made for remote control motor tracking of the aerials on a single axis.

An outdoor part of the receiver with an integral waveguide horn is placed at the focus of the aerial and provides fixed-tuned conversion from 12GHz to 410MHz, with a noise figure of about 7dB. It consists of a microstrip Schottky-barrier-diode mixer, followed by a 40dB amplifier. The local oscillator is a Gunn device delivering about 10mW at approximately 11.7GHz and, in the Mullard version, enclosed in an aluminium cavity integral with the converter. Dielectric temperature com-

pensation maintains frequency drift within 5MHz (over the range -40°C to +40°C which is well within the range of the automatic frequency control applied to the second mixer. This is located in an indoor unit fed with the 410MHz signal by a coaxial cable.

Fig. 7(b), is a compromise in terms of image stability between these extremes. Extremely thin rectangles (whether long or wide) cannot be expected to give good results, although the layout control adjustment will help to mini-
imize the inevitable defects. Part 2 will give details of the decoding matrices used. Patent rights in circuits described in this and subsequent parts of this article are owned by the National Research Development Corporation. A bit of parts for the decoder will be available from Intregic Ltd – see advertisement.

References

Broadcasting satellite receivers

Mullard's research laboratories have released details of the microwave receivers which they, in co-operation with Philips at Eindhoven, have built for picking up broadcast television signals from "Hermes", the Canadian-American Communications Technology Satellite (News, April, p.40). The receivers consist of the 12GHz f.m. broadcast signals picked up by small dish aerials to a form suitable for feeding into the aerial socket of stan-
dard NTSC colour television sets. Five receivers and associated 1.6m (or in some cases 1.2m) diameter metal-coat-
ed glass-fibre-reinforced polyester par-
able aerials were supplied by Philips, and one receiver of somewhat different design but using the same aerial was supplied by Mullard. To accommodate satellite drift provision was made for remote control motor tracking of the aerials on a single axis.

An outdoor part of the receiver with an integral waveguide horn is placed at the focus of the aerial and provides fixed-tuned conversion from 12GHz to 410MHz, with a noise figure of about 7dB. It consists of a microstrip Schottky-barrier-diode mixer, followed by a 40dB amplifier. The local oscillator is a Gunn device delivering about 10mW at approximately 11.7GHz and, in the

The indoor part of the receiver provides further conversion to 120MHz prior to limiting and frequency discrimi-
nation to yield the NTSC composite video colour signal and 3.14MHz f.m.
sound signal. The last-mentioned is converted to the normal 4.5MHz inter-
carrier frequency and with the video is used to amplitude-modulate a 900MHz carrier to provide a 10mA signal suitable for the aerial input of a standard NTSC colour television set. Extensive use is made of integrated circuit techniques.

The Mullard receiver is installed at the Canadian government communica-
tions research centre in Ottawa. The aerials were aligned first by a simple level of compass then final adjustment was made by means of the satellite signal itself and a signal strength meter. Mullard say excellent picture and sound quality was achieved and the received signal strength was close to the expected level of -105dBW.
Plessey chief wants social responsibility

Sir John Clark, chairman and chief executive of Plessey, has expressed concern about unemployment caused by technical change. Plessey workers making electromechanical telephone exchange equipment are threatened with redundancies as a result of the Post Office's unexpectedly sudden decision to change to electronic exchanges. Speaking at the opening of the London Electronic Component Show, Sir John asked 'Should technology be pursued for technology's sake? And what impact will the changes caused have on people? We are constantly being told we live in the technical age. But there is, I think, an optimum by which it is not cost-effective to go. The impact of change on people should be given the most urgent consideration. Not only how it will affect the jobs they do and how they do them, but also on the crucial social question of whether some jobs will remain to be done at all.'

"In contemplating the equation of change", continued Sir John, "the social consequences must be taken into account and weighed carefully against any other advantages which might accrue. This is why one of your major customer-industries - namely telecommunications, which as you know Plessey has a considerable interest in - has appealed to the Government against the cumulative effects of Post Office cuts, recently announced, in the traditional electromechanical telephone systems. Of course we believe the British telecommunications industry should move forward quickly into the new technical area with equipments brought to modern technical standards. But some regard must be paid to social responsibility by the decision-makers. By their decisions, they have the power to wipe out the livelihood of thousands of people without adequate time being given for an orderly and manageable transition from the old to the new. In my view, it should not be done without due regard to the consequences.'

Plessey is one of the companies mentioned by Mr Ernest Harrison, chairman of Racal, as possibly being involved in a rationalization of the British electronics industry (see leader).

A to D conversion at 30MHz

A design group at Cambridge Consultants working on high speed analogue-to-digital conversion have developed a converter which they describe as the fastest eight-bit a.d.c. in Europe. It will perform, they say, "a full accuracy eight-bit conversion every 33ns." Two have now been delivered, one each to Plessey Ltd, whose Allen Clark Research Centre developed a high speed comparator using the circuit element, and the Admiralty Surface Weapons Establishment.

Two years ago CC were working on a military contract for which they developed a six-bit, 30MHz converter. Cambridge believed the technology available would allow the development of an eight-bit version. With the completion of the previous contract, however, they needed funding and a client to build both the circuit element to Cambridge's specifications and a circuit in which to use it. The money came from the Ministry of Defence directorate for Components, Valves & Devices (CVD), and Plessey's comparator circuit provided an opportunity to use Cambridge's expertise.

The Cambridge equipment is designed for use in radar signal processing and transient recorder applications where low aperture uncertainty, a parameter affecting the accuracy of sampling at a signal's zero crossing point, and full accuracy at high sampling rates are required.

A commercial version, the ADC30.8 is available from Cambridge Consultants. It includes a matched, high speed, low jitter sample hold, operates at a 50 ohm analogue input and samples with an aperture time uncertainty of 10ps r.m.s. The sample command input and the offset binary coded digital output, overrange and internal 30MHz clock signals are all of 50 ohm impedance and c.e.l. compatible. The unit, priced at £3,510, comes with power supplies in a 19in case. The designers were Dr Chris Davies and Julian Coles, and the project manager was Dr Robin Smith-Saville.

Post Office buys solid state stored speech

The Post Office have installed two prototype, automatic, changed-number intercept equipments for service trials in Birmingham and Chelmsford telephone exchanges. If, at a moment, a number is changed the caller, on dialing the old number normally has his call intercepted by the operator, who then tells him the new number. The new system puts the caller through to an automatic spoken message which is stored digitally in memory. This stored message is passed on to the caller.

The equipment supplied by Pye TMC, builds up the message from a limited vocabulary of words and phrases. Each word or phrase is decoded from its digital form and kept going round an audio highway. If one were to listen to one of these highways one would hear a single word or phrase repeated continuously. Line circuits which recognise that a call has reached a disused line are programmed to select the highways in the correct sequence to build up a message for that line. A test message is available by dialing Chelmsford 62101.
Following the Home Secretary's call for comments before the 1979 World Administrative Radio Conference the Mobile Radio Users' Association have published their submission to the Home Office. The Association, who say they represent 80% of all private mobiles in the UK, submit that

- Mobile radio use should be encouraged on economic grounds.
- Demand will increase, also because of the need for economies.
- The Home Office's predictions of spectrum requirements "are based on reports which appear negative in spirit."
- 100MHz extra spectrum is needed for mobile radio, the extra frequencies being found by moving fixed services to higher bands, standardising on 12.5kHz channel spacing, and releasing frequencies from bands 1 and 3, and other places in the spectrum allocated but under-used.
- Mobile radio is important enough to justify setting up a body like the Annan Committee whose conclusions should be published, they say. The MRUA say the submission is based on feedback from their members, study of the Home Office Warden Report and Pye's Pannell report, a survey which MRUA did of all p.m.r. users in the UK, and other submissions which they have seen. The MRUA believe that mobile radio is the one use of spectrum which gives tangible and measurable economic benefits and, since most western countries' problems at the moment appear to be economic, mobile radio ought to have first priority.

The UK commercial and industrial world was not yet conscious of the benefits offered by p.m.r. and so the government should actively encourage them to use it, instead of restricting p.m.r. use. Demand may be artificially low, say MRUA, because of delays in issuing licences. The submission continues: "Our main objection to the policy apparently to be followed by the UK delegation is that their attitude from all indications to date appears to be negative. It seems to be a matter of how few people should use radio and how small the necessary allocation can be, whereas we feel the attitude should be the opposite."

MRUA also say they believe that if the government has allocated to it large areas of the spectrum which they do not use they should release them for p.m.r. 60MHz would not win some measure degrade system performance, but this must be tolerated in the interests of spectrum economy. However we are of the opinion that any further channel splitting is not a true economy with existing modulation systems owing to degradation of signal to noise ratio. "This view had been expressed before when channels had been progressively split as technology developed. "Our objection to a further split in channels is not based on any shortcomings of the equipment, which may well be capable of performing at narrower spacings; it is based on the degraded signal-to-noise performance resulting from the reduced bandwidth. The MRUA would oppose any move away from the general policy of two frequency working as a result of pressure from any other administration. They also believed that fixed point to point links should be moved eventually to beyond 512MHz. Propagation difficulties and high costs would prevent the use, for the time being, of frequencies in the 800-960MHz band for p.m.r."

"We believe that in the interests of progress it is too easy to underestimate the information capacity of simple speech. Speech has the advantage of infinite flexibility and to a small extent an additional range of meanings resulting from tone of voice. It is unlikely that data systems will ever match this, and they are costly both in capital and maintenance terms. We believe that there are a few p.m.r. applications which could usefully consider data, whereas we believe that many government services, such as police and fire brigades, could make great use of data for routine messages, and thus effect spectrum economy in those regions of the bands."

No two uses of p.m.r. are alike, they add, and they would oppose any blanket for measuring channel occupancy.

The British Gas Corporation have published a paper presented to a private meeting of the Joint Radio Committee of the nationalised industries held at Lincoln College Oxford in late March. The main points of the speech made by East Midlands Gas Marketing Board director Peter Quinn are that: the use of self-identification in the calling procedure takes up to 20% of the message length, and can exceed the message time; that the greater demands on operators made by selecting among a number of base stations "is not ideal, and that his time could be more beneficially spent controlling work allocations, etc"; that operators need to be well trained to control incoming calls, and to ensure that all calling mobiles are correctly acknowledged, passed on immediately or put on standby; the amount of information that has to be passed on by a fitter takes some time and "represents poor use of the channel"; and the passing on of a message to a third party often involves bringing whoever is to receive the message into the radio room to take over the equipment for the duration of the call, with considerable disturbance.

On selective call systems Mr Quinn noted that their use in the gas industry had reduced call sign transmission time, shown a caller immediately that his call had been received, alerted fitters returning to vehicles that a call had been made while they had been away, all of which produced "better channel management and hence the possibility of supporting more mobiles per channel."

The normal view of selective calling systems among other users appears to be that until interference becomes very much worse the selective calling equipment would provide unrequired facilities at greater cost. Hence Mr Quinn's remark that they had been "slow to find supporters." He added that they would be an essential part of future fully automated systems.

Details are emerging of the Post Office's delayed Viewdata market trial, to begin in the middle of next year. One thousand sets are to be distributed among interested viewers selected to represent an exact cross-section of the British population, according to income and social class, chosen from 6,000 applicants. The Post Office have even stipulated that the suppliers of the sets, ITT, Philips, Thorn, GEC and so on, supply a proportion of the 1,000 to the television networks according to their market share. Although the news that the Post Office and the manufacturers were co-operating closely was published in the annual report of the British Radio Equipment Manufacturers' Association, issued on May 19, the Post Office is reluctant to discuss the experiment as yet. In a statement issued to Wireless World they said: "We have agreed with BREMA on an integrated approach to the development of Viewdata decoders. This employs a unit in the tv sets which will also include the line interface with the telephone network and as such will demodulate the incoming signals from the telephone line and also generate appropriate loop-disconnect pulses for calling the designated Viewdata computer." They said they would be making an announcement shortly.

The Post Office originally requested that the sets used in the test should be as near as possible to the final production models but the manufacturers told them this would be out of the question in the time available. For that reason rather more equipment will be hung outside the set than the viewer who buys Viewdata equipment would
With the Viewdata coming the German PTT in Bonn, who have already bought the Viewdata software programme, want to keep a grip on the system whoever wins. The German PTT have already taken over BBC's Ceefax service and shown it to some of their staff, and the BBC have German sub-editors working with them. At the Funkaustellung there will be demonstrations, including those by British TV manufacturers, notably GEC. Philips and ITT will also be involved.

GEC have also announced that they have delivered to the German Post Office a 4080 computer system for the proposed German equivalent to Viewdata, the Bildschirntext. The hardware also includes a 128kbyte core store, 4.8/4.8 Mbyte fixed/exchangeable cartridge disc, magnetic tape storage and paper tape equipment. GEC say the equipment was installed at Darmstadt five weeks after official receipt of the order. In February we reported (p.40) on a system which used teletext to provide information for the deaf. Now teletext is being used for the blind. Clarke and Smith last year developed with the National Research & Development Council a Braille computer terminal that would fit into a suitcase. It consists of a typewriter keyboard for writing and a 48 character, 14 inch long touch strip operated by t.t.l. controlled solenoids. The information is put in one line at a time and the operator signals "next line" for the tactile display to be changed. The operator can also skip back to previously-read lines.

The snag at the moment is the high price, £2,800, but a read-only version is available at around £500.

**Alternative to cellular radiotelephone proposed**

Three radio common carrier firms have asked the FCC for permission to build 'and test a new radio telephone and paging system in competition with the ART cellular system in the Washington-Baltimore area (WW June p40). The alternative would cost just over $1 million with equipment and technical help to be provided by Harris Corporation. The group have told the FCC they could test and install the service by the 1979 deadline. It would, according to Harris, be less costly to build and maintain, and would use digital transmission to provide the "ultimate in communications security." The pocket pagers and radiotelephones provided to customers would be lighter and less expensive than those currently in use.

The Harris system would use a single powerful transmitter to cover the same area instead of the many base station transmitters within small geographic cells proposed in the cellular system. It would also operate in the 900MHz band. The single, high power, broadband transmitter, similar to that used in broadcasting, would cover 30 to 50 miles in radius. Ninety-six or more channels could be accommodated by time division multiplexing to mobile units. Broadcast remote receivers could pick up conventional narrow band f.m. signals from the mobile units. The receivers would "transmit the spectrum occupied by mobile units back to the central base station via microwave links, where signal processing will occur. The system does not require wireline links between satellite receivers and the base station. The only telephone lines that will be required are those interfacing the [radio common carrier's] main terminal with the telephone company's central office equipment".

**Naval weapon life study**

The Royal Navy has initiated a three year study aimed at reducing the life cycle costs of naval weapons equipment. Announcing the contract to carry out the study, Mr Brian Mair, manager of Plessey's Product Assessment Laboratories, said the analytical study was intended "to provide a basis for designers of future weapons equipment to predict the life cycle cost of that equipment." The reasons for the study "will become apparent when you consider the way modern technology has changed the Navy's equipment."

Naval equipment has become much more complicated, and difficult to repair. It is no longer possible to keep a full set of spare parts on board ship and expect sea-going personnel, no matter how well trained, to be able to repair it on the spot. It is more likely that plug-in modules would be used which can be repaired when the ship is returned to port. All that is needed is to identify a faulty module and replace it. The difficulty, which the Navy hopes the Plessey study will sort out, is that ships may be at sea for long periods. It is not certain which equipment is more likely to fail, or how much spare equipment it is economical to store in a ship, even with the high reliability the Navy needs. The design of the equipment can make these variables more predictable, As Mr Mair said, "There is an increasing cost of materials support to the Navy for modern weapons equipment. The designer can make trade-offs between reliability of equipment and subsequent maintenance costs. The study is to understand these trade-offs and to study how they can be more effective in the use of money in future." The cost of the study is undisclosed, but most of the expenditure will be in the salaries of the 14 scientists who will be engaged on it for the next three years. According to a Plessey statement, "The Plessey team will be devising a series of computer operated models in a form which can easily be used by project design teams. The data, vital to validate the models, is being obtained with the co-operation of other major defence contractors."

Brian Mair is now taking charge of an expanded business. Product Assessment Laboratories is now augmented by Plessey Reliability Services and Plessey Calibration Service. The group is called Plessey Assessment Services, of which Mair is business manager. His previous post as manager of PAL will be taken over by Geoff Matthews. The expansion means that PAS will be recruiting over 50 engineers and technicians over the next two years to work at their Titchfield, Hants, base.

**Wireless World, July 1977**
Digital television via satellite

Multiplexed 60Mbit/s PAL television and sound signals sent through Intelsat IV from Goonhilly


For many years now the transmission of colour television and sound signals via geostationary satellites has made possible the world-wide exchange of programmes for broadcasting, either "live" or with a few hours delay to suit programming. Such transmissions usually involve analogue baseband signals and f.m. techniques, but in recent years interest has grown in digital coding in conjunction with multi-phase-shift keying modulation.

Provided that efficient bit-rate reduction and modulation methods are used, theory shows that digital coding can form the basis of a better transmission system than f.m. for the economic use of r.f. bandwidth and power. The DITSEC system of Comsat Laboratories in the USA, described in 1972, was the first practical attempt to realise a digital system of this kind. It has been used in North America for the experimental transmission of NTSC 525 line, 60 field/s, 4.2MHz bandwidth colour television signals in the form of a 33.6Mbit/s digital signal through geostationary satellites. Four-phase-shift keying modulation was used, occupying an r.f. bandwidth of about 20MHz, which is about half of that available in an Intelsat IV transponder.

To transmit a high-quality picture using 33.6Mbit/s for PAL, 625 line, 50 field/s, 5.5MHz bandwidth colour television signals, i.e. for System I signals as broadcast in the UK, is a more difficult problem than DITSEC had to cope with. This is because of the higher horizontal and vertical resolution, offset somewhat by the reduced field-rate.

In 1974 the U.K. Post Office agreed to support a BBC Research Department proposal that experimental digital transmissions of System I signals should be attempted via an Intelsat IV satellite. The bit-rate envisaged for the video signals was between 44Mbit/s and 54Mbit/s. Added to this would be bit-rates corresponding to error-correction and audio signals, bringing the total bit-rate of the "package" up to 60Mbit/s, the capacity of the experimental channel through the satellite.

The experiments took place in April and May 1976 (see Wireless World, August 1976, page 71); they were envisaged as a further contribution to a programme of field-research into digital tv and audio transmission. They were not the first PO-BBC co-operative exercise on digital video transmission. 120Mbit/s video waveguide-transmission experiments were demonstrated jointly by the Post Office, the BBC and GEC in September 1970 at the inauguration of the first 1km length of circular waveguide at the Post Office Research Department. In 1971, Standard Telecommunications Laboratories and the BBC demonstrated 120Mbit/s video transmission through an optical fibre at the IEE's centenary celebrations. In 1975, the BBC co-operated with the PO, STC, GEC and Plessey in 60Mbit/s cable-transmission tests, involving two 60Mbit/s video-audio packages provided by the BBC Research Department (see News of the Month, Wireless World, February 1976, and Reference 2).

Further transmission tests with satellite, cable, optical fibre, s.h.f. link, and waveguide systems are envisaged, and some of these tests may use a video bit-rate as low as 30 to 34Mbit/s, if the continuing work on bit-rate reduction leads to satisfactory picture quality at these rates. A precise choice of bit-rate in the 30 to 34Mbit/s region would take into account the bit-rates of 34368kbit/s...
and 32064kbit/s from the transmission bit-rate hierarchies proposed for Europe and Japan respectively.

Experimental transmission system
The transmission system used in the 1976 satellite experiments is shown in Fig. 1. The primary video sources were provided in London by the BBC Designs Department; they comprised a flying-spot colour slide-scanner, BBC Television network channels, conventional test-waveform generators, and a transverse scan video-tape recorder.

Much use was made of the slide-scanner, with a wide selection of colour transparencies drawn from a new set prepared by the European Broadcasting Union — one of which is shown in Fig. 2(a) — together with other slides often used by television authorities in subjective assessments of picture quality.

The analogue video signal was transmitted by the Post Office via permanent cables and s.h.f. f.m. links to and from their Earth station at Goonhilly Downs in Cornwall. For the digital tests, the analogue video signal was fed to BBC Research Department equipment temporarily located at Goonhilly; this equipment was by-passed on one occasion to afford a brief test using an f.m. channel through a satellite.

The digital video signal was incorporated in a video-audio 60Mbit/s multiplex, which was fed as two 30Mbit/s signals and a clock signal to a quadrature phase-shift keying (q.p.s.k.) modulator, built by the Post Office Telecommunications Development Department. The 36MHz bandwidth, 70MHz i.f. output from the modulator was up-converted to s.h.f., amplified, and transmitted through Aerial I to and from the Intelsat IV Flight 1 satellite stationed over the Indian Ocean, occupying virtually the full bandwidth available in one transponder. Video and audio monitoring was provided at Goonhilly and at the BBC Designs Department in London. Audio transmission, both ways, between the Designs Department and Goonhilly was provided by BBC sound-in-syncs equipment.

Video coding
In the digital video coder the analogue PAL signal was sampled at precisely twice the PAL colour subcarrier frequency, i.e. at 2fsc about 8.87MHz. According to Nyquist's theory this is too low a sampling frequency to conserve the video information. However, G. J. Phillips and M. Weston of the BBC Research Department had shown that, because of the nature of the line spectrum of the video signal, sub-Nyquist sampling at 2fsc conserves virtually all of the wanted video information, unwanted "alias" components fall halfway between the lines of the video spectrum and are removed by comb-filtering, with the teeth of the comb spaced at line-frequency.

Eight bits per sample were used in the initial video signal quantisation, including its line and field synchronising signals.

The eight-bit sample-words were re-quantised non-linearly as six-bit words, or, optionally, five-bit words, using differential pulse-code modulation (d.p.c.m.) or a hybrid of differential and "straight" p.c.m. termed h.d.p.c.m. When five-bit video words were used, a dummy sixth bit was added for instrumental convenience. Six-bit straight p.c.m. was also provided. The essence of h.d.p.c.m. is that straight p.c.m. is used for a sample when the numerical difference between its actual value and its value predicted in the d.p.c.m. coder is large. In this 2fsc equipment the second-previous sample is used as the prediction. Large differences result from sharp luminance transitions, for which the eye accepts relatively coarse quantising, perhaps because they are relatively rare. When the difference is small, and can therefore be accurately represented by five-bit or six-bit words, differential p.c.m. is used, i.e. the five-bit or six-bit word gives the value of the difference rather than the absolute value of the sample; in plain coloured areas the difference is zero.

Of the various options available, six-bit h.d.p.c.m. was the one mostly used.

Video scrambling
During preliminary tests with the q.p.s.k. modem it was found that the channel performance was not independent of the transmitted bit-sequence. The salient problem arose with carrier recovery in the demodulator, where
recovery was quite all right with pseudo-random bit-sequences but was somewhat picture-dependent with digital video signals; certain pictures gave rise to troublesome and lengthy bit-sequences. The problem arose because the troublesome bit-sequences contained insufficient carrier-recovery information for the particular type of recovery circuit used, which was designed for digital telephony applications and not for the experiments described here. The problem was overcome by scrambling the digital video signal to make it appear pseudo-random for transmission, and de-scrambling it before decoding. The way in which this was done is outlined in Fig. 3, where the modulo-2 addition is equivalent to the exclusive OR logic function. The square boxes represent one-bit shift registers clocked at the serial bit-rate. The modulo-2 sum on the figure shows how the output of the de-scrambler always equals the input to the scrambler.

**Video error-correction**

P.c.m. video-transmission errors cause small points of enhanced or reduced brightness to appear in the picture. But d.p.c.m. transmission errors are more serious since the effect of a single error is to cause a streak across the picture from the point at which the error occurred to the right-hand side where the sample difference is reset to zero. H.d.p.c.m. transmission error-streaks do not often extend so far because they stop where the coding mode changes from d.p.c.m. to p.c.m.; indeed this effect is the main advantage of h.d.p.c.m. However, even h.d.p.c.m. is not rugged enough to withstand a random transmission-error rate of more than about 1 in $10^6$, without more than a very slight picture impairment, and the error-rate on the satellite channel was expected to be somewhat higher than 1 in $10^6$. Therefore a form of video error-protection was provided in the BBC equipment.

The method used is known as Wyner-Ash convolutional error-correction with a $(16, 15)$ code. The numbers mean that the ratio of the number of error-correcting bits to the number of video-data bits is 1:15. Six error-correctors of this kind were provided to operate independently on each bit of the six-bit video words. Six-bit words at a rate of 264Mbit/s give a serial bit-rate of 532Mbit/s. Adding the error-correcting bits brought this rate up to 56.8Mbit/s.

The use of six independent error-correction means that an error in one of the six consecutive bit-words could be corrected. This feature was important because the use of q.p.s.k. could extend a single phase-shift error beyond a single video-bit period. Placing the error-correction coders downstream from the scrambler avoided upsetting the burst-error correcting feature by scrambling.

The performance of this error-correction method was such that an actual random transmission-error rate of 1 in $10^6$ was reduced in effect to a rate of about 1 in $10^8$.

**Audio coding**

The 3.2Mbit/s between the bit-rate of the error-corrected video signal and the 60Mbit/s satellite channel capacity was used for audio signals, and for multiplexing and synchronisation. The audio-coding equipment was designed to multiplex six high-quality 15kHz sound signals into 2048kbit/s (including audio synchronisation and error-protection signals) using "near-instantaneous" digital companding. This is a companding technique in which, in this case, a block of 32 ten-bit sample words is coded to a quantising accuracy which corresponds to 13, 12, 11 or 10 bits per sample depending upon the peak value of the audio signal occurring in the block of 32 samples. In the equipment used in the satellite experiments two of the possible six audio channels were equipped with coders and decoders.

**Multiplexing**

The audio multiplexer and demultiplexer were designed to give and receive a serial 2048kbit/s signal, coded and timed for interfacing with national and international digital transmission paths meeting CCITT standards. The 60Mbit/s video-audio multiplexer combined the serial 2048kbit/s signal with the parallel 56.8Mbit/s error-protected video signal, the latter being provided on six wires each bearing approximately 9.5Mbit/s. Because the protected video signal thus comprised six-bit words, it was convenient to form up the multiplex "frame" from six-bit words, some of them audio, most of them video, a few for synchronisation, and a few bits spare in some of them for auxiliary signalling. The frame length was 1800 bits (30µs).

To maintain the proper relationship between the output (60Mbit/s) and input bit-rates, without locking any of them together, the content of some of the synchronisation words was controlled to comprise either dummy data or real video or audio bits; this "elastic" timing method is known as "positive justification."

The 60Mbit/s output was then divided into the two serial 30Mbit/s signals and a clock signal to drive the Post Office q.p.s.k. modulator; similar signals were returned from the q.p.s.k. demodulator to the 60Mbit/s demultiplexer, as shown in Fig. 1.

**Error and slip monitor**

Perhaps the most important parameter to monitor on a digital transmission channel is the bit-error rate. It is a sensitive indicator of the state of most parts of the channel equipment and transmission path. The error-monitor module used in the experiments is shown in Fig. 2(c). Fed with data from the error-correction and multiplexing equipment, it gave a clear presentation of the overall error rate or error count, together with a display of lights and audible alarms to indicate bit-errors in the video (VID) and synchronising (FAW), signals, and slips in overall synchronisation (MUX) and synchronisation of video error-correction (PAR).

**The test transmissions**

For most of the test transmissions the slide-scanner in London was used as the video source, but some more critical tests were done using a BBC digital video waveform generator located at Goonhilly. The audio source was usually a stereophonic tape-recorder at Goonhilly, replaying orchestral or piano music, but synthesised audio signals and live speech were also used, the
latter chiefly as a commentary to accompany the transmitted video signals for tape-recording in London.

The elevation of the Goonhilly aerial above the horizon was necessarily small, namely about five degrees, which is about the smallest elevation for satisfactory analogue or digital transmission. Consequently, careful adjustment of parameters such as group-delay equalisation of filters was needed. When this was done, a bit-error rate of about 1 in 100 was attained, which was random in nature and adequate, using error protection, for high-quality picture and sound transmission. Indeed, with this channel condition, the video and audio qualities were negligibly affected by transmission to and from the satellite. This was shown by bridging across the transmission path at the 70MHz i.f. stage or at the 60Mbit/s BBC/PO interface.

A brief comparison was made between the picture quality attained with the 60Mbit/s package using six bits per video sample (h.d.p.c.m.) and that with an analogue f.m. arrangement provided by the Post Office, virtually the full bandwidth of one transponder on the satellite being occupied in both cases. The consensus was that, although both picture qualities were very good, the digital picture was slightly better than the f.m. picture. The absolute impairment of the digital picture was known from previous research to be "just perceptible," the salient feature of the impairment being a small loss of diagonal detail, a characteristic of sub-Nyquist sampling. The salient impairment of the f.m. picture was slightly increased chroinance noise.

Conclusions
The informal subjective assessments of picture and sound quality obtained during the experiments suggested the long-term possibility of attaining slightly higher quality using digital techniques rather than analogue f.m. techniques, without requiring additional r.f. bandwidth or incurring unacceptable interference between satellite channels. This possibility will be studied further in the broader context of efficient use of satellite channels having useable r.f. bandwidths both narrower and wider than the 36MHz used in these experiments. However, the current use of equipment employing f.m. transmission techniques, which provides a service even under degraded propagation conditions or in reduced bandwidth situations such as two television channels per 36MHz transponder, makes it unlikely that analogue f.m. will be superseded by digital techniques in the near future.

Acknowledgements. The author acknowledges the valuable contributions to the experimental work made by a large number of colleagues in the BBC Research, Designs, and Communications Departments, and in the Telecommunications Development and Service Departments and External Telecommunications Executive of the UK Post Office. The permission of the BBC Director of Engineering to publish this paper is also acknowledged. The co-operation of the authorities responsible for Intelsat operations in providing free use of the satellite channel for the experiments was greatly appreciated.

References

High-fidelity Designs
The second edition of our popular collection of reprinted articles, High-Fidelity Designs, is now on sale. It is bigger, with twenty-five of the most popular articles on audio equipment and techniques that we have published in the last few years. Some of the material in the first edition has been kept, but most of the content is new, including David Read's tuners, the Dolby noise reducer, the Linsley Hood cassette deck and Doug Self's advanced preamplifier. Jack Dinsdale's and John Greenbank's horn loudspeakers are also printed again here. The book is obtainable from booksellers at £2.50 or direct from General Sales Department, Room 11, Dorset House, Stamford Street, London SE1 9LU, at £2.75 inclusive of postage and packing. Cheques and postal orders should be made out to IPC Business Press.
Eliminating adjacent-channel interference


Adjacent-channel interference between amplitude-modulated signals can be overcome, even when the carrier frequencies are so close together that the sideband of one signal overlaps the carrier of the other.

The problem of adjacent-channel interference has been with us almost since radio communication began. Fig. 1 illustrates the situation in which it arises: the carrier frequency of an unwanted amplitude-modulated signal U is too close to the carrier frequency of a wanted signal W. The result is that some of one sideband of U intrudes into the part of the spectrum occupied by W. A receiver tuned to W must have a pass-band sufficiently wide to accept the sidebands of W, and so cannot reject the unwanted sideband of U. The audible result, after detection, is unintelligible and annoying “sideband splash” or “monkey chatter” caused by the beating of the unwanted frequencies with the carrier of W.

If U is not too close to W, as in Fig. 1(a), then it is possible to design the receiver to accept only the “clean” sideband of W (which contains all the modulation information in itself) and to treat the result as a single-sideband signal; but this requires very sharp and precise filtering, which of course is expensive. If the two carrier frequencies are as close together as is shown in Fig. 1(b) it has been generally thought that there is nothing one can do about the situation. In addition to the monkey chatter one must put up with an inter-carrier whistle at the difference frequency between the two carriers.

Here are two methods which provide solutions to the problem. Both begin with synchronous demodulation of the wanted signal, as in the homodyne and synchrodyne receivers. For brevity, the wanted signal will be represented by \( A_W \cos W \), where \( W = 2\pi f_w t \), \( f_w \) being the frequency of the wanted carrier. Similarly, the unwanted signal will be represented by \( A_U \cos U \). We want to recover \( A_W \) uncontaminated by \( A_U \).

In synchronous demodulation, the wanted carrier is multiplied by an oscillation having exactly the same frequency and phase. The result is
\[
A_W \cos W \times \cos \omega = \frac{1}{2} A_W \cos (W+U) + \frac{1}{2} A_W \cos (W-U)
\]
(1) may be a helpful reminder).

Thus the wanted signal is recovered, together with an oscillation at twice the carrier frequency, which is easily removed by filtering.

\[
\begin{align*}
\cos A \cos B &= \frac{1}{2} \cos (A-B) + \frac{1}{2} \cos (A+B) \\
\sin A \sin B &= \frac{1}{2} \cos (A-B) - \frac{1}{2} \cos (A+B)
\end{align*}
\]

The phase function \( \phi = \cos \omega \) for \( \omega = 0 \) is then easily navigated.

First method

Figure 2 is the block diagram, in which the expressions in square brackets should be ignored, since they relate to

\[ A_W \cos W \times \cos \omega = \frac{1}{2} A_W + \frac{1}{2} A_W \cos (W-U) \]

This is history repeating itself. When Professor Tucker did his work on the synchrodyne he was led to consider the present problem, and suggested an approximate solution. Some while ago the author was casting round for projects for his final-year undergraduate students and thought it might be interesting to see what could be made of the synchrodyne using modern technology. He, too, was led to consider the problem; this time the suggested solution is exact.
the second method. The combined signals are applied to demodulator 1, where they are multiplied by cos W. The output of this demodulator (after filtering) is now \( \frac{1}{2} A_W + \frac{1}{2} A_U \cos (W-U) \). The second term in this expression is the audible interference. The multiplier cos W is obtained from a voltage-controlled oscillator VCO, which is phase-locked to the wanted carrier via demodulator 2. VCO produces quadrature outputs. The phase-lock loop will settle itself so that the v.c.o. output which is presented to demodulator 2 is in quadrature with the wanted signal, so this output must be represented by sin W and the quadrature output will be cos W. It is arranged that when capture has occurred the loop bandwidth is reduced to about 1 Hz by extra filtering so that the oscillator is not disturbed by the other frequencies present in the signals. Also, the loop includes an integrator so that the phasing is exact.

Now the output of demodulator 2 contains the component \( \frac{1}{2} A_U \sin (W-U) \), but no component involving \( A_W \). The clue is too obvious to be missed: if the phase of this oscillation could be changed from sin (W-U) to cos (W-U) it could be used to cancel the unwanted component in the output of demodulator 1. This could be done by multiplying, in a third demodulator, by sin (W-U):

\[
\frac{1}{2} A_U \sin (W-U) \times \sin (2W-U) = \frac{1}{4} A_U \cos (W-U) - \frac{1}{4} A_U \cos (3W-U)
\]

Thus the desired phase-shifting has been accomplished but at the cost of introducing a 3rd harmonics oscillation, and, if (W-U) is small, it may not be possible to filter it out. But if \( \frac{1}{2} A_U \sin (W-U) \) is multiplied by the series

\[
S_n(W-U) = \sin 2(W-U) + \sin 4(W-U) + \ldots + \sin 2n(W-U).
\]

the result is:

\[
\frac{1}{4} A_U \sin (W-U) S_n(W-U) = \frac{1}{4} A_U \cos (W-U) - \frac{1}{4} A_U \cos (2n+1)(W-U).
\]

The intermediate products give rise to sum- and difference-frequency terms which cancel, leaving the interfering oscillation at a frequency which may be made as high as desired by suitable choice of \( n \); it is thus easily filtered out. In this method the wanted signal is taken from the output of demodulator 3.

### Function generation

It would be possible to generate the series \( S_n \) by taking a number of oscillators, of appropriate harmonic frequencies, and phase-locking them together and to the beat frequency (W-U). But this would be clumsy, and would also require that the demodulator 3 should be a true multiplier. The simplicity of a switching demodulator may be retained as follows.

In normal use a switching demodulator acts to change the sign of the signal to be demodulated in step with alternate half-cycles of the multiplier oscillation. That is, it effectively multiplies the signal by a square wave switching function \( f \), drawn as the solid line in Fig. 3, which alternates between the values +1 and -1 with the same period \( T \) as the multiplier oscillation. As drawn in Fig. 3, the function \( f \) is odd (in the mathematical sense), that is, \( f(-t) = -f(t) \), and the graph has rotational symmetry about the point \( t=0 \). Hence its Fourier series consists of odd functions (sine terms) only:

\[
f(t) = \sum_{n=1}^{\infty} \frac{4}{n\pi} \sin \frac{2\pi nt}{T} \]

Thus, the demodulator does multiply the signal by the required frequency (the first term in the series). It also multiplies by the higher frequencies in the series, but the results are usually filtered out.

Now, suppose that two extra edges are introduced, at \( t_1 \) and \( t_2 \), to give the dotted wave. Since \( S_1 \) consists only of sine terms the rotational symmetry must be preserved, by introducing corresponding edges at -\( t_1 \) and -\( t_2 \). Now \( t_1 \) and \( t_2 \) can be chosen at will; the question is, can we choose them so that the first two harmonics of the new waveform have amplitudes equal to the fundamental? The answer is yes, and the result is quite general: if \( n \) extra edges are introduced, then the first \( n \) harmonics can be made to have amplitudes equal to the fundamental. The correct constants \( t_1, t_2, \ldots, t_n \) are found as follows. The expression for the Fourier series of the new waveform is found in the usual way, and from it the conditions that the coefficients of the first \( n \) harmonics shall be equal are found. This results in a set of simultaneous equations in the unknown \( t \). However, the equations are non-linear, so the solution of them is best entrusted to a computer.

Thus a square waveform can be designed such that the first terms in its Fourier series form \( S_1 \). A similar argument leads to a waveform the terms of which form \( S_2 \). There is a small complication in this case because only the odd harmonics are required. Both series continue with higher-order terms, but these do not matter because the unwanted products to which they give rise will be filtered out anyway.

The waveforms may be generated quite easily by digital techniques. VCO is made a high-frequency oscillator, the cycles of which may be presented to a digital counter. The counter output is presented in turn to a number of digital comparators (one for each edge) which are hard-wired with numbers defining the instants at which the edges occur. Whenever a coincidence is detected an edge is generated by triggering a bistable.

In an alternative method, numbers representing the differences between successive edges are placed in a read-only memory (r.o.m.). A presettable counter is loaded with the first number, and is counted down to zero by VCO. When zero is reached an edge is generated, the number in the next address in the r.o.m. is loaded into the counter and so on until the cycle is
completed and control is returned to the first address in the r.o.m. This method is more economical of hardware, and more flexible because the numbers for several series can be stored in one r.o.m. Any waveform can be selected simply by choosing the appropriate starting address.

Sidebands

Though the mathematical analysis given above indicates that the methods should work, and experiment shows that they do work, it is not so far clear exactly how it is that the overlapping sidebands are disentangled.

Take as an example the first method. Suppose that initially VCO1 has not locked on to the wanted signal, but is running at some frequency F higher than W. The output of both demodulators 1 and 2 is a group of signals at the sum- and difference-frequencies, as in Fig. 4(a). Only the lower frequency group is retained; the other is eliminated by the low-pass filter.

Now suppose that F is reduced towards W. The lower frequency group moves towards zero frequency and a stage is reached when some of the sideband frequencies of the wanted signal should become negative, as shown at (i) in Fig. 4(b). The practical effect differs in the two demodulators. In the case of demodulator 1 the product is cos W \times F, and therefore is also a cosine. The cosine of a negative quantity is the same as the cosine of the same positive quantity (see Table I) so the negative frequency components are reflected about zero frequency, without change of sign, to become positive frequency components as shown at (ii). In demodulator 2, which is multiplying cos W \times F, the output is a sine; and the sine of a negative quantity is minus the sine of the same positive quantity, so in this case the reflected components must be shown as negative, as at (iii).

Finally, let F be reduced to equal W so that VCO1 locks. In the output of demodulator 1 the lower sideband of the wanted signal folds back to reinforce the upper sideband, and both now start from zero frequency, i.e. the wanted signal is demodulated. This is shown in Fig. 4(c). The unwanted signal is modulated on to the beat frequency (W-U) and its lower sideband is folded back. In the output of demodulator 2, Fig. 4(d), the sidebands of the wanted signal exactly cancel each other, being of opposite sign, so the wanted signal does not appear in the output of this demodulator.

Now consider the effect of multiplying (d) by the series S1. The resulting spectrum of the output of demodulator 3 is shown at (e). First, there are sum- and difference-components centred on the frequency of the first term in the series, 2(W-U). We are now dealing with a sine \times sine product, which is a cosine, so the part of the lowest sideband which is partially reflected about zero is reflected without change of sign; and the sum-frequency components have a negative sign.

For clarity, the sum- and difference-frequency components centred on the frequency of the next term, 4(W-U), are shown on a lower line. The diagram is drawn for the case where it is necessary to go only as far as the third term in the series, of frequency 6(W-U). When all the various bands are added together there is a lot of mutual cancellation; there are left only the lowest group of frequencies, which are now of the right form for subtraction from (c), and the highest group; in between there is a big gap, so that filtering out the highest group is easy.

The foregoing description makes it clear that the methods are really exploiting the fact that an a.m. signal has two symmetrical sidebands to effect mutual cancellation of unwanted signals. It is also clear that the cancellation will be less than exact if the sidebands suffer differential gain and/or phase shift in their passage through the r.f. and i.f. stages of a receiver. It is unlikely, therefore, that these methods will form a satisfactory basis for an "add-on" unit for an existing receiver, in which these aspects of performance will probably not have received much attention. It is also clear that, unfortunately, they will not work for s.s.b.!

I am very grateful to Mr L. J. Unsworth for constructing the experimental apparatus in which these ideas were tested.

References

1. Patent applied for.

Space shuttle comms

The Battelle Institute say the communications industry could save millions of dollars in the 1980s if their satellites used the space transportation system of which the shuttle is a part. A NASA-funded study is being carried out at Battelle's Columbus Laboratories with five satellite manufacturers to make their systems compatible with s.t.s.
This is the answer to those, including both Annan and yourself in last month's issue, who quote the cost of a national broad band network from the Technical Sub-Committee of the Television Advisory Committee and rule it all out because we cannot afford a billion. Nobody is suggesting we should but, even so, it is a fact that we must find some, however it were to be found, in order to cope with the 6 billion which we are cheerfully spending to equip ourselves for colour. What is suggested is that the investment already made in networks with a capacity of six channels or more should be put to use so that the public can decide what extra services, if any, it will support. When we know that, the basis of any further investment in cable will be secure.

Having recognized the importance of cable for the future and the need to conserve the frequency spectrum, one might have expected the Committee to look with some care at the proposal that the remains of Phase I of the u.h.f. transmitter programme covering groups of population exceeding 1,000 and Phase II for populations between 500 and 1,000, might employ wire instead of wireless wherever it was simpler and cheaper to do so. This proposal was first made by the TAC/TSC in 1972 and was supported by the Crawford Committee in November 1974. Nothing has happened, mainly because there is a genuine difficulty about how such cable networks might be financed. Everyone concerned had hoped that the Annan Committee might make some sensible recommendation for finance and administration but all they do is to propose that Phase II should be completed at once by transmitters at a cost of £114 per person or over £300 per home covered. That is around five times as much as it would cost to do the job by cable which would also avoid altogether the need for still more space for broadcasting in the frequency spectrum. Here again, they have simply bowed to the authority of the BBC with its insatiable appetite for the frequency spectrum and its determined view of cable as a rival instead of an ally and a source of extra revenue for them which it so easily could be.

As you say, the proposal for a telecommunications committee to determine national policy for all telecommunications, not only broadcasting, is overdue and very welcome. Considering its importance and the intensity of the opposition such a proposal will meet from the heavily entrenched broadcasting and telecommunication establishments, it is a pity that the Committee did not devote more than the odd paragraph or two to the reasons for it and the form it should take.


**RADIO SETS OF THE FUTURE**

Further to the interesting article by Duncan MacEwan in the May issue ("Radio in the 80's"), the following observations come to mind.

The average listener to the portable radio of today probably doesn't find station finding very difficult, and just listens to background music on Radio 1 or 2 all the time.

Is there really a need for a “better” portable set with improved f.m. reception (for the serious listener)? This probably couldn't be all that cheap for a few pounds more he or she could obtain a budget priced hi-fi tuner-amplifier and get far better results if “serious” music listening is the object.

What I suggest we do not need is legislation, the effect of which is costly, and multi-channel push-button complicated receivers that are not wanted or necessary, that could spring into life when the great gods news and sport come on the air every few minutes!

There is room for improved, easily readable printed information on programmes: the poor design, layout, typography and general presentation of the Radio Times is perhaps the obvious example.

E. Gilbert, London N18.

Mr MacEwan replies.

I think Mr Gilbert may be overestimating people's ability to find their way around a crowded dial; certainly our own extensive Audience Research supports this. Radio has

**ANNAN AND CABLE**

The Annan Committee was asked to report, among other things, the future technology of broadcasting and any changes in organisation which would be required as a result. It was perhaps a silly question to put to a group of academics, politicians, trade unionists, and the rest of them to which it has drawn a silly answer. At the time of its appointment some senior engineers in broadcasting recommended that it should have a technical sub-committee which could keep it straight on the facts and prevent it from having the wool pulled over its eyes by important people with their own interests to serve. That this, unfortunately — but inevitably — has happened is shown most clearly by the Committee's report on cable. They accept, quite correctly, that the future of broadcasting lies primarily in cable and that the next 15 years will be the swan-song of conventional broadcasting (paragraph 25.2), but they provide no guidance as to how the inevitable transfer from wireless to wire might be made and prefer to leave it all to the woolly generalisation of the Post Office about the possibilities of integrated national networks in the late 1990s.

How little they have understood the technology of cable is clear from their reference (paragraph 25.41) to broad band Post Office systems on the one hand and private narrow band networks on the other. The Post Office system in Milton Keynes, to which so much importance is attached, is a conventional type using a v.h.f trunk network with final distribution at v.h.f. for 405 lines and sound programmes and at u.h.f. for 625 lines. It is no "broad"er than anybody else's network of that type and nothing like as "broad" as the switched h.f. system which has been developed in the private sector.

In short, the Committee was overcome by the air of unchallengeable authority in which the Post Office managed to present them, and refused to allow that the people of this country should be permitted — while waiting for the Post Office's new millennium — to pay the existing cable operators for a wider choice of programmes if they wanted to. In spite of all their expressed desire for diversity and the claim that "we act in accordance with the concept of pluralism which has been the leitmotiv of all of us in this Report", they have rejected for no discernible reason the one immediate possibility of achieving those ends. A possibility, moreover, which involves no cost to anybody except those who wish to pay for more diversity and those who are prepared to risk their own money in providing it.

**IMPROVING MATRIX H SURROUND-SOUND?**

Reading the surround-sound articles in Wireless World, 451 by Michael Gerzon in April 1977, and Matrix H by Dr P. A. Ratcliffe and D. J. Meares in May 1977, it is apparent that the main difference between the two systems is the effect of the coding of the back sound sectors.

In Matrix H the better mono and stereo compatibility of a bent locus is considered more important, whilst in 451 the listener with a surround-sound decoder is favoured with the improved side image localization and ambience reproduction of a circle locus (whose side view on the energy sphere is a straight line).

Those who have to choose between the two systems will resort, inevitably, to decision by committee.

However, Michael Gerzon mentions other properties of 451 coding which are not referred to in the BBC article and which, if incorporated, might offer in improvement to Matrix H coding. If my understanding is correct they are:

1. Reduce the centre-front interchannel phase angle from 48 to 45 to improve the stereo phasiness of front-sector sounds and to improve mono compatibility.

2. Reduce the curvature of the pan locus until it just touches the "speaker position" curve and, therefore, no longer goes through the left-only and right-only points. If the circle locus of 451 is better than a bent locus for ambience reproduction, it is intuitively obvious that reducing the curvature of the Matrix H locus will improve its ambience reproduction.

3. Optimize the distribution of the different encoded directions within the elliptical cross-section of the pan locus, to improve the reproduced ambience in surround sound and to widen the stereo presentation for front stage sounds and, therefore, improve the stereo compatibility.

Perhaps the BBC men would be kind enough to comment, favourably or otherwise.

Andrew Sturt.
London Weekend Television.
London, SE1.

Wireless World, July 1977
Digital Filters Using Microprocessors

It was with great interest that I read recently V. J. Rees’ article “Digital filter design” in your 1976 issue. I am impressed with much of what he said. With a variety of digital filtration algorithms available, it is indeed useful to check out the response to a simple sawtooth or square-wave input, whether aided by calculator or computer. Not only does this, as Gérald Garon (Letters, May issue) indicates, increase understanding, it may also point out some of the pitfalls.

In V. J. Rees’ example the input was a 10V 50Hz sawtooth, the single-pole low-pass filter had a turnover frequency of 180/πHz and the sampling period was 1ms. In Fig. 1 I have drawn the actual filter response as the smooth solid curve. The algorithm used by V. J. Rees was:

\[ V_1 = AV_0 + BV_1 \]

with \( A = 1/CR \) and \( B = e^{-CR} \), where \( V_1 \) and \( V_0 \) are the input and output voltages for the present sample, \( V_1 \) is the output in the previous sample, \( r \) is the sampling period and CR the time constant of the filter. Taking V. J. Rees’ figures, I have plotted out the result of formula (1) as a staircase – as the output of one’s d.-to-a. converter would be. The error at the peaks is over 20%. The performance of formula (1) would indeed correspond to the theoretical curve if \( k \) were small – like 0.01. In practice one can rarely afford the luxury of such a high sampling rate. Normally, either one’s computer is too slow or a great deal of other real-time signal processing is required as well as the filtration.

An alternative low pass algorithm is as follows:

\[ V_1 = AV_1 + BV_0 \]  

where \( A = 1 - e^-T \), \( B = e^-T \) and \( k = \pi/CR \).

The performance of this formula is shown in Fig. 1. Not only is formula (2) much more accurate at sizeable values of \( k \) but, as shown by Gérald Garon, it is also faster when rearranged to use only one multiplication:

\[ V_1 = -(C(V_0 - V_1)) \]

with \( C = e^{-k} \). Gérald Garon also obtained in his elegant M6800 programme a “high pass” output as well as the low pass output:

\[ V_0 = V_1 - V_2 + BV_1 \]

where \( V_2 \) is input in previous sample (4).

In Fig. 2 I have used the sawtooth input and kept \( r \) and CR at the same 1ms and 1/360 respectively. Again the response of the capacitor and resistor high pass filter is shown as the solid curve (also courtesy a PD P12). The effect of formula (4) is indicated by the dotted staircase. Once more there are errors of nearly 20% at the peaks. A rather more accurate high pass formula that still only requires one multiplication is:

\[ V_0 = V_1 - V_2 + BV_1 \]  

with \( B = 1 - k \).

Formula (5) is plotted as the solid staircase in Fig. 2 – the errors at the peaks seem to be around 4%.

Finally, I’d just like to add the filtration of e.g. to the list of applications where a “slow” microprocessor like the M6800 has proved adequate. In a 2ms sampling period there is still plenty of time left over for other useful processing.

T. A. Perkins,
MRC Neurological Prostheses Unit,
London, SE5

Reviving Nickel-Cadmium Cells

I ran across Mr Johnson’s article on reviving NiCd cells in the February issue and used the method successfully to rejuvenate a set of four cells which had been in the discard bin for some months.

These four AA cells had perished when a young visitor left my pocket calculator on, a fact which went unnoticed for a week or so. When I found them they then would not hold a charge, they were replaced and left on the back of the bench for about six months. After reading the article, I checked them and, sure enough, each cell was shorted and read zero volts.

I first processed one cell as described, with a battery charger as the current source and an ammeter as the load – the only deviation being that the low-current was removed during the high-current phases. The cell came “unstuck” after the first jolt, eventually responded to the overcharge state, and provided 500 mA on slow discharge. I then processed the other three cells as a series unit and achieved the same results, in much less time than it would have taken to do each one individually. Perhaps I was fortunate in having cells in approximately the same condition.

After a 24-hour normal 50mA charge, all four cells in series were drained across a dummy load at 50mA, and lasted close to eleven hours, with the No. 1 cell going dead.
LONG WAVES FOR AMATEURS?

Mr. May's announcement (Letters, May issue) that he is "normally in favour of amateur radio" must have caused all amateurs to read the rest of his letter with justifiable suspicion.

His present approval, or disapproval, of us appears to be based on a lamentable lack of research. It is a shame to see in the pages of Wireless World the suggestion that amateur radio is "just for low power local broadcasting." We will happily accept the accusation that we use low power, indeed we do so with a certain pride in our aerial systems and operating techniques. On the other hand we must point out that contacts with the antipodes are routine and that amateur signals have been bounced off the Moon, which is hardly local! The use of the term "broadcasting" instead of "transmitting" displays an almost unbelievable ignorance and must have upset many people, including, no doubt, some at the Home Office.

In reply to Mr. May's warning about interference, we can only point out that amateurs have learnt to live with interference from domestic machines and broadcast stations as well as from each other. We often operate on channels the professionals would describe as unusable.

It may be recalled that in the early days of radio the amateurs were given frequencies thought to be too high for "serious" use. It is tempting, but inaccurate, to draw a parallel here; we merely suggest that anyone truly concerned that the very low frequencies are being underused could do worse than give them to radio amateurs.

N. R. W. Long (G4BIB), J. G. Morgan (G3ZHL) and R. A. L. Williams (G4EAL), Cambridge University Wireless Society.

INTERFERENCE FROM AMATEUR STATIONS

Sporadic listening to professional usage of the "ether" leaves me with the impression that interference from amateurs is but a drop in the ocean of the problem as a whole. I look forward anyway to the second part of the article by I. Jackson in the issue of March 1977 [see June issue - Ed.]. In the meantime, you can see from the enclosed cutting from the Electrican of February 9, 1912, that, like the poor, interference by amateurs has always been with us.

"Wireless Telegraph Notes. — The "Electrical World" states that an investigation of the extent of interference by amateur wireless-telegraph operators in the transmission of legitimate messages between ship and shore stations has been undertaken by the United States Navy Department. The immediate cause of the investigation was a delay of more than one hour in the transmission of messages of importance from the torpedo-boat "Terre." During this delay the wireless-telegraph apparatus on the vessel was disabled, and the exact position of the ship in distress could not be ascertained. It is estimated that at least 500 stations are in use and owned by amateur operators in the neighbourhood of New York."

Or is it that amateurs have always been a vulnerable minority, and therefore a convenient scapegoat? Having no personal involvement, I could wish only that all users of the radio spectrum would turn over a new leaf, starting with the commercial stations that sit on top of the standard frequency transmissions. Blatant use of 2182kHz for personal chit-chat during the silent listening periods is not at all uncommon, almost certainly maritime mobile users fouling their own nest. Amateur bands are parts of the radio spectrum which get very little use at all! Desmond Thackeray, Department of Chemical Physics, University of Surrey, Guildford.

AURAL SENSITIVITY TO PHASE

Though I believe that the effects of phase shift on the wavefront and the sound quality of the signal in a monaural channel are of no importance provided that the concomitant time delays stay within the CCIR limits, Mr. Lipshtz's letter in the May issue draws attention to one of the many situations where phase shifts are of importance in their effect on sound quality. There are many others.

It has long been the practice of amplifier designers to arrange for the compensation of distortion between the stages in an amplifier by adjusting the operating conditions of successive stages to allow the distortion introduced by one stage to be reduced by the introduction of distortion in the opposite phase by the following stage, the explanation of Mr. Lipshtz's results. Similarly, it has been the practice of recording engineers to minimise the peak signal amplitudes and hence the amplitude dependent distortions by appropriate phasing of the signal components. These phase dependent distortion compensation effects make it difficult to measure and specify the amplitude distortion in any good f.m. receiver. The distortion introduced by a signal generator is of the same order as that introduced by the best current receivers and in consequence the measured overall distortion may vary between almost zero and twice that introduced by the receiver, depending upon the relative phase of the distortion introduced by generator and tuner.

The sound quality of a loudspeaker is subtly dependent upon the relative polarity (phase) of the studio microphone and the listener's loudspeaker but, unless equipment of professional quality is used throughout, the effect is extremely difficult to detect. In part because it is critically dependent upon volume setting.

There are some of the many situations where phase shifts may introduce audible effects but little understanding of this by the ordinary user, for the distortion cancellation is dependent upon the relative phase and relative amplitude of the recorder-reproducer distortions.

Mr. Lipshtz's letter draws attention to a situation where nature anticipated engineers in this practice of distortion cancellation. It has long been known that the negative and positive peaks in ordinary conversation speech are of unequal amplitude but second apparently arranged this to compensate for the non-linear stiffness relation of the ear drum. Which effect came first is difficult to identify. James R. Moor, Chipperfield, Herts.

I suggest that if one regards the ear as a non-linear transducer followed by a set of high-Q tuned circuits each driving a mean amplitude meter, the outputs of which are separately sent to the brain, all arguments are resolved and all observations and tests accounted for, are they not?

As far as the brain is concerned it only receives one parameter for each frequency, namely amplitude of the signal arriving at the resonator. It receives no information concerning phase. However, when a sine wave arrives at the ear, because of non-linearity it produces its own harmonics. If now for example a second harmonic is added to the signal this will be reinforced or reduced in amplitude by the time it reaches the inner ear by the harmonic of the original signal produced by the distortion of the first stage of the ear. In this sense the ear is phase sensitive, as altering the phase of the second harmonic fed to the outer ear alters the amplitude of the second harmonic received by the inner ear.

If, however, we have a generator in which we can control the amplitude of all the harmonics, after altering the phase of one or more we can usually by altering the amplitude of these and the other harmonics apparently reproduce the original sound. This is because changes in amplitude of applied signal correct for the changed cancellation reinforcement pattern of the "ear-produced" harmonics. In this sense the ear is not phase sensitive.

There are cases when this is not true. If for example the amount of second harmonic applied is of the right amplitude and phase to cancel the ear-produced 2nd harmonic, the amount of this arriving at the inner ear will be nil. If we now alter the phase of the 2nd harmonic from our speaker, cancellation will no longer take place and second harmonic will reach the inner ear. No amount of change of amplitude will cause the amount of second harmonic reaching the inner ear to be reduced to zero.

One cannot answer the question "is the ear sensitive to phase?" by a yes/no answer, only by "the inner ear is insensitive to phase but the outer ear distorts". J. H. Asberry, Wellfield, Middlesex.

Perhaps I may be allowed to reply to Mr. Coleman's letter in the February 1977 issue, even in isolation from the long correspondence on aural phase sensitivity. There is, I
think, very little in that letter which relates to his earlier convictions (as expressed in September 1976 letters), whilst those few points he chooses to expand from my reply in December 1976 show further misconceptions or even mistakes.

The phasor representation of amplitude and angle defines the variation of output amplitude and phase of a realisable system to an input sinusoid, to which it is responding in the steady-state. In this condition, any characteristic phase advance or delay may be assigned. The concept may be extended to isolated waveforms, wherein the Fourier Integral allows the response of the system in the transient state to be described in terms of its steady-state characteristics. There are cases, for example in simultaneous amplitude and angle modulation, where the concept of instantaneous phase may be defined, though this cannot be done simply by specifying an elementary reference time. If Mr. Coleman wishes to attach any meaning to system phase other than the widely accepted one, he should specify the conditions and give his own reasons for doing so.

I am content to be identified with James Moir, in a commonsense approach to resolving any problem; in teaching or in research, to picture a problem in another domain may help its understanding, which is advantageous. Commonsense is not born of ignorance, as Mr. Coleman would seem to baffle your readers into accepting, it is a quality by which the truly knowledgeable scientist may be distinguished from the untrained academic mind.

My grasp of basic principles is not so uncertain that I could believe Coleman’s claim that “one bursts which differ in the framing of phase of the sine wave with respect to the burst envelope have spectra of different shapes.” A little commonsense would reveal that by shifting the carrier with respect to the pulse train in this waveform a simple linear phase shift of all spectral lines is produced, as was the purpose of my experiment. Hence it is Mr. Coleman’s conclusions which are invalid, not mine.

Roger C. Driscoll,
The Polytechnic of North London,
London, N7.

TRANSPORT INTERMODULATION DISTORTION

I would like to comment on the very informative article on transient intermodulation distortion by Bert Sundqvist, published in your February 1977 issue.

He has shown by analysis that in order to prevent transient intermodulation distortion in an amplifier, the method proposed by Professor M. Otala (that of extended open-loop bandwidth in the power amplifier with subsequent passive band limiting in the preamplifier) need not be adhered to rigidly and the simpler method of band limiting the first stage of the amplifier achieves the same result. He suggested three methods for producing this band limiting: (1) input lag compensation, (2) use of a high-impedance current source as collector load, (3) operation of the first stage with a very low collector current. Of these, however, only the third seems to be new, as far as preventing transient intermodulation distortion is concerned.

Mr. Sundqvist replies:

I would like to thank Mr. Gift for his clear explanation of the input stage frequency roll-off mechanisms. When I wrote my article I had not yet considered the details of how the frequency roll-off should be effected in practice. However, I would suggest that any band limiting procedure that gives a high input capacitance should be avoided, as this could give trouble when using a pre-amplifier with high output impedance, especially in combination with long connecting cables.

I have two other comments on my article which could be of interest to the readers. Using the original Otala design method, one ends up with a power amplifier with very wide bandwidth. However, the total audio system bandwidth is still limited by the pre-amplifier roll-off at 20-30 kHz. Although I do not think that an excessively large bandwidth is always desirable, this has always seemed to me to be a waste of good design work. Using the method outlined in my article the system bandwidth can be made as large or small as desired, as no frequency limits are involved in the design.

I would also like to point out that there are other methods to avoid t.i.m. without using Professor Otala’s design method. My article was written in January, 1976, and since then Malmqvist has published an interesting analysis of why t.i.m. is not produced by the Xelex range of amplifiers in spite of their relatively heavy feedback.

Bert Sundqvist,
Umeå, Sweden.

Reference

INDUSTRIAL CONSULTANCIES IN UNIVERSITIES

I noticed with interest your article in the February 1977 issue on the "Crisis in sponsored and endowed research" and am writing to comment on certain statements made in the article.

Most of the universities in the UK have established industrial consultancy or liaison offices of one kind or another. The current count is some 33 universities with such offices. In general, consultancy work carried out for industry using university facilities is conducted on a commercial basis by these units and the universities require a proper return to them for such work. While it would be highly undesirable to restrict the contact of individual academics with their industrial counterparts, most universities now require that academic staff be given permission for any consultancy work that they undertake and there is normally some limit as to the level of additional remuneration they can receive from such work.

In conclusion I would comment that most of the universities have established liaison bureaux and industrial consultancies which aim to exploit the research that is conducted, and there is a growing degree of co-operation between university staff and their opposite numbers in industry.

R. J. L. McLaren,
Director of Industrial Research and Consultancy,
University of Dundee.
Crystal ladder filters

How to build low-cost s.s.b. filters using surplus crystals
by J. Pochet, F6BQP

This article gives design calculations for making crystal filters for s.s.b. applications and includes results of tests made on samples constructed by the author. The arrangement used in each case is that of a ladder filter where the crystals are connected in series. This very simple arrangement, see Fig.1, enables constructors to make low-cost filters, in comparison with commercial units, by using crystals having identical resonant frequencies.

The filters to be described in this article were made using 8314kHz crystals, as these were readily available to the author. The measurements were made in a laboratory with automatic instruments of high precision. Table 1 gives the results of measurements on one of the filters compared with the well-known XF9A filter. Definitions of the terms are shown in Fig. 2.

The results obtained from these tests are very satisfactory; the ultimate out-of-band rejection, better than 95dB, is excellent, the slopes of the sides of the filter are a little less steep than those of the XF9A, and the pass-band at -6dB is a little narrower. It should be mentioned that the measured characteristics of the XF9A filter are better than those claimed by the manufacturers.

How to design the filter
A filter of this kind can be made using two, three or four crystals in series. Fig.

Table 1 — Comparative results between a four-crystal ladder filter and the XF9A filter

<table>
<thead>
<tr>
<th></th>
<th>Ladder filter</th>
<th>XF9A filter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insertion loss</td>
<td>1.4dB</td>
<td>2.5dB</td>
</tr>
<tr>
<td>Ripple</td>
<td>0.8dB</td>
<td>0.8dB</td>
</tr>
<tr>
<td>Bandpass:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-3dB</td>
<td>1800Hz</td>
<td>2350Hz</td>
</tr>
<tr>
<td>-6dB</td>
<td>2050Hz</td>
<td>2540Hz</td>
</tr>
<tr>
<td>-20dB</td>
<td>2950Hz</td>
<td>3200Hz</td>
</tr>
<tr>
<td>-40dB</td>
<td>5200Hz</td>
<td>4250Hz</td>
</tr>
<tr>
<td>-50dB</td>
<td>6950Hz</td>
<td>4650Hz</td>
</tr>
<tr>
<td>Ultimate out-of-band rejection</td>
<td>&gt;95dB</td>
<td>&gt;48dB</td>
</tr>
<tr>
<td>Impedance</td>
<td>830 ohms</td>
<td>500 ohms</td>
</tr>
</tbody>
</table>

3 gives the values of the capacitors as a function of the impedance and frequency values adopted. The choice of impedance is important because, in effect, the more this is reduced the more the pass-band is reduced and the higher will be the insertion loss. This is because the series resistance of the crystal becomes more significant in relation to the impedance.

On the other hand, if one chooses an impedance which is too high, the calculations will result in low capacitance values, and construction then becomes limited by the stray circuit capacitances.

In practice, for a frequency of about 8 to 10MHz, the impedance should be about 800 to 1000 ohms to obtain a pass band of 2100Hz, suitable for s.s.b.

It is necessary to underline the importance of the impedance of a filter, no matter what type is used. It is also of paramount importance that the filter should be correctly terminated because any significant mismatch could lead to a pass-band ripple of some 10dB.

Fig. 3. Typical crystal ladder filters. All crystals are of the same resonant frequency — preferably between 8 and 10MHz for s.s.b. units. The coefficients indicated against each capacitor should be multiplied by 1/2πfR, where R is the design impedance and f is the resonant frequency of the crystal in hertz, to give the correct capacitor value. Three and four-crystal filters are capable of giving very good results. Two-crystal filters, although reasonably good, have relatively poor shape factors. See text.
It is possible to adjust the values of the capacitors, reducing them increases the passband but also increases the ripple in the pass-band. Note that it is advisable not to take advantage of this opportunity unless the necessary test instruments are available to check the results of any such adjustments. The ideal instruments for this type of adjustment.

The following is an example of how to calculate capacitor values for crystal ladder filters.

When \( R \) is the design impedance and \( f \) is the resonant frequency of the crystal in Hz, if \( f \) is 8314kHz and \( R \) is 830 ohms, then \( 1/2fR \) is equal to 23pF.

From this one may obtain capacitor values for a four-crystal filter, as follows.

\[
C_0 = 0.4142 \times 23 = 9.5pF (8.2pF)
\]
\[
C_1 = 1.82 \times 23 = 41.8pF (39pF)
\]
\[
C_2 = 2.828 \times 23 = 65pF (56pF)
\]

and for a three-crystal filter:

\[
C_0 = 0.707 \times 23 = 16.3pF (15pF)
\]
\[
C_1 = 2.121 \times 23 = 48.8pF (47pF)
\]

and for a two-crystal filter:

\[
C_0 = 1 \times 23 = 23pF (22pF)
\]
\[
C_1 = 2 \times 23 = 46pF (47pF)
\]

The values in brackets refer to 10% preferred values.

These three filters have been constructed and the results obtained are shown in Table 2. In all three cases the passband ripple is less than a decibel. The results showed that with three or more crystals one may obtain a very good filter.

Although the two-crystal filter gives a reasonably good out-of-band rejection (50dB), the sides are not very steep and the shape factor is modest. With a single crystal the out-of-band rejection is only about 20dB.

**Remarks**

In the cases described above the passband extends from approximately 8314 to 8316kHz. The series-resonant frequency of the crystals therefore determines the lower limit of the passband; this is of interest since it is necessary only to use an additional crystal, of the same frequency as the others, for the carrier, to permit the selection of the upper sideband.

The choice of filter frequency depends on the availability of the crystals. It is possible to use frequencies from 5 to 20MHz, but if one has the choice it is preferable to use 8 to 10MHz. As an example, for a frequency of 5MHz it would be necessary to use an impedance of at least 1500 ohms in order to obtain the necessary bandwidth for s.s.b.

By using a lower frequency and lower impedance, it is possible to make an excellent c.w. filter.

The filters described above could be constructed on a p.c.b. and fitted into a small metal box, which should be connected to ground to avoid stray leakages.

**An example circuit arrangement**

Let us finish with an example of a circuit arrangement allowing the filter to be inserted at points of impedance equal to its own. This circuit is shown in Fig. 4. The output impedance of the first stage is practically equal to the collector resistance of \( T_1 \) (common emitter configuration) and the input impedance of the second stage (\( T_2 \) in common collector configuration). In this way the correct termination of the filter is obtained with the advantage of a very low output impedance (that of \( T_2 \)), suitable for connection to the mixer on transmit and the i.f. stage on receive.

This circuit could also be very useful for measuring the filter's response curve with a sufficiently stable h.f. generator, a digital frequency meter and a voltmeter incorporating an h.f. probe, or better still a wobulator.

In conclusion the author recognizes that it would be interesting to study this technique further; trying for example readily-available surplus FT243 crystals, or low-cost 27MHz crystals having 9MHz fundamentals.

![Fig. 4. One method of connecting a crystal filter into a transceiver circuit to ensure correct impedance matching. See text.](image)

**Table 2 — Measurements on two, three and four crystal ladder filters (for 8314kHz and 830 ohms impedance)**

<table>
<thead>
<tr>
<th></th>
<th>Two crystals</th>
<th>Three crystals</th>
<th>Four crystals</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Insertion loss</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6dB</td>
<td>0.9dB</td>
<td>1.1dB</td>
<td>1.4dB</td>
</tr>
<tr>
<td>10dB</td>
<td>2150Hz</td>
<td>2050Hz</td>
<td>2050Hz</td>
</tr>
<tr>
<td>20dB</td>
<td>2700Hz</td>
<td>2350Hz</td>
<td>2250Hz</td>
</tr>
<tr>
<td>30dB</td>
<td>4850Hz</td>
<td>3400Hz</td>
<td>2950Hz</td>
</tr>
<tr>
<td>40dB</td>
<td>8900Hz</td>
<td>5050Hz</td>
<td>3900Hz</td>
</tr>
<tr>
<td><strong>Ultimate out-of-band rejection</strong></td>
<td>&gt;50dB</td>
<td>&gt;75dB</td>
<td>&gt;95dB</td>
</tr>
</tbody>
</table>

**Pat Hawker comments:** This is a free translation of an article, "Essais, mesures et réalisation de filtres a quartz" by J. Pochet, F6BQP, published in Radio-REF, journal of the Réseau des Emetteurs Français, in May 1976. For many years the vast majority of crystal bandpass filters used in h.f. communications have been based on the half-lattice or lattice configuration, plus some limited use of the bridged-T approach. The recent use of higher frequency filters, particularly around 5, 9 and 10.7MHz has opened the way to greater use of the attractive ladder filter. At these frequencies it is possible with three or four identical frequency crystals and with practical values of impedance and capacitors to achieve bandpasses of between 2 to 3kHz, reasonably good shape factors and high ultimate out-of-band rejection.

While it would seem possible to obtain better shape-factors and ultimate rejection by using more crystals, this will usually require careful adjustment of capacitor values and is less easy to arrange in a symmetrical form having equal input and output impedances.

**Acknowledgement.** Wireless World thanks Pat Hawker, G3VA, for translating this article from the original French.
Logic design — 6

Examples of clock-driven circuits

by B. Holdsworth* and D. Zissos†

*Chelsea College, University of London
†Dept. of Computing Science, University of Calgary, Canada

Some examples of the design of clock-driven circuits using the techniques set out in the last article can now be considered.

Example 1. Paper Tape Reader
Design a circuit that will stop the paper tape reader, shown in Fig. 9(a), by turning signal m off when the character sequence 4-5-6 is detected, and at the same time generates a buzzer signal b.

A synchronizing pulse is generated by the reader each time a new character is output.

A diagram the input equations to the JK flip-flops are obtained.

\[ S_A = S_5 + (S_6) \]

where the term in brackets is an optional product.

\[ S_A = \overline{AB}S_5 + (AB) \]

The optional product cannot be used for reduction purposes.

Hence, \( S_A = \overline{AB}S_5 \) and \( J_A = B5 \)

\[ R_A = S_4 + S_5 \overline{A} + (S_6) \]

\[ = S_5 \overline{A} + (S_6) \]

\[ = AB\overline{6} + (\overline{A}B) \]

The optional product cannot be used for reduction purposes.

Hence, \( R_A = AB\overline{6} \) and \( K_A = B6 \)

\[ S_B = S_4 + (S_4) + (S_5) + (S_4) \]

\[ = \overline{AB} + (AB) + (\overline{A}B) + (AB) \]

The optional product (\( AB4 \)) need not be used for simplification purposes since \( B \) will be eliminated when converting from \( S_B \) to \( J_B \).

Hence, \( S_B = \overline{AB}4 \) and \( J_B = \overline{A}4 \)

\[ R_B = S_45 + S_4\overline{A} + S_6 + S_5 \]

\[ = S_65 + S_5 \overline{A} + (S_6) \]

\[ = AB45 + AB4 + (\overline{AB}4) \]

\[ = B45 + AB\overline{4} + (\overline{AB}4) \]

The optional product cannot be used for simplification purposes, hence

\[ R_B = B45 + AB4 \]

The circuit is shown in Fig. 9(d)

Example 2. One-shot circuit
High-frequency clock pulses are fed to terminal X in Fig. 10(a). Design a circuit

Fig. 9. Circuit of Example 1 is shown at (a). Its state diagram is at (b) and its state table at (c). The resulting circuit is shown at (d).
so that each activation of a manual switch \( m \) allows one complete clock pulse output on line \( Z \). The duration of signal \( m \) can be assumed to be greater than the pulse width.

(1) I/O characteristics. These are shown in the time diagrams of Fig. 10(b).

(2) Internal characteristics. A suitable state diagram is shown in Fig. 10(c).

(3) State reduction. It is left as an exercise for the reader to construct the state table and examine the possibility of state reduction.

(4) Primitive circuit. By direct reference to the state diagram the following turn-on and turn-off equations are obtained.

\[
S_A = S_2m = \overline{AB}m. \text{ Therefore } J_A = B\overline{m}.
\]

\[
R_A = S_1 + S_3 + (S_2m) + (S_0\overline{m})
= AB + AB + (\overline{AB}) + (\overline{A}\overline{B}m)
= A. \text{ Therefore, } K_A = 1.
\]

\[
S_B = S_1 + (S_2m) = AB + (\overline{A}\overline{B}m) = \overline{AB}.
\text{ Therefore } J_B = A.
\]

\[
R_B = S_2\overline{m} + S_3 + (S_0)
= \overline{AB}m + AB + (\overline{A}\overline{B})
= B\overline{m} + AB. \text{ Therefore } K_B = m + A.
\]

\[
Z = S_1X = A\overline{B}X
\]

The circuit implementation of these equation is shown in Fig. 10(d).

**Example 3. Pulse distributor**

Signal \( X \) in Fig. 11(a) is a pulse train. The input pulses are to appear at the output terminals as shown in Fig. 11(b). 

**Fig. 10.** Problem of Example 2, (a) and the required timing at (b). The state diagram is seen at (c) and the circuit realization is shown at (d).

**Fig. 11.** (a) is the problem for Example 3, with the specified output at (b). State diagram (c) and state table (d) result in the circuit shown at (e).
Cost of new licences

Somewhere, sometime, somebody in authority will have to make his mind up whether amateur radio should be treated purely as a tolerated hobby or as a socially useful form of technical self-training. For it is becoming more and more expensive for a youngster to obtain a British amateur licence. The latest increase in the fee for taking the Post Office amateur-licence Morse test — it goes up from £4 to £6 on July 1 — means that this charge (which was only 50p until October 1970) will have gone up by a factor of 12 in less than 7 years! It is similarly difficult to keep abreast of the steadily rising cost of taking the Radio Amateurs Examination, since this involves not only the City & Guilds fee but also the local centre fee. Applicants for these examinations may also have to meet substantial travelling costs, and, of course, if successful pay the first annual licence fee. All of this is certainly not a way of encouraging a new generation of amateurs.

Yet such costs could surely be greatly reduced by adopting some elements of the system used in some overseas countries of bringing the local clubs and groups into the licence-issuing process. Is it for instance really necessary for the Morse Test to be given by one of the now relatively small number of trained Post Office operators? There are plenty of local amateurs who could do this, with any necessary precautions against abuse.

If Lord Wallace, the RSGB president, can argue that the communications industry has reason to be grateful for the enthusiasm and expertise implanted in young industry apprentices by their participation in amateur radio, is it not time that the whole procedure was looked at with a view to making this more possible? One can understand the Post Office view that it cannot be expected to subsidise the cost of Morse tests — the real question is should they be involved at all?

European v.h.f./u.h.f. records

The following is a listing of current European distance records for the amateur bands above 144MHz as published recently in the Dutch journal *Electron*:

- 144MHz: F8JC/SM5AGM (tropo, 1930km), SM6FBQ/UA3TGF (aurora, 1830km), SM5LE/UA9GL (aurora, 2200km), SM7BYU/9H1CD (sporadic E, 2250km).
- 70-cm: F8MM/SM5LE (tropo, 1560km), SM5CUI/UA3ACY (aurora, 1260km), SM5LE/VK2AMW (moon-bounce, 15,680km).
- 23-cm: G3QLR/SM5CCY (tropo, 1100km), PAOSSB/VK3AKC (moon-bounce, 20,000km).
- 13-cm: OK1KIR/OK1WFE (tropo, 400km).
- 9-cm: PAODBQ/G3LQR (tropo, 230km).
- 6-cm: G3BNL/G3EZZ both portable (tropo, 180km).
- 3-cm: OK1VAM/OK1WFE (tropo).

This list brings out several interesting contacts although the two records attributed to Czech stations appear to have been overtaken by the G3QLR/OZ8OR tropo contact on 13cm (760km) and an ICBRS/G3MXX contact on 9cm (521km) recorded during the past year.

Band scan

Microwave beacons are now operation-al on The Wrekin (GB3WRN) on 1296.91MHz and near Sheffield (GB3UOS) on 3465MHz.

The weekly G2ATG rty news bulletins transmitted on Sunday mornings (1200 local time on 3590kHz, 1230 and 1245 on 144.6MHz) are now also being sent on 3590kHz at 1900 local time on Sunday evenings.

The well-known New Zealand short-wave listener, Arthur Cushing, who is being interviewed on the Club Forum programmes transmitted by Radio Australia on Saturday mornings. This is one of a number of amateur and s.w.l. programmes broadcast regularly on the h.f. broadcast bands; the Dutch programmes on Radio Netherlands were recently judged the most popular in a ballot organised by I.S.W.L.

The "Phase 1" programme of amateur u.h.f. repeaters has been completed with the coming into operation of GB3H at Ipswich, GB3LV at Cheshunt and GB3LW in Central London.

859 certificates of Morse proficiency have been issued by the Royal Naval Amateur Radio Society since the regular transmissions on G3BZU were begun in 1962. These transmissions are made on the first Tuesday of every month on or about 3520kHz at 2000 hours local time. Speeds from 15 to 40 words per minute in increments of 5 w.p.m. are sent for 3 minutes each, and must be copied without any errors to obtain a certificate or endorsement. A charge of 30p is made for a 15 or 20 w.p.m. certificate and endorsement "stickers" for other speeds require only a stamped addressed envelope. Present manager of the service is Mick Puttick, G3LIK, and transmissions are made from the RNARS headquarters station in Hampshire using a KW Viceroy transmitter and dipole aerial (RNARS, G3BZU, HMS Mercury, Leydene, Petersfield, Hampshire).

The American National Association of Broadcasters has recently petitioned the FCC, seeking the right to rebroadcast transmissions made on Citizens' Band and amateur radio bands. It has been suggested to broadcast stations that they could broadcast emergency traffic or weather reports and information vital to public safety and convenience.

In the picture

Mike Cox, G8HUA, of Brigg, South Humberside has taken over from Joe Rose, G8CTG, as general secretary of the British Amateur TV Club. CQ-TV also shows, in a letter from Peter Cossins, VK3BFG, that there are now some 20 fast-scan amateur tv stations in the Melbourne area. A weekly WIA news bulletin is transmitted on amateur tv every Sunday morning and pictures are sent from time to time exchanged with VK7EM in Tasmania some 400km distant.

Several British amateurs are now using standard u.h.f. transverters driven from h.f. or v.h.f. standard equipment with simple homebrew video modulators: for example, Lawrence Woolf, GJ8AAZ, uses an FT620 drive source, Modular Electronics 50 to 432MHz transverser. To receive 70-cm ATV signals the output from the transverter is fed into a Band 1 tv receiver, for transmission a 50MHz video modulator uses just one transistor plus an SL610c integrated circuit.

In brief

The number of amateur licences in the USA has for the first time passed the 300,000 mark, an increase of over 10 per cent in a year. ... Of 2351 Austrian licences, 1317 are for h.f./v.h.f. operation, 980 for v.h.f. only and 54 are club stations. ... The RSGB's VHF National Day Field runs from 1600 GMT July 2 to 1600 GMT July 3 with groups operating up to four separate stations, each one for the 70, 144, 432 and 1296MHz bands. ... The Royal Naval Amateur Radio Society is holding its annual mobile rally at "HMS Mercury" (a shore establishment between Clanfield and East Meon, near Petersfield, Hants) on Sunday, June 19 with trade stands, arena events and a static display of pre-1963 racing cars. Talk-in stations GB3SN on 144MHz, 70MHz and 3660kHz. ... Sprout, the journal of the G QRP (low power club) points out that it is illegal for a station to sign /QRP but calling CQ QRP is within the Terms of the licence.

PAT HAWKER, G3VA
The provision of an alarm circuit is relatively simple and requires the digital comparison between a stored alarm time in b.c.d. form and the current received time also in b.c.d. The alarm time is determined by the positions of thumbwheel switches, which are easy to set and give a continuous read-out. The received time is present on the inputs to the display of the clock, except during the instant that the new code is being received serially. The alarm is blanked during this time by the application of waveform G to the digital comparator circuit. When the GMT to BST changeover is carried out automatically, and the alarm is connected to the output of the converter, a further blanking signal is applied in the form of waveform H. During the time that H is high the alarm is inhibited while the output of the converter continuously changes until all of the information has been received by the date decoder.

Exclusive-OR gating is used to make the comparison between the actual time and the alarm time. This system is cheaper than digital comparators, and full information about the comparison such as greater-than and less-than is not required. The output of each exclusive-OR gate is only low when both inputs are either high or low. Any exclusive-OR output being high will keep Tr, turned on, including the outputs G and H previously mentioned. However, when all outputs are low the collector of Tr, goes high and clocks IC,\textsubscript{NOR} Although rarely occurring in normal use, it should be noted that a break in transmission or noisy conditions could cause a particular display to be “skipped” and prevent detection of the required alarm time. The virtue of high accuracy may justify the extension of the alarm time to include seconds, which requires two more sections to the thumbwheel switch unit and one extra 7486 i.e. plus diodes. It is equally possible to reduce the precision and hence reduce the chance of skipping the alarm time, by not including the minutes’ comparison, and setting the alarm to the nearest ten minutes or even to the nearest hour.

The time at which the alarm is cancelled is determined by counting minutes, although seconds may be substituted if preferred, and resetting the D type flip-flop after a pre-selected number of minutes. The c.m.o.s. decade counters IC\textsubscript{D} and IC\textsubscript{A} have ten decoded outputs allowing pre-selection of a count from 0 to 99. When the pre-selected count is reached, both inputs to IC,\textsubscript{NOR} are high which resets the D type until the next alarm is detected. A reset may be effected at any time before this by the use of Sw, During the alarm period a relay is energized allowing a wide variety of functions to be switched electrically and independently. If a number of circuits need to be automatically switched on and off at different times and for different periods, several alarm circuits can be used in parallel.

### Printed circuit boards

A set comprising two double-sided boards and one single-sided board for the date decoder/BST switch, display, and alarm circuit is available for £8.00 inclusive from M. R. Sagin, at 23 Keyes Road, London N.W.2. The decoder board allows leading zero blanking, and the alarm board offers automatic cancelling after a preselected number of minutes.

A set of five p.c.b.s and special components are still available for the original time code clock as detailed in the August 1976 issue of Wireless World.

### Component list for one alarm circuit (shown overleaf)

#### Integrated circuits

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>1, 2, 3, 4</td>
<td>7486</td>
</tr>
<tr>
<td>5</td>
<td>4013</td>
</tr>
<tr>
<td>6, 7</td>
<td>4017</td>
</tr>
<tr>
<td>8</td>
<td>4011</td>
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#### Resistors

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<tr>
<td>1, 2, 4, 5</td>
<td>100k</td>
</tr>
<tr>
<td>3</td>
<td>8.2k</td>
</tr>
<tr>
<td>6</td>
<td>2.7k</td>
</tr>
</tbody>
</table>

#### Capacitors

<p>| | |</p>
<table>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1, 3</td>
<td>0.1µF disc</td>
</tr>
<tr>
<td>2</td>
<td>47µF 6V electrolytic</td>
</tr>
</tbody>
</table>

#### Misc.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
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<tbody>
<tr>
<td>Tr, 2</td>
<td>BC182</td>
</tr>
<tr>
<td>D\textsubscript{16}</td>
<td>1N916 or similar</td>
</tr>
</tbody>
</table>

#### thumbwheel switch sections

- push to make push button or use s.p.c.o. switch for possibility of alarm inhibit position

**Correction**

IC\textsubscript{3} in Fig. 2 of the June issue should be a 4013 and not a 4015 as shown in the components list.
Complete alarm circuit. To improve noise immunity the 13 exclusive-OR gate inputs from the thumbwheel switches can be fitted with 8.2 kΩ pull-up resistors to +5V. The complementary b.c.d. code contacts in the switches should be used and marked with a bar.

IC29 (G.M.T. converter) pin 7
IC28 pin 9
IC13 (decoder) pin 12
IC13 (decoder) pin 11
IC3 pin 6
IC3 pin 5
IC4 pin 4
IC4 pin 11
IN5416
D4
D1
D2
D3
D4
D5
D6
D7
D8
D9
D11
D12
D13

IC4 7486
IC2 7486
IC3 7486
IC4 7486

HOURS
10s of MINS
MINS
10s of SECONDS

From switch 4
From switch 3
From switch 2
From switch 1

0V
+5V

Time decoder

Tr1 BC102

Time code entry

00 sec
ALARM INHIBITING WAVEFORMS

IC8a
IC8b

1/4 4017
1/4 4017

Enable
VDD

VSS

Manual alarm reset

Alarm time out selection

Tr2 BC182

10k

+10V
(unregulated)

D16

Alarm contacts

IN5416

+5V

0V

Wireless World, July 1977
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WW—09 FOR FURTHER DETAILS
Decoupling

Some circuits and some thoughts on their purpose

by S. W. Amos, B.Sc., M.I.E.E.

Decoupling is usually defined in technical dictionaries as the reduction of unwanted coupling between stages in multi-stage equipment and, in the example usually quoted, the unwanted coupling is caused by an impedance in the common power supply. Such coupling can cause oscillation and the remedy is to include a decoupling network as illustrated in Fig. 1 which shows the essential components of a three-stage RC-coupled amplifier. \( R_1 \) represents the resistance of the power supply and \( R_1C_d \) is the decoupling network. By redrawing the circuit diagram as in Fig. 2 we can see that it has the form of an astable multivibrator circuit. \( R_2 \) is the effective collector load of \( T_2 \) and, if large enough, causes the circuit to generate relaxation oscillations at a frequency determined primarily by the capacitors \( C_2 \) and \( C_3 \) and the associated base resistors. In audio amplifiers the oscillation frequency is usually very low — of the order of 1Hz — and gives rise to an audible effect known as motor boating. The decoupling network is situated between \( T_2 \) collector and \( T_2 \) base in one of the cross couplings which gives rise to oscillation and, if it introduces sufficient attenuation at low frequencies, can prevent oscillation.

Fig. 2 is useful in showing, for example, that there is little point in putting a decoupling network in the collector circuit of \( T_2 \). Such a circuit would appear at the point marked X in Fig. 2: it would smooth the supply to \( T_2 \) but would do nothing to discourage multivibrator action. \( R_2 \) and \( C_d \) serve purposes other than the prevention of multivibrator oscillation. For example they act as smoothing components for the supply to \( T_1 \) and attenuate any 50Hz or 100Hz ripple. Such ripple is applied directly to the base of \( T_2 \) and is subjected to the gain of this and subsequent stages of the amplifier. For example if \( R_2 = 1 \) kilohm and \( C_d = 100\mu F \) any 100Hz components present at the output of the power supply are attenuated by a factor of approximately 60 (the reactance of \( 100\mu F \) being 16 ohms at 100Hz).

But possibly the most important effect of a decoupling network is on the transfer of signal-frequency energy from one stage to the next. To illustrate this consider Fig. 3, which shows a common-emitter tuned amplifier. \( R_2C_2 \) are collector decoupling components similar to \( R_4C_d \) in Fig. 1. But by arranging \( R_2C_2 \) as shown in Fig. 3 we can see that \( C_2 \) plays an important role in the output circuit of the transistor. The output signal from the transistor is, of course, generated between collector and emitter and, to minimise signal loss, these two electrodes should be connected by low-impedance paths to the output load, i.e. the primary winding of the output transformer \( T_2 \). There is a direct connection between the collector and one end of the load: the decoupling capacitors \( C_2 \) and \( C_3 \) provided they have suitable capacitances, provide a low-reactance path between emitter and the other end of the load.

Similar considerations apply at the input of the amplifier. The input signal should be applied between the base and the emitter of the transistor. The source of input signal is the tuned secondary winding of the transformer \( T_1 \) and one end of this is directly connected to the base. A low-impedance path from the other end of the tuned winding to the emitter is provided by the decoupling capacitor \( C_1 \) (which effectively short-circuits the lower arm \( R_2 \) of the
Emitter decoupling

C3 was introduced in the preceding paragraphs as a means of providing low-impedance paths for the input and output signals of the transistor. It has, however, another function and this is to eliminate the negative feedback introduced by the emitter resistor R3. This feedback is generally undesirable because it reduces the gain of the transistor and increases the input and output resistances. Increase in the input resistance would be a nuisance if this resistance is used to determine the passband of the tuned input transformer T1. To be effective in eliminating feedback C3 must have a low reactance at the operating frequency. Because the reactance of a capacitor is inversely proportional to frequency, feedback elimination becomes less effective as frequency is reduced and the value of C3 is therefore so chosen that effective elimination is achieved at the lowest frequency of interest: it is then automatically better at higher frequencies. This requirement also ensures that the capacitor is large enough to provide low-impedance paths for the input and output signals. It might be thought that the value of the emitter decoupling capacitor would be determined by R3 and the operating frequency, the loss due to feedback being 3dB at the frequency for which the reactance of C3 equals R3. This is not true, however, because the internal emitter resistance re of the transistor is effectively in parallel with R3 and is normally much smaller than R3. Thus the true 3dB loss frequency is that for which the reactance of C3 is equal to the parallel resistance of R3 and re. From this relationship it is possible to deduce the value of the decoupling capacitor to use in a particular circuit. It is given by the following expressions.

For bipolar transistors

$$C = \frac{h_{fe}}{2\pi f_{3DB}(R_e + R_3)}$$

where Re is the value of the external emitter resistor.

For field-effect transistors and valves

$$C = \frac{1}{2\pi f_{3DB}} \left( R_e + \frac{1}{R} \right)$$

where R is the value of the external source or cathode resistor.

The formal deduction of these expressions was given by P. Engstrom in Wireless World for December 1971.
We have so far discussed collector, base and emitter decoupling. In valve technology decoupling is also required for the screen grid of pentodes (still used in high-power equipment such as transmitters). For an a.f. pentode the effect of resistance in the external screen-grid circuit is precisely analogous to that of resistance in the external cathode circuit, i.e. it causes negative feedback and reduced gain. To eliminate this effect an external screen-grid decoupling capacitor is introduced and its value can be calculated from the expression given above by substituting $g_e$ the screen conductance for $g_m$ and $R_e$, the external screen-grid resistance, for $R_e$.

R.f. pentodes also require screen-grid decoupling but here it is necessary for a different reason. As its name suggests the screen grid is required to act as an electrostatic screen between anode and grid circuits and to do this it must be effectively connected to cathode at signal frequencies though at a positive potential to give a reasonable anode current. A capacitor between screen grid and cathode enables this to be done and such a capacitor can legitimately be called a decoupling component because it confines anode and grid signals to their respective areas and prevents leaks between them which could cause r.f. instability.

Decoupling circuits

Examination of Fig. 3 shows that the circuit could be simplified and the impedance of the output signal path further reduced by omitting $C_3$ and returning $C_2$ to emitter as shown in Fig. 4. Indeed this arrangement must be adopted in certaincircuits where signals are injected into the emitter, e.g. some types of oscillator or frequency changer circuit. A disadvantage of this circuit is that the smoothing of the collector supply by $R_3C_2$ is offset by the ripple injected into the emitter circuit via $R_3$. But possibly a more serious objection to the circuit of Fig. 4 is that $R_3$ is no longer decoupled and so provides negative feedback. However, this disadvantage can be overcome by applying to the input circuit the same technique used for the output circuit and which led to the circuit diagram of Fig. 4, i.e. by returning $C_4$ (Fig. 3) to emitter as shown in Fig. 5, which also includes output-circuit decoupling. Although the emitter resistor $R_2$ is not now shunted by a low-reactance capacitor there is no negative feedback: this is because the input signal is applied directly between base and emitter and the signal generated across $R_2$ by the collector current is not returned to the base circuit.

In some tuned amplifiers the step-down ratio required in the input transformer is achieved by use of a capacitance potential divider. It is then possible to dispense with capacitor $C_1$ by returning the potential divider to the positive supply lines as shown in Fig. 6. Here the single decoupling capacitor $C_5$ provides a low-impedance path for input and output signals. $C_4$ and $C_5$ in series tune the secondary winding and $C_4$ is larger than $C_5$ to give the required impedance match to the low input resistance of the transistor.

Hartley oscillator

Similar decoupling techniques are possible in oscillator circuits. In the Hartley oscillator, for example, one end of the tuned circuit should be connected to collector, the other end to base and the inductor tapping to emitter. Fig. 7 shows a circuit diagram in which stabilisation of the mean collector current is achieved by the potential divider $R_2R_4$, and the emitter resistor $R_3$. Such an arrangement is likely to be used if the transistor is required to operate in class A as in oscillators required to give a particularly pure waveform. The required low-impedance connection to the collector is achieved by direct coupling and to the base by the low-reactance capacitor $C_4$. The connection between tapping and emitter is, however, achieved via the decoupling capacitors $C_2$ and $C_3$; $C_3$ is sometimes a smoothing capacitor in the power supply but to minimise impedance in the tapping-emitter connection $C_2$ should preferably be a separate local component. As before, $C_3$ can be dispensed with provided $C_2$ is returned to emitter as in Fig. 8.

Tobey-Dinsdale circuit

A particularly interesting application of decoupling occurs in the Tobey-Dinsdale amplifier circuit. a development of the Lin circuit. The essential features of the decoupling circuit are shown in Fig. 9. The complementary pair $T_2, T_3$ are driven by common-emitter amplifiers from the output of $T_1$. The impedance of $D_2R_2$ is very small and thus $T_2$ and $T_3$ are effectively in parallel although, because they are complementary, their output currents are in push pull. We can thus simplify the circuit by replacing $T_2$ and $T_3$ by a single transistor $T_4$ as in Fig. 10 and the output current from $T_4$ must be directed into the base-emitter junction of $T_4$. There is a direct connection from $T_4$ collector to $T_4$ base and thus a low-impedance connection is required between $T_4$ and $T_4$ emitter. Unfortunately such a connection would short-circuit the output of the amplifier which is taken from $T_4$ emitter. The inclusion of a resistor in $T_4$ emitter circuit would not make the circuit satisfactory because the internal emitter resistance of $T_4$ would still act as a shunt on the amplifier output: moreover the return of the output signal to $T_4$ emitter would give rise to considerable feedback. This problem is solved, as shown in Figs 9 and 10, by providing a low-impedance path between $T_4$ emit-
Inductors in decoupling circuits

Many of the decoupling circuits which have been discussed include a resistor in the supply lead. This reduces the collector supply voltage available to the transistor and the need to retain an adequate collector voltage limits the resistance that can be used for decoupling. This difficulty can be overcome by use of an inductor in place of a resistor, for its reactance then determines the effectiveness of the decoupling circuit while the resistance determines the loss of collector supply voltage. A.f. inductors are, however, bulky and expensive components and this solution is generally reserved for r.f. amplifiers where small and inexpensive inductors can give adequate reactance. At u.h.f. and v.h.f. ferrite beads threaded on supply leads can give adequate reactance and these can be combined with bush capacitors to form particularly compact decoupling networks.

Diode a.m. detectors

In all the examples of decoupling networks so far considered we have concentrated on the provision of low-reactance paths to confines signals to the areas where they are required. We could, however, alternatively regard these networks as examples where the signals are prevented from reaching areas where they are not required. For example in Fig. 3 signals in the output circuit are prevented from entering the transistor by the provision of 

\[ C_2 \] and from entering the feedback path by the provision of 

\[ R_2 \] and \n
\[ R_3 \] of which \n
\[ R_2 \] and \n
\[ R_3 \] are both, in fact, current dividers in which the current is mainly confined to the capacitor by making its reactance small compared with the associated resistance. In some decoupling circuits the same end is achieved by the use of potential dividers and the diode a.m. detector circuit of Fig. 11 provides two examples. \n
\[ R_C \] is intended to prevent direct current to the earlier stages of the receiver to control their gain but it must prevent audio signals from reaching these earlier stages. To be effective therefore the reactance of \n
\[ C_2 \] must be small compared with \n
\[ R_2 \] even at the lowest audio frequency of interest, say 50Hz. \n
\[ R_3 \] is normally given a value large compared with the diode load resistance so that there is no appreciable shunting effect. 50 kilohms might be a suitable value for \n
\[ R_3 \] and \n
\[ C_2 \] can then be 1µF which has a reactance of 3 kilohms at 50Hz.

Similarly \n
\[ R_C \] is intended to prevent r.f. signals from entering the a.f. amplifier but it should not, of course, attenuate audio signals significantly. Thus the reactance of \n
\[ C_2 \] should be large compared with \n
\[ R_2 \] at the highest audio frequency: it will then be even larger at lower frequencies. It would be satisfactory therefore to make the reactance of \n
\[ C_2 \] equal to \n
\[ R_2 \] at, say, 10kHz. The loss will then be 3dB at 10kHz, 1dB at 5kHz and less at lower frequencies. If the reactance of \n
\[ C_2 \] is equal to \n
\[ R_2 \] at 40kHz it will be only 0.02µF at 460kHz, approximately the effective reactance of \n
\[ R_2 \] and \n
\[ R_3 \] which can be used in this case. A simple example is shown in Fig. 11(e).

\[ Z_1 = S_A X = \bar{A}B \]
\[ Z_2 = S_B X + S_A X = \bar{A}BX + ABX = BX \]
\[ Z_3 = S_B X + S_A X + S_A X = S_A X = \bar{A}BX = (\bar{A} + B)X \]

The circuit implementation of these equations is shown in Fig. 11(e).

---

*continued from p.65*

Design a clock-driven circuit using JK flip-flops and NAND gates that will satisfy the given specification.

(1) I/O characteristics. As shown in Fig. 11(a) and 11(b).

(2) Internal characteristics. The internal state diagram of the required circuit is shown in Fig. 11(c).

(3) State reduction. The state table is shown in Fig. 11(d) and examination of this table shows that no state reduction is possible in this case.

(4) Primitive circuit. Binary codes are allocated as shown on the state diagram. By direct reference to this diagram the following equations are obtained.

\[ S_A = S_B + S_A = AB + AB = \bar{A} \]
\[ \text{Therefore } J_A = 1 \]
\[ R_A = S_B + S_A = AB + AB = A \]
\[ \text{Therefore } K_A = 1 \]
\[ S_B = S_A + (S_B) = AB + (\bar{A}B) = AB \]
\[ \text{Therefore } J_B = A \]
\[ R_B = S_A + (S_B) = AB + (\bar{A}B) = AB \]
\[ \text{Therefore } K_B = A \]

The World Radio Club have announced revised times of transmission on the BBC World Service: the Sunday transmission at 0815 GMT will be cancelled. The times from Wednesday, September 10 will be: Wednesday, 0815 to 0830, 1330 to 1345 and 2315 to 2330 GMT, and Friday 2100 to 2115 GMT.

**Announcements**

Professor D. Zissos will conduct a five day course on Logic, Interfaces and Microprocessors from July 4 to 8 at the Southgate Technical College, London N14. Further details from Interprojects Ltd, 29 Church Street, Edmonton, London N9 9DY.

Philips and MCA will present their first UK public demonstration of the optical video disc system at the Video Disc '77 conference in London, November 8 and 9, say the organisers. The last Video Disc conference was held two years ago, before which similar demonstrations were to be held but the only equipment shown was the now defunct Tedele.

2,000 candidates responded to NASA's invitation to participate in the Spacelab experiment in 1980 (See WW May 1977, p66). NASA say that the European Space Agency have now selected 222 representing the US and 14 other countries: NASA chose 81 from the US and the rest from India, Japan, Canada, France and Belgium. The other 136 investigators came from 10 ESA member states, Austria and Norway.
For one week in April, Paris again became the centre of world electronics. It brought together 1260 exhibitors, of which 534 were French and 726 were from 30 other countries. Entrance passes alone indicated that there were 75,972 visitors, from 87 countries, almost 13% of these being from foreign countries. Although this is 5.1% more than last year, it must be remembered that last year's show did not include a section on test and measuring equipment.

Apart from increases in the number of foreign exhibitors this year - for example, there were about 30% more British and 10% more West German participants - and the introduction of newcomers from countries such as Korea and India, there were also changes in the mixture of activities of the companies exhibiting. Although exhibitors from the USA increased by almost 60%, the number of major American semiconductor companies was less than in 1976.

It is always difficult, at a show of this size, to assess a particular industry, but, if judged solely on the enthusiasm of the exhibitors and visitors at the show, a fair conclusion would be that the European electronics industry is alive and well.

Several families of power semiconductors were launched by RCA Solid State - Europe. Among these developments was a 'quick-connect' package intended for medium and high-power silicon-controlled rectifiers and triacs. The package, which may be fixed on a TO-3 heatsink, uses AMP type connectors. An example device in the new package is the T6260 40A triac. Also being launched by RCA was the Versawatt TO-220 range of silicon-controlled rectifiers. These fast-switching devices are designed for reverse-blocking applications and have turn-off times as short as 6µs. The rectifiers are rated at 5A r.m.s. with maximum trigger currents of 50mA. RCA was also showing a new range of epibase power transistors in TO-3 packages, which they claim is the largest range of its kind on the market. This range includes the 2N3055 device, which is also available in homoeaxial construction.

Other products launched by the company included a range of medium-power n-p-n transistors, several integrated circuits and a microprocessor aid. The transistors, designated as RCP111/3/5 and 7, are high-voltage, low collector-base capacitance types, especially designed for television applications such as video and audio output stages, regulators and linear amplifiers. The new microprocessor aid is a hand-held data terminal which offers a low-power, soft-copy alternative to conventional printing terminals. It uses a calculator-type keyboard and an eight-digit I.E.D. display. The Cosmac CDP185021 Micro-terminal, as it is called, is designed to interface with Cosmac hardware support systems to provide control, communications and debugging functions.

On the AEG-Telefunken stand was the TDA1062, an f.m. tuner unit for car radios. The unit consists of a mixer, modulator and phase-sensitive detector suitable for frequencies up to 200MHz. It also has a built-in a.g.c. amplifier for external p-i-n diodes, and is adaptable to capacitance diodes. Variometer or variable capacitor tuning may be used and tuning a voltage of only 2 to 7.5V is necessary. The makers claim that no alignment is needed. Another device was the TDA1068 noise suppressor, which is designed for the a.f. section of car radios. It will work from a supply voltage from 9.5 to 15V and is suitable for mono or stereo operation. Three PAL colour-TV devices, TDA2140/50 and /60, were also shown. Type 2140 is a sub-carrier reference oscillator, type 2150 forms a luminance and chrominance amplifier and type 2160 contains the synchronous modulator and RGB matrix.

Of particular interest on the Texas Instruments stand was the TBM0103, a non-volatile, 92,304-bit, magnetic-bubble memory on a single chip. The bubble chip is comprised of a gadolinium-gallium garnet substrate upon which a magnetic epitaxial film is grown. Patterns of permalloy metal are deposited on the film to define the path of bubble domains, which are made to move in a shift-register fashion when in the presence of a rotating magnetic field. The 14-pin d.i.l. module measures 1.0 x 1.1 x 0.4in and is specified for 100KHz operation, with an access time of 4ms for the first bit and a cycle time of 12.8ms for the 144-bit page. Continuous-rated power consumption is 15W.

For differential line-transceiver i.c.s, types SN55118, SN55119, SN75118 and SN75119, were also announced by Texas Instruments. These devices, are designed for interfacing between t.t.l.-type digital systems and differential data transmission lines. Each circuit combines a three-state driver and a receiver in one package.

A m.o.s.f.e.t transistor has been developed by Texas Instruments to help manufacturers improve the performance of the r.f. section of Citizen's Band tuners. The TIS148 transistor provides 20dB conversion gain with only a 3.2dB conversion noise figure when used as a mixer for 27MHz. The device also eliminates the need for an r.f. amplifier.

The new miniature 220 to 250V Bimnil shown by Boss Industrial Mouldings Limited. The drill is supplied with three collets for accepting twist drills, burrs and mops with shanks up to ¼ in. diameter. Its 7500 rev/min motor is powerful enough to drill through brass and steel.
A new 16-bit microprocessor has also been introduced by Texas. It is believed to be the first monolithic central processing unit produced using bipolar integrated injection logic (IIL). The SBP9900 microprocessor uses this technique to provide selection by the user of speed and power and static operation, to enable a single non-critical d.c. power supply to be used and to ensure direct t.t.l.-compatible inputs and outputs.

A digital multimeter was launched at the show by Gould Advance Limited. This model, called the Alpha III, is a low cost version of the Beta multimeter launched in 1976. The instrument has a 3½-digit i.e.d. display and is claimed to operate for more than 50h from one set of batteries.

Nippon Electric were showing a microcomputer board teaching kit called the TK-80. The kit, which until the show had not been introduced to the European market, provides all the hardware elements, software tools and information for tutorial introduction to, and advanced details for, the µP8080A 8-bit microcomputer and its software. The TK-80 is built around NEC's µCOM-8 microcomputer family of I.S.I. devices, including the µP8080A c.p.u., a clock generator, a r.o.m., a r.o.m., and a keyboard and an i.e.d. display.

The largest of all the stands at the show was that representing Thomson-CSF, who had a large array of new products ranging from transistors and capacitors to brushless d.c. motors and cathode-ray tubes. Included in the devices from the Electron Tubes division was the TH5108 electronically-tunable, X-band Gunn diode source. This model delivers more than 30mW over its ±100MHz tuning range and its centre operating frequency can be anywhere in the 9200 to 9300MHz band. The frequency drift for this varactor-tuned source is less than 200kHz/°C.

The TH9X14, also from Thomson-CSF, is a plasma display panel having a capacity of over 1300 characters (32 lines of 42 characters) with a useful screen area of 163mm square. The TH9X14, which is t.t.l-compatible, has all the normal functions of an a.c.-driven plasma panel, with a fast access time of 200us to write a five-by-seven point character.

Another device from the Electron Tubes Division was the THX1107 c.c.d. device which is a development of the THX1105, first introduced in 1976. This analogue delay line has 512 elements, a maximum bandwidth of 5MHz and a distortion figure of 1% for a 500mV output signal.

SGS-Ates have managed to produce i.c. amplifiers capable of handling high currents (I<sub>CM</sub> = 3.5A) and high voltages (V<sub>CE(sat)</sub> > 44V). This has allowed a typical output power of 20W into a 4Ω loudspeaker, with a distortion of less than 1%, using a single and inexpensive integrated audio amplifier, the TDA2020. Output powers of 180W can be achieved using two of these amplifiers. SGS-Ates is also developing a new family of power transistors giving up to 50A current handling capability, high switching speeds of less than 5μs, and operating frequencies of 50MHz. Devices in the range also have low leakage currents. The transistors will be manufactured in planar technology, so that they will withstand adverse operating conditions.

A large selection of new devices was being shown by Siemens. An audio amplifier i.c., in a TO220 case, was developed by the company specifically for use in car radios. With two 4Ω loudspeakers connected in parallel, the TDA 2870 provides 10W from 14.4V, and when used with only one 4Ω loudspeaker the output power is 5W. The device has built-in temperature-sensing overload and short-circuit current protection. In addition it has a low thermal resistance of 5°C/W maximum.

Among the new power semiconductors from Siemens was a fast silicon diode for TV receivers, a mains thyristor and two fast power diodes. The silicon diode, type BY302, has a soft recovery performance and a reverse recovery time of 250ns. The thyristor, type D10, has a high blocking stability and a mean on-state current of 8A. The power diodes, types SSIN36 and SSIN46, are intended preferably for use in commutated s.c.r. circuits. Model N36 is a screw bolt design having a maximum allowable r.m.s. current rating of 550A and model N46 is of the disc type, rated at 900A. Maximum forward voltage ratings for the devices are 2.0V and 2.0V respectively.

Other power devices were the BSTP49 and the BSTQ63, both high-speed thyristors, and the BSTR68L power thyristor, all in flat-pack ceramic insulated cases. These devices were developed mainly for line-commutated converters. Maximum r.m.s. on-state currents and turn-off times (at the maximum junction voltage) for the P49 and Q63 are 1100A & 10µS and 1000A & 50µS respectively.

**Also seen at the show**

**Continental Device (India) Limited:** a solar cell designed to supply transistor radios. The device provides about 6V at 300mW (in India), and is available in different sizes and with various specifications.

**Interis:** types 7106 and 7107 c.m.o.s. monolithic a-d converters designed for direct drive of 3½-digit i.e.d. displays or equivalent i.e.d. displays.

**Raytheon:** type 2901A, a four-bit microprocessor slice, said to be 30% faster than the 2901. Three quad op-amps; type HA 4741, which has no crossover, the pin-compatible LM348 with built-in overload protection, and type RC4156, having an improved noise figure and a 3.5MHz bandwidth.

**Silicon Transistor Corporation (STC):** the model STA9160 switching transistor in a TO-3 can. This device has ratings of 500W and 100A, and a V<sub>CEO</sub> of 120V.

**Jaybeam Limited:** a 2.5m skeleton parabolic dish antenna having yagi and shrouded feed assemblies. Models available include an 18dBd (v.r.t. a dipole) antenna for the 400MHz band, a 24dBd antenna for u.f.h. TV bands, and a 26dBd antenna for the 900MHz band. In addition there is a 28dBd dish for 1500MHz and a 31dBd dish for 2GHz.

**ITT:** a battery-operated laser torch designed specifically for use with night vision equipment. The lens system can be adjusted and will provide a spot diameter from 1.5 to 8m at 100m range.

**Hewlett Packard:** two dual optically-coupled isolators, models HCPPL-2730 and 2731. These units have very high transfer ratios (10:1) and low input currents of 500A and will operate up to 290k-bits/s. Isolation between inputs and outputs is 3000V.

**Thomson-CSF:** a bipolar power transistor, designed by the Microwave Microelectronics Division, which is claimed to be one of the best r.f. transistors on the market. The 250W p.p. device, model TH430, is intended for s.s.b. transmitters in the range 2 to 30MHz. It has a power gain of at least 14dB.
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WW — 078 FOR FURTHER DETAILS
Modification of the facsimile machine for radio weather charts

by G. R. Kennedy

Parts one to four of this article described a prototype rotating-drum facsimile machine for producing APT, SR and WEFAX transmission pictures. This final part describes modifications to the basic design of the machine so that it may be used specifically for meteorological purposes. The modifications will enable both weather satellite and radio facsimile broadcasts to be printed.

Weather charts, prepared by hand or computer, are transmitted by short-wave and long-wave radio by most national meteorological organisations, (see Ref. 13). The internationally adopted standards for drum rotation speeds and index of co-operation (i.o.c.) are 60, 90 and 120 rev/min and 576 or 288 respectively. The 288 index is sometimes referred to as 'alternate line scanning'. 90 rev/min charts are invariably for aeronautical use. The transmissions are frequency shift keyed ±400Hz on short-wave and ±150 Hz on long wave. Some charts are sent on one sideband of a double side-band transmission, often with teleprinter traffic on the other. Reception requires a good communications receiver with a stable beat frequency oscillator (b.f.o.) and a frequency shift keying (f.s.k.) terminal connected to the receiver audio output (see Fig. 16). This provides a machine-compatible output to the facsimile machine described earlier. The audio signal from the receiver is detected and applied to one input port of an analogue modulator or mixer, an accurate 2.4kHz signal being applied to the other. The output is the product of the two signals. Since most charts are black and white, the detector is arranged to latch between two levels corresponding to black and white; this enhances copy under poor signal conditions. For those cases where greys are required, such as for the Russian composite chart and Meteor satellite transmissions, the detector can be switched to respond to varying levels. The detector and a.m. modulator are powered from a stabi-
lized power supply with a very low output ripple.

The circuit details for the input detector are shown in Fig. 17. The receiver audio is applied to one input of the phase-lock loop IC23 via C37, while the other input is balanced to ground. The output comprising the f.m. demodulation of the input frequency-shift passes through the low-pass filter R36, R37, C41 and C42 to operational amplifier IC24. The d.c. level from IC23 is maintained by the input to the non-inverting input of the op-amp via R38. C43 decouples any residual v.c.o. signal, and together with the low-pass filter removes the loop p.s.d. sum frequency. IC24 is run with its negative rail to ground to ensure that only positive signals are passed to the next stage. Switch S9 allows the option of a black and white picture by placing a large value feedback resistor, R92 across IC24 so that it latches solidly between positive and ground. Alternatively a lower value of feedback gain can be obtained by selecting RV17 which can be preset to give the required grey scale. The grey reference level for half carrier shift is finely set by preset RV16.

The output of the detector is applied to the detector i/p terminal of balanced modulator IC25 via RV19 which sets the modulation depth. IC25 is a double balanced mixer which is used here to amplitude modulate the detected signal onto a 2.4kHz carrier. This is fed in via RV19 which sets the carrier level, to the carrier input. Input biasing is effected by R85, R87, R88 and R89. The residual level of the output carrier is set by RV30 so that the carrier is modulated to 75%, the residual 25% being used in the facsimile machine for clocking. The gain is preset by R90, the bias by R85, and R86 and R94 are the chip output transistor collector loads. The output terminals are at approximately +10V, so the output signal is a.c. coupled by C44, R46 and R85 set the carrier mean d.c. level. The −12V rail is derived from the −12V supply by R85, D17 and C49. (Note: pin assignments are shown in Fig. 18 for the 'L' 14 pin d.i.l. version of the Motorola MC1496. With appropriate pin connections, the Motorola 'G' version or the Signetics NE5596 'A' or 'K' can be used).

With the circuit values given, the v.c.o. frequency of IC23 is 5.5kHz. This was found to be a good compromise between the upper frequency limit of the receiver audio amplifier and the lower frequency limit for black to white transitions for fine detail. Tests showed that for a b.f.o. frequency of 3kHz fine lettering was not discernable, and few communication receivers have a good response above 8kHz.

A crystal-controlled 2.4kHz generator is shown in Fig. 19. There are many ways of producing the frequency accurately, but this shows a method using a fairly standard crystal bar. The 144kHz crystal is the feedback element in a simple t.t.l. gate oscillator, IC26. The
The output is divided by five in IC_{26} and further divided by 12 in IC_{28}. The resultant 2.4kHz is taken directly to the f.s.k. modulator IC_{25} and buffered and inverted in IC_{26}. This output is used in the facsimile machine to drive the motor circuitry and detector. The inversion in IC_{29} partially corrects for phase shift in the f.s.k. input detector and precludes RV_{5}, the sample pulse delay pot in the facsimile machine having to be adjusted differently for satellite pictures and facsimile charts. The power supply circuit for the f.s.k. terminal, shown in Fig. 20, uses I.C. voltage regulators IC_{26a} and IC_{26b} with external transistors Tr_{20} and Tr_{21} to increase the regulating sensitivity. This gives no output protection, but gives a very high input rejection and hence extremely low ripple If a less smoothed supply is used, hum bars are prone to appear on the final print as a regular speckling of the chart lines.

The actual modifications to the facsimile machine itself are straightforward and involve the addition of a phase-locked frequency generator, two binary dividers, and switching to change the motor drive frequencies. Fig. 21a shows the essentials of the basic system before modification. Note that the APT/SR switch S_{3} has been added to illustrate the routing of APT or SR line division frequencies — in the basic machine the 1/5 line position of the line division switch S_{3} can be used for APT/WEFAX. The modifications to the basic design are shown in Fig. 21b. The line division switch remains, but the APT/SR switch is enlarged to give positions for 60, 90, 120 and 240 drum revolutions per minute, as well as the SR line division rates of 240 rev/min for 1/5 line, 192 rev/min for 1/4 line and 144 rev/min for 1/3 line. For 60, 120 and 240 rev/min the 2.4kHz is divided by 50 and is selected by S_{5}, to pass directly to the motor drive power amplifier, or divided by two, or divided by four, to give 240, 120 or 60 rev/min respectively. For 90 rev/min the path is the same as for 60 rev/min except that the 2.4kHz is increased 1½ times to 3.6kHz to give an output of 60 rev/min times 1½, i.e. 90 rev/min. The 3.6kHz generator is shown in Fig. 22. The 2.4kHz input is applied to phase-lock loop IC_{27}. The output of the 3.6kHz v.c.o. is amplified by Tr_{21} and taken to the drum function switch S_{2}, and to duodecal divider IC_{33} connected as a divide-by-three circuit. The 1200 Hz output from this circuit is returned to IC_{28} in order to phase lock the v.c.o. to the 2.4kHz input. The SR signal path remains the same as in the basic scheme. Since the motor drive circuit is not as efficient at lower frequencies, RV_{11} in the motor drive circuit (Fig. 12) is advanced when the chart modification is carried out. The drive at the higher frequencies is then automatically reduced by S_{12}, switching the RV_{11} wiper to ground via R_{11}, for 240 rev/min and R_{12}, for the SR frequencies. The motor drive voltage therefore remains

<table>
<thead>
<tr>
<th>Charts (rev/min)</th>
<th>IC_{0}.c.</th>
<th>Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>120</td>
<td>228</td>
<td>(no expansion, linear)</td>
</tr>
<tr>
<td>120</td>
<td>576</td>
<td>(no expansion, linear)</td>
</tr>
<tr>
<td>90</td>
<td>576</td>
<td>(no expansion, linear)</td>
</tr>
<tr>
<td>60</td>
<td>576</td>
<td>(no expansion, linear)</td>
</tr>
<tr>
<td>NOAA's, Meteor-25</td>
<td></td>
<td>with appropriate log/lin and expander settings</td>
</tr>
<tr>
<td>ATS-3</td>
<td></td>
<td>with appropriate log/lin and expander settings</td>
</tr>
</tbody>
</table>

**Table 1. Settings for gain potentiometer RV_{6} (on a scale of 0-10) as used on the prototype facsimile machine.**

![Fig. 19. 2.4kHz oscillator of f.s.k. terminal circuit.](image)
approximately constant at all drum rates. Depending on the type of transformer used in the motor power amplifier, the values of coupling capacitors $C_{24}$, $C_{25}$ and of tuning capacitor $C_{27}$ in Fig. 12 may have to be increased, although in the prototype this was not found to be necessary.

The traverse modification concerns the provision of two traverse speeds by switching and an alternative gear train. The same gears are used for SR pictures and 120 rev/min charts, but for 60 rev/min charts the standard synchronous motor used for the traverse would not run on a 12Hz supply in the prototype and simple switching was arranged to apply 50Hz mains to the motor with a replacement gear train to give the correct rate of drive. For 120 rev/min the switching between the synchronous low speed (normal) and the 50Hz rate (fast) gives approximately the correct drive speeds for 576 and 288 i.o.c. respectively. At 60 and 90 rev/min, charts are normally only sent at 576 i.o.c. The gearing has to be changed to a ratio of 7:1, using the motor and roller size described earlier. The situation for printing satellite pictures remains the same, i.e. direct drive (1:1) for ATS-3, 2:1 at “normal” for NOAAs, and 2:1 at “fast” for Meteor-2. (Note: as a guide, in the original machine the 7:1 nominal gearing was 60-107 for motor to shaft, 23-90 for shaft to roller, these representing teeth of diametrical pitch 100).

Operation for radio facsimile charts
The facsimile machine gain pot setting has to allow for the effective writing speed of the crater-tube light beam at different drum and traverse rates. The prototype used an analogue turns counting dial for setting $RV_g$ (see Fig. 7). The settings used are set out in Table 1.

The output of the f.s.k. terminal is taken to the expander input, with the expander set for a direct signal i.e. no expansion. Phasing is carried out as for satellite pictures. No strobing is used and the monitor oscilloscope is triggered from the sync output socket. The drum edge pulse thus appears every two or four sweeps of the oscilloscope time-base; this is quite adequate for positioning the drum and chart edges. Detector switch $S_5$ is set to black-and-white, the receiver is tuned to the required signal and the beat frequency oscillator set to give bright/dim keying of the crater tube. This can be done without great precision on short-wave
but requires more finesse on v.i.f. signals due to the reduced frequency shift. Received chart quality can be improved in the presence of interference by reducing the receiver i.f. bandwidth to just encompass the carrier shift. As a matter of detail, most transmissions have a white inter-chart level and short duration black edge phasing pulses. Those stations of French, or previously French colonial origin, send a black resting level and half-line black/white phasing bars. According to which side of the b.f.o. is tuned — for double sideband transmissions — the chart may be printed as black lines on white or vice-versa. The option is useful not only for slide projection but also to enable a readable copy to be obtained if there is severe interference to one side of the carrier.

The Russian weather charts, that contain strips of computer-processed Meteor satellite pictures, require the detector to be switched to grey on $S_3$ and $RV_{17}$ adjusted for optimum results, consistent with black lines being printed on the chart.

Photographic materials
The author has found that a most suitable material for all prints, both satellite pictures and radio facsimile charts, is Ilford's Ilfospeed 2.1 M and 3.1 M, a fast-processing resin coated, polyethylene laminated paper. For development an Ilfospeed developer is available, although Kodak D-19 used in its concentrated working solution has given excellent results.

It should be noted that this article refers to special radio transmissions and any enquiry concerning receptionlicencing should be addressed to the relevant licencing authority.

Fig. 22. Phase-locked 3.6kHz generator circuit for "90 rev/min" charts. Correction note! On IC$_{32}$ the connection shown from pin 10 to ground via $C_{67}$ should be a connection from pin 11 to ground via $C_{67}$.
New Products

Electromagnetic pump
The Appliance Components Eckerle ETU 21 electromagnetic piston pump will handle both corrosive and non-corrosive thin, clear liquids. The latest version is fitted with Delrin inlet and outlet fittings but a more expensive model with stainless steel fittings is available. Measuring 2 1/4 in x 3 1/4 in, the pump is self-priming and will handle up to 11 gallons an hour. It may be driven via a silicon semiconductor diode for a 12 to 240V 50Hz a.c. supply, and operates at 25 times a second. Maximum discharge height is 65ft and the maximum vertical lift is 10ft. Apart from non-return valves, the only moving part is the metal piston. Internal metal components, which require no lubrication, are made from corrosion resistant materials. The materials used for the moulded seals and valves can be selected to suit the liquid being handled. Appliance Components Ltd, Cordwallis Street, Maidenhead, Berks SL6 7BQ. WW 301

I/O ports
Bidirectional, latched input/output ports (interface vector bytes) are announced by the Signetics group of Mullard. The 8-bit ports are intended as interface elements for microprocessors, being compatible with the 8X300 micro. Each i.v. byte contains eight data latches, which can receive data from either a microprocessor port or a user port, the two modes being under separate control. Priority is given to the user port.

The bytes are programmed by the user or manufacturer to recognize an 8-bit address, which opens the port and allows data through when a 'select' signal is applied. Data transfer is stopped when the address no longer matches the programmed, internal address of the byte. Types 8T32 and 8T36 possess three-state outputs, while the 8T33 and 8T35 bytes are open-collector units. 8T32 and 33 are synchronous, 35 and 36 asynchronous. The voltage supply needed is 5V and the modules are in 24-pin packages. Mullard Ltd, Mullard House, Torrington Place, London WC1E 7HD. WW 302

Component meter
The Wayne Kerr component meter B424 measures resistance, capacitance and inductance on the bridge principle. The display reads up to 1999, and measurements are given up to 20MΩ, 20mF and 2kH. Resolution on the most sensitive ranges is 10mΩ, 0.1µF and 0.1µH. An analogue output is available to feed ancillary equipment. The instrument has an accuracy of 0.25% (± one digit) on all ranges, and is suitable for battery or mains operation. Selection of R, C or L is by push-button, and range-changing by 9-position rotary switch. Illuminated pointers indicate the most appropriate range, and the display also includes decimal points and units. Operating the range switch automatically selects the most suitable test frequency: 1kHz or 100/120Hz. Two test terminals are normally used, but a third is available if required for screened connections. Bias voltage is provided for polarising electrolytics under test. When inductors with high-permeability cores are being measured the test signal level is held below 100mV. Wimbot Breeden Electronics Ltd, 442 Bath Road, Slough, Berks SL1 6BB. WW 303

Fluxmeter
The Austrian made Norma Fluxmeter detects voltage time integrals to measure magnetic flux, flux density and mutual induction. The range is from 0.1 to 50mWb in six ranges with a sensitivity of 1µWb and an accuracy of ±1% of f.s.d. The instrument has an auto-zero facility and a recorder output, with a source resistance of 2kΩ, on which 1V corresponds to f.s.d. The instrument operates either from the mains or rechargeable batteries. Two probes are available, one with a turns x area of 10⁻²m², and the other 6x 10⁻²m². A standard source is also available with a 3.5 x 15.5mm airgap having an induction, say Cropico, of 500 mT, accurate to within 1%. The unit measures 160 x 240 x 310mm and weighs 3.8kg. The price is £964 excluding v.a.t. The search coils and calibrating magnet are extra. Cropico say delivery is around three to four weeks. Cropico Ltd, Hampton Road, Croydon CR9 2RU. WW 304

Microwave power meter
The Sanders Division of Marconi Instruments have introduced a programmable, thin film, thermo-electric (t.f.t.) power meter, type 6550B, for power measurement at microwave frequencies. Replacing the type 6555A, the meter has binary-coded decimal, programmable ranging, automatic range and scale selection and auto-zero

WW 303

WW 304

WW 301
facilities. It can be used with a range of
t.f.t. power heads covering frequencies
between 10MHz and 40GHz with a
power range from 1µW to 3W. The
instrument can be used in automatic
test systems, but in its manual modes
is also suitable for use as a conventional
power meter. The t.f.t. power heads
available are compatible with all the
power meters in the company's range.
Marcini Instruments Ltd — Sanders
Division, Gunnels Wood Road, Steven-
age, Herts, SG1 2AU.

Dual-in-line reed relay
A range of d.i.l. packaged reed relays is
now offered by Feme. Single-pole
normally-open, double-pole normally-
open, and single-pole changeover con-
tact arrangements are available as
standard with coil voltage ratings of 5,6, 12, and 24 volts d.c. Rhodium contacts
are used to obtain maximum life at
power levels within the ratings of
the contacts. Quiller Components Ltd,
Cardigan House, Winton, Bournemouth, Dorset, BH9 1AU.

Dot matrix printer
A dot matrix serial printer developed by
Honeywell Information Systems Italia
is controlled by a built-in microproces-
sor. Its printing head (see photo) has
needles operated electromagnetically to
a 7 x 7 or 7 x 9 dot matrix and operates
at speeds up to 120 characters per
second. There are 132 print positions
and the character set, which can be
changed by replacing a character
that generates read-only memory, com-
prises 128 symbols. An original and up
to four copies can be printed, and
options such as front feed or dual paper
movement are available. At every print
interruption the print head automat-
cally moves a space to the right to make
the printed characters visible. The inked
ribbon is contained in a removable
cartridge. Honeywell Information Sys-
tems Italia, Caltuso, Turin, Italy.

25MHz oscilloscope
A range of measuring facilities usually
found on wider-band instruments is
provided by Philips on the dual-trace
PM3214. The delayed timebase, which
can be displayed effectively at the same
time as the main sweep and strobe, is
calibrated and can be made to start
immediately after the delay or on
receipt of a trigger after the delay.
Sensitivity is 2mV per centimetre from 0
to 25MHz and triggering modes include
full-range auto, a.c. or d.c. and tele-
vision line or frame.
For those occasions when signal
"low" cannot be earth, the instrument is
double-insulated to enable it to be used
without an earth connexion. Batteries
may alternatively be used and a variety
of mains supply voltages can be accom-
modated. Pye Unicam Ltd, York Street,
Cambridge.

Television off-air receiver
A crystal controlled mono-channel,
mono-standard receiver for off-air
professional television applications has
been introduced by Barco. Designated
VSD2/X, the receiver is supplied for any
channel between 47 and 865MHz,
including mid-band channels, and for
television standards BG, DK, I, and L.
The channel selectivity is sufficiently
high that the receiver can be used in
situations where the field strength of
the adjacent (disturbing) channel is
several times higher than the strength
of the chosen channel. Relative indica-
tion of the field strength is presented on
a front panel meter. N.V. Cobar Barco
Electronic, Video Systems Department,
Th. Sevenslaan 106, 8500 Kortrijk,
Belgium.

1000-watt transceiver
The National Radio transceiver type
NCX-1000 has a transmitter power
output of 1000 watts p.e.p. on s.s.b.; 1000
watts c.w. (normal c.w. duty cycle); and
500 watts a.m. or f.s.k. Its frequency
coverage is 3.5 to 30MHz. Output
impedance is 25-100 ohms (minimum
tuning range of pi network). Carrier and
opposite sideband suppression is
greater than 40dB, while receiver sensi-
tivity is better than 0.5µV for 10dB (s +
n)/n ratio. Selectivity is 2.7kHz (a
crystal lattice filter is used) and the
receiver dynamic range is 105dB. Image
and i.f. rejection is better than 60dB.
Export Division, EMEC Inc., P.O. Box
1285, Hallandale, Florida 33009, USA.

Operational amplifier
The 1435/1435-S3 is a differential input
operational amplifier designed for
amplification of wideband complex
waveforms with fast rise-time
components from d.c. to 1GHz. Gain accuracy is
0.01%. This is reflected in the settling
time specification of 70ns to 0.01% for a
10-volt output step. There is a level
frequency response beyond 100kHz and
smooth 6 dB/octave roll-off beyond
100MHz. When handling complex
waveforms such as square pulses,
overshoot is less than 1% of output pulse
amplitude. Operating temperature is
—55°C to + 125°C. Teledyne Philbrick,
Heathrow House, Bath Road, Cranford,
Middlesex TW5 9OQ.
Sidebands by mixer

Bletherization

The on-going initiation of marketing-oriented buzzwords develops in their enunciator an in-built motivation for the generation of enhanced input/output ratios. When it comes to the crunch, marketing is an aggressively-formulated scenario of both software and hardware-oriented data organization, using sophisticated, number-crunching equipment for the on-line analysis of a cash-flow situation. At the end of the day, the viability of any throughput-motivated validation operation must hopefully depend on the dialogue between personnel engaged in hardware generation and those who basically adjust output-level values to maximize financial advantage, in a committed operation. When intelligence communication is contra-indicated, obscuration can be generated by sophisticated employment of in-built jargonisation, soonest. Or something.

Update

Some of our readers who have been amateur constructors since capacitance was measured in jars have been baffled by the newer system of component values that are now common. We have explained them before, but we still receive the odd query: if you’ve been used to dealing with 0.01µF capacitors for fifty years, it comes as a shock to find that you should have been calling the wretched things 10p.

Briefly, it goes something like this. The idea developed from a British Standard designed to avoid decimal points and long strings of noughts on components themselves. On circuit diagrams, the nature of the component can also be omitted — a capacitor is obviously measured in fractions of a farad, so the F is redundant. The decimal point is replaced by the multiplier of the unit (k, M, µ, etc) and the full range of noughts needed is two. For example, 0.0053µF would be written 3n, meaning 3.3 nanofarads (nano = 10⁻¹²). A resistor of 3.3kΩ is 3k and an inductor of 0.0048 henries becomes 4m8 (4.8mH). A 0.1µF capacitor is 100n, and so on. It’s much simpler than the old way and it does avoid decimal points, which can so easily be missed out.

Sounds philological

The sheer labour that engineers go through to bring forth a new device or system fades into insignificance beside the agonies of mind they suffer when they have to think up a name for it. The systems of sound reproduction that use three or more loudspeakers are no exceptions. The use of such caledions, everything from quadraphonic to surround-sound, from perisonic to four-channel: and they are just the printable ones. Surely, it’s now time to settle down, put away the Latin, Greek and Oxford English dictionaries and come up with a sensible name.

"Quadraphony" is not a good choice. To start with, it’s a Graeco-Roman mess, conceived on the wrong side of the blankets, and secondly, the meaning is wrong. It implies a square sound, which is surely not what is intended: a square-sounding punk rock group is not an idea I can easily contemplate. In any case, it should be quadro-, the adjectival form, not quadra-. Or perhaps quadri-, if the number four is intended.

"Surround-sound" has been used rather a lot and has the merit of describing the effect rather than the means of producing it, which could change — it avoids the use of any part of a word meaning "square" or "four". We already have systems, which can use three or six loudspeakers, to which the term quadraphonic is not applicable. My feeling is, though, that the word is too long and is ugly when used adjectively.

"Ambisonic" is good, but is used almost as a trade-name. For this reason, it is unlikely to be adopted by organizations who have their own nominal axes to grind.

Any reference to the number four is not a good idea, even if it were always the right number. It has most relevance to a system using four completely separate channels, but this can’t be used for all types of sound reproduction and can’t, therefore, be used in any overall description. My own suggestion is to term the reproduced surrounding sound field the phosphene and to coin the word "phonospheric" to describe such equipment. I shall now sit back and await retribution for my temerity.

2p or not 2p?

Not that tuppence will get you very far in this inflationary age. But it does seem extraordinary that a plain, ordinary (or even coloured ordinary) resistor can cost up to 2p. It seems possible, since the majority of our readers are employed in the electronics industry, that whenever they are seized with the desire to build an amplifier, a commensurate number of relevant components promptly disappears from their labs (a company I know of used to keep small components for engineers to use as they needed them, without having to sign a stores chit, on the basis that each engineer would probably only build one tele-

vision set and one amplifier and that number of components could be written off.

But that is irrelevant if the prospective builder is not able to liberate components or does not possess the legendary "junk box", beloved of writers of books entitled "The Practical Guide to . . ." So, they are faced with problems of supply and, having located a source, the cost. Time was when you could find a radio shop in any town which sold components, not teak-finished furniture with knobs on, where you could buy everything needed. I remember buying everything I needed for a 12v television set, quite casually, from the local shop. (I won’t say how long ago, but Sutton Coldfield and Ally Pally had it all to themselves.)

The way you can buy stuff now is to send off to a mail order establishment, and very good some of them are, if expensive. I would have thought, and I have no doubt that a great number of component suppliers will put me straight here, that the High Street shops of yore could still perform a very useful function and make a profit doing it. Admittedly, they couldn’t stock all the exotic bits and pieces we are now used to, but the ordinary components and materials ought to be no problem. They would be able to buy in bulk from manufacturers who won’t deal with the public and, in any case, couldn’t handle an order for a few pence. Free of the burden of postage, packing and insurance, they could probably sell components at a lower price, and to boost their sales they could assemble kits of parts for the more popular small designs and sell them both directly and by mail order. Perhaps the new 'byte' shops will do something like that.

Cuckoos

"Nah, well, it’s analogue, innit? Wot yer want’s a digital readah." Thus spake a young man of nearly six at the recent RSGB exhibition, as his friend (well turned seven) commented on some frequency-measuring instruments. They caught sight of me and, since it looked as though they might draw me into the discussion, I hurried away before they discovered my relative ignorance of such matters.

But really, haven’t these infants more immediately fascinating pursuits to occupy them? Have grass snakes and guinea-pigs totally disappeared from these islands? Surely not, and yet here were these two, looking as unlike infant prodigies as it is possible to imagine, discussing oscillator stability and instrument design while outside, the toads were toadying and field-mice fielding away like anything.

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Regd. office Dorset House, Stamford Street, London SE1 9LU
## Transistors

Transistors are available in various brands and types. Some examples include:
- **BC107**: Price £0.12
- **BC108**: Price £0.12
- **2N3904**: Price £0.18
- **7495**: Price £0.75

### 74 Series TTL ICs

74 Series TTL ICs are fully specified and guaranteed. Prices range from £0.33 to £3.90.

<table>
<thead>
<tr>
<th>Type</th>
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<tr>
<td>7413</td>
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### MOS ICs

MOS ICs are also available in various types. Prices range from £0.30 to £0.98.

<table>
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### Linear ICs

Linear ICs are available in different types. Prices range from £0.68 to £2.10.

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## Diodes

Diodes are available in various types and prices range from £0.07 to £0.22.

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## Silicon Rectifiers

Silicon rectifiers are available in different types and prices range from £0.10 to £0.70.

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## Ordering

Please word your orders exactly as printed, not forgetting to include our part number. **V.A.T.** Add 12 1/2% to prices marked*. Add 8% to others excepting those marked †. These are zero.

* Prices marked with * include VAT.
† Prices marked with † exclude VAT.
High quality modules for stereo, mono and other audio equipment.

PUSH-BUTTON STEREO FM TUNER

OUR PRICE ONLY

£20.45

Fitted with Phase Lock-loop Decoder

The 450 Tuner provides instant program selection at the touch of a button ensuring accurate tuning of 4 pre-selected stations, any of which may be altered as often as you choose, by simply changing the settings of the pre-set controls. Used with your existing audio equipment or with the BI-KITS STEREO 30 or the MK60 Kit etc. Alternatively the PS12 can be used if no suitable supply is available, together with the Transformer T538.

The S450 is supplied fully built, tested and aligned. The unit is easily installed using the simple instructions supplied.

STEREO PRE-AMPLIFIER

A top quality stereo pre-amplifier and tone control unit. The six push-button selector switch provides a choice of inputs together with two really effective filters for high and low frequencies, plus tape output.

MX. 60 AUDIO KIT: Comprising 2 x AL60's 1 x SP800 1 x BTM80 1 x PA100 1 front panel and knobs 1 kit of parts to include on/off switch, neon indicator, stereo headphone sockets plus instruction booklet. COMPLETE PRICE £25.55 plus 65p postage

TEAK 60 AUDIO KIT: Comprising Teak veneered cabinet size 16 1/4" x 11 1/2" x 3 1/4" other parts include aluminium chassis, heatsink and front panel, braced back panel and appropriate sockets etc. KIT PRICE £10.70 plus 85p postage

ONLY £3.60

STEREO 30

COMPLETE AUDIO

7 + 7 WATTS R.M.S.

NEW AL30A 10w R.M.S. AUDIO AMPLIFIER MODULE

The AL30A is a high quality audio amplifier module replacing our AL20 & 30. The versatility of its design makes it ideal for record players, tape recorders, stereo amps, cassette and cartridge players or power supplies available comprising a PS12 together with a transformer T538. Also for stereo, the pre-amp PA12 SPECIFICATION:

- Output Power 10w
- Supply 22 to 30 volts
- Input Impedance 60K
- S/N Ratio 90dB
- Total Harmonic Distortion Less than 1.5% (Typically)
- Frequency Response 50Hz to 20KHz
- Dimensions 90 x 44 x 27mm

£16.25

AL 60

25 Watts (RMS)

- Max Heat Sink temp 90C
- Frequency response 20Hz to 100KHz
- Distortion better than 0.1 at 1KHz
- Supply voltage 15-50V
- Thermal Feedback
- Latest Design improvements
- Load – 3, 4, or 16 ohms
- Signal to noise ratio 80db
- Overall size 63mm, 105mm, 13mm

£6.70

Stabilised Power Supply Type SPM80

SPM80 is especially designed to power 2 of the AL60 Amplifiers, up to 15 watts (RMS) per channel simultaneously. With the addition of the Mains Transformer BTM80, the unit will provide outputs of up to 1.5A at 35v. Size 63mm x 105mm x 30mm incorporating short-circuit protection.

Transformer BTM80

£3.75

MPA 30

Enjoy the quality of a magnetic cartridge with your existing ceramic equipment using the new M.P.A. 30, a high quality pre-amplifier enabling magnetic cartridges to be used where facilities exist for the use of ceramic cartridges only. It is provided with a standard DIN input socket for ease of connection.

Full instructions supplied

£2.85

MPA 30

ENJOY THE QUALITY OF A MAGNETIC CARTRIDGE WITH YOUR EXISTING CERAMIC EQUIPMENT USING THE NEW M.P.A. 30, A HIGH QUALITY PRE-AMPLIFIER ENABLING MAGNETIC CARTRIDGES TO BE USED WHERE FACILITIES EXIST FOR THE USE OF CERAMIC CARTRIDGES ONLY. IT IS PROVIDED WITH A STANDARD DIN INPUT SOCKET FOR EASE OF CONNECTION. FULL INSTRUCTIONS SUPPLIED.

£2.85

NEW PA12 Pre-Amplifier module completely re-designed for use with AL30A Amplifiers. Modules feature includes on/off volume, balance, bass and treble controls. Complete with tape output.

£6.70

PS12

Power supply for AL30A, PA12, SA450, etc

Input voltage 15-20V A.C. Output voltage 22-30v D.C.

Output current 800 mA Max. Size 60mm x 43mm x 26mm

Transformer T538 £2.30

£1.30

OUR PRICE

£1.30

NEW PA12 Stereo Pre-Amplifier completely re-designed for use with AL30A Amplifiers. Modules feature include on/off volume, balance, bass and treble controls. Complete with tape output.

£6.70

STABILISED POWER SUPPLY TYPE SPM80 80 Watts

SPM80 is especially designed to power 2 of the AL60 Amplifiers, up to 15 watts (RMS) per channel simultaneously. With the addition of the Mains Transformer BTM80, the unit will provide outputs of up to 1.5A at 35V. Size 63mm x 105mm x 30mm incorporating short-circuit protection.

Transformer BTM80

£3.75

NEW SA450 Power supply for AL30A, PA12, SA450, etc

Input voltage 15-20V A.C. Output voltage 22-30V D.C.

Output current 800 mA Max. Size 60mm x 43mm x 26mm

Transformer T538 £2.30

£1.30

OUR PRICE

£1.30

NEW SA450 Power supply for AL30A, PA12, SA450, etc

Input voltage 15-20V A.C. Output voltage 22-30V D.C.

Output current 800 mA Max. Size 60mm x 43mm x 26mm

Transformer T538 £2.30

£1.30

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SHOP AT

18 BALDOCK ST., WARRENTON, HERTS.
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Terms of business: C.W.O. postage and packing valves and semiconductors 25p per order. CRt's 75p. Items marked * add 12% V.A.T. Others 8%.

1. Indicates cheap quality version at surplus, but also available by leading UK and USA manufacturer. Price quoted at time of acceptance.

2. Account facilities available to approved companies with minimum order charge £10. Carriage and packing £1 on credit orders. Over 10,000 types of valves, tubes and semiconductors in stock. Categories £1 each. Free on orders over £50.00.

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4W, 40 watt £7.00 (x 2 pairs only). 2W, 20 watt £5.00. Post £40.

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motor, torque
FHP
(sheet)
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heavy
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11cm

£6.00.

A.C.

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Hansman Type V Mk. 1. Time Switch 200/250 volt A.C. for use with 24 hours or at any time of day. Price £3.50. Post £20.

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A.C. MAINS TIMER UNIT

Based on an electronic timer, with 25 amp compression switch, which can be preset for any period up to 12 hours ahead. Switch on for any length of time from 10 to 60 hours, then switch off. An additional 60 min. audible timer is included, ideal for Timer Recorders. 75 watt and 115 watt with adjustable clip-on knob. £25.25. Post £20. (Close out VAT £8.75).

POWER RheOSTats


PROGRAMME Timers

230-250 volt A.C. circuit breaker. Available in 1, 2, 3, 4, 6, 8, 10, 12, 16, 20 amp. or 120/240 volt A.C. 4, 6, 8, 10, 12, 16, 20 amp. Price £9.50. Post £5. (Close out VAT £4.30.)
In Hi-Fi News there was published by Mr. Linsley-Hood a series of four articles (November 1972, February 1973) and a subsequent follow-up article (April 1974) on a design for an amplifier of exceptional performance which has as its principal feature an ability to supply from a direct coupled fully protected output stage power in excess of 75 watts whilst maintaining distortion at less than 0.01% even at very low power levels. The power amplifier is complemented by a pre-amplifier based on a discrete component operational amplifier referred to as the Linsley which is employed in the two most critical points of the system, namely the equalization stage and tone control stage positions where most conventional designs run out of gain at the extremes of the frequency spectrum. Unusual features of the design are the variable transition frequencies of the tone controls and the variable slope of the scratch filter.

There is a choice of four inputs, two equalized and two linear, each having independently adjustable level control. The attractive slimline unit pictured has been made practical by highly compact PCBs and a specially designed Toroidal transformer.

To complement the world-wide acclaimed Linsley Hood 75W Amplifier, this kit provides the perfect match April - May 1974 published original circuit has been developed further for inclusion into this outstanding slimline unit and features a pre-aligned front end module, excellent performance and temperature compensated variable trap, which may be controlled either continuously or by push button pre-selection. Frequencies are indicated by a frequency meter and attack and decay are both available in this kit. The PLL stereo decoder incorporates active filters for immunity suppression and a toroidal transformer and integrated regulator. For the long term stability metal oxide resistors are used throughout.

Published in Wireless World (May, June, August 1976) by Mr. Linsley-Hood, this design, although straightforward and relatively low cost nevertheless provides a very high standard of performance. To permit circuit optimization separate board is used and the latter using a discrete component from-end design such that the noise level is below that of the top end background. Push button switches are used to provide a choice of equalization time constants, a choice of both levels and also an option of using an additional pre-amplifier for microphone use. The mechanism used is the Goldsmid-Lemien CRV, a unit distinguished in its robustness and ease of operation. SMD control and automatic cassette deck length are both implemented by electronic circuitry. This unit is powered by a toroidal transformer and uses metal oxide resistors throughout offers an excellent match for the Wireless World Tuner and the Linsley-Hood 75W Amplifier.

ORDER STYLE

Order with confidence irrespective of any price changes as the 1977 price of this article is quoted with your order. RASO VAT rate remains unchanged. All components are brand new first grade full specification devices. All resistors (except where stated) are low noise carbon film types. All printed circuit boards are fibre-glass, drilled, roller tinned and supplied with circuit diagrams and construction layouts.

Value Added Tax not included in prices.

ORDER EXPORTS

Non-VAT charged. Postage charged at actual cost plus 50p. Please note that purchase by irrevocable letter of credit is £100 minimum. Bank Draft, Postal Order, International Money Order or Sterling SECURICOR DELIVERY for this optional service (U.K. Mainland only) add £2.50 (VAT inclusive) per kit.

U.K. ORDERS Subject to 12½% surcharge for VAT. Carrier free. MAIL ORDER ONLY.
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T20 + 20 and our new T30 + 30 20W, 30W AMPLIFIERS

Designated by Danish engineers and described in Practical Wireless the Texan was an immediate success. Now developed further in our laboratories to include a Toroidal transformation and additional circuitry the 30+30 delivers 20W per channel on true 8 ohm exceptionally low output power of this new model is 30W per channel.

SPECIAL PRICES FOR COMPLETE KITS!

T20 + 20 KIT PRICE only £34.20
T30 + 30 KIT PRICE only £39.50

With 100s of kits now available no longer is there any problem of spare parts. No problems with hardware either. Our new unit the SQM130 simply plugs into the tape monitor socket of your existing amplifier and drives two additional speakers at 30W per channel. A full complement of controls including volume, balance, tone, and tuning facilities as well as comprehensive switching facilities enabling the unit to be used for either from or rear channels, bypassing the decoder for stereo only or exchanging left and right channels. The SQM module is based upon a single integrated circuit and was designed by CBS whilst the power and tape control sections are identical to those used in our T30 + 30 amplifier which the SQM130 matches perfectly. Kit price includes CBS licence fee.

CONVERT NOW TO QUADRAPHONICS!

With 100s of kits now available no longer is there any problem of spare parts. No problems with hardware either. Our new unit the SQM130 simply plugs into the tape monitor socket of your existing amplifier and drives two additional speakers at 30W per channel. A full complement of controls including volume, balance, tone, and tuning facilities as well as comprehensive switching facilities enabling the unit to be used for either from or rear channels, bypassing the decoder for stereo only or exchanging left and right channels. The SQM module is based upon a single integrated circuit and was designed by CBS whilst the power and tape control sections are identical to those used in our T30 + 30 amplifier which the SQM130 matches perfectly. Kit price includes CBS licence fee.

EXPT NO PROBLEM

Our Export Department will be pleased to advise on postal orders to any country in the world. Some of the countries to which we sent kits in 1978 are shown surrounding this advertisement.

Tunisia Germany Nauru Hong Kong Australia Eire Gambia Denmark France Muscat & Oman
Z & I AERO SERVICES LTD.
Head Office: 44A WESTBOURNE GROVE, LONDON W2 5SF
Tel.: 727 5641  Telex: 261306

MULTIMETER F4313 (Made in USSR)

SENSITIVITY
1200Ω DC range 10,000 Ω/V
1200 AC range 6,000 Ω/V
600Ω AC range 15,000 Ω/V
300V AC range 15,000 Ω/V
Other AC ranges 20,000 Ω/V

AC/DC current ranges
60-120Ω DC range 3-12-300mA-1-2-6A
120Ω DC range 6-20mA-200mA

Resistance ranges: 300Ω-10-100-1000Ω

Accuracy: 1.5% DC, 2.5% AC (of full scale deflection)

Mirror scale and knife edge pointer. Test suspension of movement. Transistor amplifier is used for all AC ranges thus achieving a common linear scale for both AC and DC ranges.

Meter is protected by a transistored cut-out relay circuit. Range selection is achieved by clearly marked piano keys. Power source: 5 1.5V dry cells.

Dimensions: 95 x 225 x 120mm.

PRICE £39.50 plus VAT. Shipping and postage 1.1%.

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1976/1977
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The full listing can be seen in Wireless World, July 1977. This listing must be carried with the rate of V.A.T. otherwise 20%. Please order O.A.T. for more stock & catalogue.

ALL PRICES EXCLUDE V.A.T.
**RETURN OF POST MAIL ORDER SERVICE**

<table>
<thead>
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<th>Price</th>
<th>Description</th>
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</table>
| £1.195 | Manual: A high quality unit backed by BSR for 12 months guarantee. A.C. 200-250V, 50/60Hz. | **BERK MAJORS 12" £14.95**
| £3.95 | The best quality available, 10 watts, 8 ohm. **BECMAJOR 12" £14.95** |
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| **£4.50** | Portable Torch and Speaker Cabinet **£4.50** |
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| **£3.25** | VOLUME CONTROLS **£3.25** |
| **£2.95** | R.C.S. M.O.S. 10 watt AMPLIFIER KIT **£2.95** |
| **£5.95** | DOUSCH SHELVES **£5.95** |
| **£16.00** | KUBA-KOPENHAGEN STEREO **£16.00** |
| **£33.50** | E.M.I. 13" x 8in. **£33.50** |
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| **£6.50** | TUNER-AMPLIFIER CHASSIS **£6.50** |
| **£8.95** | TWO STEREO CHANNEL **£8.95** |
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Ten balanced inputs, four output groups, 4 limiters, bass, mid and treble EQ, modular construction, headphone monitoring. Extremely high quality construction only matched by mixers costing around £1,000.

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20-4 £1190
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IMMEDIATE DELIVERY
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PRICES EXCLUSIVE OF V.A.T.

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The essential guide to anyone associated with broadcasting or television... national or international, professional or amateur DX-er.

Copies at £5 each can be obtained from Argus Books Limited, Station Road, Kings Langley, Herts.
## VALVES

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## UHF POWER GENERATORS

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## TRANSISTORS 12½% Please add VAT 12½% for valves, etc.

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**Please note that all the above information is subject to change without notice.**

**WIRELESS WORLD, JULY 1977**

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NRDC-AMBISONIC 45J SURROUND SOUND DECODER

The first ever kit specially produced by Integrex for this British NRDC backed surround sound system which is the result of 7 years research by the Ambisonic team. W.W. July, Aug. and Sept. '77.
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SOLID MAHOGANY CABINET

A high-quality push-button FM Varicap Stereo Tuner combined with a 24W r.m.s. per channel Stereo Amplifier.

Brief Spec. Amplifier: Low field Toroidal transformer, Mag. input, Tape In/Out facility (for noise reduction unit, etc.). THD less than 0.1% at 20W into 8 ohms. Power on/off FET transient protection. All sockets, fuses, etc., are PC mounted for ease of assembly. Tuner section uses 3302 FET module requiring no RF alignment, ceramic IF, INTERSTATION MUTE, and phase-locked IC stereo decoder. LED tuning and stereo indicators. Tuning range 88—104MHz. 30dB mono S/N @ 1.2 µV. THD 0.3%. Pre-decoder 'birdy' filter.

PRICE: £58.95+VAT

NELSON-JONES STEREO FM TUNER KIT

A very high performance tuner with dual gate MOSFET RF and Mixer front end, triple gang varicap tuning, and dual ceramic filter/dual IC IF amp.

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IC stabilized PSU and LED tuning indicators. Push-button tuning and AFC unit. Choice of either mono or stereo with a choice of stereo decoders.

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With ICPL Decoder £36.67+VAT
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1/4" dia. copper wire, 1200 turns, 30w transformer, £3.15.

Relay, 4 amp, 12 volt, 1000watts, £3.60.

Brushless Generator, 2000v, 8amp, 1200watts, £4.50.

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Black with white digits, new equipment £1.45.

Engine, 2000v, 10amp, 50watts, £6.00.

DC Motor, 100watts, £6.00.

Hole Saw, 1" dia., 300 rpm, £4.25.

Fluorescent Choke, square flush panel mounting, face 4'6" x 1'/2".

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**Oscilloscope**: Type 546 50KHz, 547 100KHz, 548 200KHz, 549 500KHz, 550 1MHz, 551 2MHz, 552 5MHz, 553 10MHz, 554 20MHz, 555 50MHz, 556 100MHz, 557 200MHz, 558 500MHz, 559 1GHz, 560 2GHz, 561 5GHz, 562 10GHz, 563 20GHz, 564 50GHz, 565 100GHz, 566 200GHz, 567 500GHz, 568 1THz, 569 2THz.

**Oscilloscope**: Type 546 50KHz, 547 100KHz, 548 200KHz, 549 500KHz, 550 1MHz, 551 2MHz, 552 5MHz, 553 10MHz, 554 20MHz, 555 50MHz, 556 100MHz, 557 200MHz, 558 500MHz, 559 1GHz, 560 2GHz, 561 5GHz, 562 10GHz, 563 20GHz, 564 50GHz, 565 100GHz, 566 200GHz, 567 500GHz, 568 1THz, 569 2THz.

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TELEPHONE TEST EQUIPMENT

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<thead>
<tr>
<th>Telephone Test Equipment</th>
<th>Price</th>
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<tr>
<td>Siemens 312 13.5 kHz</td>
<td>£558</td>
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<tr>
<td>Level Transmitter 1 33.31 kHz 1kHz</td>
<td>£565</td>
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<tr>
<td>Level Transmitter 1 26.1 kHz 1kHz</td>
<td>£160</td>
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<tr>
<td>Level Dec. 315/1 1kHz</td>
<td>£386</td>
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OSCILLOSCOPE TEST EQUIPMENT

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<thead>
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<th>Oscilloscope Test Equipment</th>
<th>Price</th>
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<tr>
<td>Tektronix 4059 4 30 kHz 500 MHz</td>
<td>£522</td>
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<tr>
<td>Tektronix 5A 10 MHz</td>
<td>£250.00</td>
</tr>
</tbody>
</table>

DIGITAL VOLTMETERS AND MULTIMETERS

<table>
<thead>
<tr>
<th>Digital Voltmeters and Multimeters</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>HP 34401A 3-20 MHz 100 MHz 20 MHz</td>
<td>£525</td>
</tr>
<tr>
<td>HP 34402A 3-20 MHz 100 MHz 20 MHz</td>
<td>£335</td>
</tr>
<tr>
<td>HP 34403A 3-20 MHz 100 MHz 20 MHz</td>
<td>£235</td>
</tr>
<tr>
<td>HP 34404A 3-20 MHz 100 MHz 20 MHz</td>
<td>£120</td>
</tr>
</tbody>
</table>

MEMBER

We also buy

We are interested in providing quotations for the purchase of good quality used and unused Test Equipment.
Goldring CK2
BELT DRIVE TURNTABLE CONSTRUCTION KIT
Complete with SAU2 arm, template and easy-to-follow instructions. Ready for operation in a short time.

A FEW OF THE MANY BIG FEATURES
- Wow Flutter 0.15% peak
- Rumble -0dB weighted
- Removable headshell
- Viscose damped cueing device
- Easily adjusted tracking force and bias setting
- T-two speed, 16 pole synchronous motor
- Dimensions 37.8 x 28.3cms

Plinth, cover and cartridge available, P.O.A.
Call in or send a cheque, P.O. M.O. or Access, Barclaycard, American Express or Diners Club number.

Lion House
227 Tottenham Court Road, London W.1. Tel 01-580 7383

The Media Department of the British Council has two vacancies for Television Engineers to operate and maintain their studios, situated in Tavistock Square, London.

The studios are used to train personnel from countries overseas in broadcasting and closed circuit television techniques in support of developmental broadcasting and education. As well as for the regular training courses, the studios are used to produce videotapes, films and other audiovisual programmes.

Some of the training activity takes place in institutions situated overseas and there may be opportunities for the successful applicants to work and travel abroad.

An essential qualification is the City and Guilds Telecommunications Certificate or HNC or equivalent or broadcast engineering training. Candidates should also have practical experience in studio operations including vision control, lighting, sound and videotape. One of the posts includes responsibility for the supervision of a small team of operational and maintenance engineers; for this post experience of managing staff would be an advantage.

The salary scales, including London Weighting and pay supplements, range from around £4760 to around £5880. There is a non-contributory pension scheme.

For further details and an application form to be returned by 4 July telephone 01-499 8011 extension 3041 or write to Staff Recruitment Department, The British Council, 65 Davies Street, London W1Y 2AA, quoting reference G/5.
As these circuits are capable of such an excellent performance we feel that it is not sensible to sacrifice this potential by designing a kit down to a price. We therefore spent a little more on professional hardware allowing us to design a very advanced modular system. This enables a more satisfactory electrical layout to be achieved, particularly around the very critical input areas of the relay preamps. These are totally stable with this layout and require no extra stabilising components. Many other advantages also come from this system which has separate record and replay amps for each channel playing in to a master board with gold-plated sockets. The obvious is the reduction of cross-talk and interaction which could cause trouble on a single board base. With our modular system the layout is compact and there is no component crowding. Testing is very easy with separate identical modules and building with the aid of our component-by-component instructions is child's play, but the finished result is a unit designed not to normel domestic standards but to best professional practice.

All printed circuits are of glass-epoxy material, fully shielded with a tin-coated finish for easy and reliable soldering. Component locations are printed on the reverse side of the board and are arranged so that all identification numbers are still visible after assembly.

71a Complete set of parts for Master Board: includes bias oscillator, relay, controls, etc. £9.83 = £12.23 VAT
72a Parts for Motor Speed and Sensor Control for Lenco C.R.V. deck. This is the proper board layout as given in the articles. £3.52 + 44p VAT
73a Complete set of parts for stereo Record Amps and VU meter drive £8.12 + £0.22 VAT
74a Complete set of parts for stereo Record Amps £6.74 + 86p VAT

75a Complete set of parts for Stabilised Power Supply to circuit given in Article. This uses a special low-hum field transformer with better characteristics than the commonly used type. £7.85 + £1.10 VAT
700M2 Individual High Quality VU Meters with excellent ballistics £8.46 + £0.66 VAT P.P.
700C2/2 High Quality Custom built rear Case Complete with Brushed aluminium front plate, mains switch, record microphones, tuned record level knob, plastic cabinet feet, all bolts, nuts and mounting hardware. All necessary holes are punched and all surfaces are electrolytised. Complete step-by-step assembly instructions are included. The cover is finished in an attractive black crankle surface. £16.50 + 2.02 VAT.

LENCO C.R.V. CASSETTE MECHANISM
273a £10.00 VAT.

MATRIX 'H' QUADRAPHONIC DECODER
Printed circuit boards and kits to our usual quality are being prepared for this design. Send for list.£30.00 a kit.

WE also supply complete kits to make a fully integrated 50 watt stereo amplifier using the Bailey Power Amplifier circuit and the Bailey Burmums Pre-amplifier with the Quilter Tone control modification.

Printed circuits and components are available for the Stuart tape circuits. These articles described a high quality tape link circuit for use with a reel-to-reel deck. Regrets of the three articles are available from us price 45p. Post Free (No VAT).

ALL PARTS ARE POST FREE

Please send 9 X 4 SAE for lists giving full details and Price breakdowns.
An influential role £7265-£8435

These senior positions within the Directorate of Radio Technology, London, present Electrical Engineers with an outstanding opportunity to help shape future usage and considerable scope for exercising their individual initiative.

The Directorate provides the technical expertise and engineering support necessary in forming and implementing management policy. It is concerned with all aspects of spectrum engineering—the forward planning, management and regulation of civil frequency bands; radio propagation over the whole frequency spectrum; specifications and equipment type approval for fixed and mobile services, including microwave links; the application of computer techniques to frequency management problems, the nationwide radio interference service; the provision of technical advice on radio services, licensing; and the operation of an international radio monitoring service. It is also very much involved in the technical preparations for the 1979 World Administrative Radio Conference.

The successful candidates will lead specialised teams responsible for key areas within the Directorate’s activities. The work should appeal to those engineers who enjoy applying imagination and new ideas to problem solving.

For further information about the work, telephone Mr. R. A. Bedford on 01-275 3381.

Candidates must have a degree or equivalent qualification in electrical engineering and should be Chartered Engineers.

In-depth knowledge and experience of spectrum engineering is essential together with a sound appreciation of allied disciplines. Candidates must also have managerial ability and be able to deploy and stimulate staff of different skills. Working knowledge of French an advantage.

Starting salary within the quoted range. Promotion prospects to £10,000 and above. Non-contributory pension scheme.

For an application form (to be returned by 8 July, 1977) write to Civil Service Commission, Alencon Link, Basingstoke, Hants RG21 1JB, or telephone Basingstoke (0256) 68551 (answering service operates outside office hours). Please quote T/9536/2.

AVIONIC TECHNICIANS

required

Interesting and varied work on Navigation and Communication Equipment including VHF, VOR, ADF, HF, RADAR, TRANSPONDER / DME & CABIN ADDRESS SYSTEMS.

* Salary from £3,750 to £4,100 according to experience, reasonable overtime opportunities could raise this to £5,000 if desired.
* 5-day week
* 4 weeks’ holiday per annum plus statutory holidays

Contact: ROBIN SHOPLAND
AIR TRANSPORT (CHARTER) C.I. LIMITED
7 WILLOW ROAD, COLNBOURNE, SLOUGH, BERKS.
Telephone Colnbrook 2654

SUNNY SOUTH COAST

Expansion on the South Coast in the Electronics Industry now demands urgently the following personnel: Electronics Engineers (R&D), Design Engineers, Software Programmers, Systems Engineers, Development Engineers, Sales Engineers, Test Engineers, QA Engineers, Test Engineers, Production Engineers, design Draughtsmen, In-pectors, Buyers.

All these positions offer excellent salaries and prospects and in most cases relocation expenses flying or driving. C.B.S. Appointments. 224 Old Christchurch Road, Bournemouth, Dorset BH2 0HH (0202) 292155 or Wimbournes 4991 evenings.
ELECTRONIC DESIGN/DEVELOPMENT ENGINEERS
FERRANTI OFFERS YOU FREEDOM

..... freedom to create. Over the years leading design and development engineers have been attracted to Ferranti by our reputation for truly innovative engineering and together they have formed specialised teams involved on a variety of sophisticated projects related to the Tornado, Sea Harrier, Jaguar, Nimrod 2 and other front line aircraft.

We now require additional engineers to join these teams engaged on the creative work of designing and developing airborne radar, laser and inertial navigation systems and their associated test equipment.

Engineers are required in the following technical fields:-
Digital and analogue electronic circuitry design.
Design and application of small digital computers.
Microwave and laser techniques.
Advanced instrument design including gyroscopes of inertial quality.
Design of small mechanical structures and analysis of stress.

In addition to the above we have vacancies for production engineers with either electrical or mechanical backgrounds in these fields.

Applicants should have some design / development experience to offer in avionics and a desire to expand their experience to project leader level.

Edinburgh, with its outstanding facilities for education, housing, sport and entertainment, is one of the ideal cities in Europe in which to live, work and bring up a family. And to make moving here easier, we pay realistic relocation expenses. Salaries are negotiable and the Company operates a contributory pension and life assurance scheme.

Apply in writing, with full details of experience and qualifications to
Staff Appointments Officer,
Ferranti Limited,
Ferry Road,
EDINBURGH, EH5 2XS.
Please quote Ref. WW / 5
Electronics Engineer today?
You could be the Computer Engineer of tomorrow!

ICL, Europe's leading computer manufacturer, supplies systems to governments, universities, research, industry and commerce. ICL is renowned for its efficient customer service, and each of our customers relies on a team of Systems Engineers - which is where you come in.

We're building up our intake of Electronics Engineers who will undergo a thorough initial training course over 18 weeks at our Training Centre in Letchworth, Hertfordshire - the largest of its kind in Europe, with accommodation provided. You will then work at one of three locations which you choose at interview, from the large number we have throughout the country. Within 18 months you will be a fully trained Systems Engineer with a career rich in opportunity.

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You listen to Radio? You watch Television? You’re a qualified electronic engineer and yet you’ve never considered working in broadcasting?

Then perhaps you need to know a little more about some of the opportunities available with the BBC.

**Studio Capital Projects**

Engineering staff are based in central London, but will travel to various studio centres to assist in the design, installation and commissioning of radio and television studio equipment.

**Transmitter Capital Projects**

Again based in central London, engineers are required to travel to studios all over the U.K. to assist with the design and commissioning of radio and television transmitters and their associated aerial systems.

Candidates for both these departments should either possess a British university or polytechnic degree in electronic engineering or physics.

**Television**

Working in the Television Service, based in West London, engineers are involved in the maintenance and operation of the equipment used in the origination and distribution of television programmes.

**Transmitters**

Engineers are allocated to the major stations in various parts of the country and are responsible for both the maintenance and operation of radio and television transmitter plant. For these positions a current driving licence would be an advantage.

**BBC Receiving Station**

This station, based at Caversham, Berkshire, requires engineers to operate and maintain the elaborate receiving terminal equipment to enable foreign broadcasts to be monitored.

For these three departments candidates should possess either a City and Guilds full Technological Certificate in Telecommunications (course No. 271) or an HNC in Electronic Engineering. Shift working will normally be involved, for which generous extra payments are made.

Candidates for all positions must have normal colour vision and hearing.

For further information and an application form, write stating which type of engineering you are interested in to the Engineering Recruitment Officer, Broadcasting House, London W1A 1AA, quoting reference No. 77.E.4034/WW and enclosing a self addressed foolscap envelope.

Closing date for completed application forms is 14 days after publication.
Radio Officers—now you can enjoy the comforts of home.

Working for the Post Office Maritime Services really makes sense. You still do the work that interests you, but with all the advantages of a shore-based job: more time to enjoy home life, job security and good money. To qualify, you need a United Kingdom Maritime Radiocommunication Operator's General Certificate or First Class Certificate of competence in Radiotelegraphy, or an equivalent certificate issued by a Commonwealth Administration or the Irish Republic.

Starting salaries, at 25 or over, are £2905 rising to £3704 after three years service. Between 19 and 24, the starting salary varies from £2234 to £2627 according to age. In addition, a supplement of £312 p.a. is payable. You'll also receive an allowance for shift duties which at the maximum of the scale averages £900 a year and there are opportunities to earn overtime. There's a good pension scheme, sick pay benefits and prospects of promotion to senior management.

Right now we have a few vacancies at some of our coastal radio stations, so if you're 19 or over, preferably with sea-going experience, write to: ETE Maritime Radio Services Division (L690), ET17.112, Room 643, Union House, St. Martins-le-Grand, London EC1A 1AR.

---

**RADIO TECHNICIANS**

Government Communications Headquarters has vacancies for Radio Technicians. Applicants should be 19 or over.

**Standards** required call for a sound knowledge of the principles of electricity and radio together with 2 years experience of using and maintaining radio and electronic test gear.

**Duties** cover highly skilled Telecommunications/electronic work, including the construction, installation, maintenance and testing of radio and radar telecommunications equipment and advanced computer and analytic machinery.

**Qualifications**: Candidates must hold either the City and Guilds Telecommunications Part I (Intermediate) Certificate or equivalent HM Forces qualification.

**Salary** scale from £2,230 at 19 to £2,905 at 25 (highest pay on entry), rising to £3,385 with opportunity for advancement to higher grades up to £3,780 with a few posts carrying still higher salaries. Pay supplement of £313.20 per annum.

**Annual Leave** allowance is 4 weeks rising to 6 weeks after 27 years' service.

**Opportunities** for service overseas. Candidates must be UK residents.

Further particulars and Application forms available from:

Recruitment Officer
Government Communications Headquarters
Oakley, Priors Road
CHELTENHAM, Glos GLS2 5AJ
Tel. Cheltenham 21491 Ext. 2270
(STD 0242-21401)

---

**ILEA Learning Materials Service**

**Television Centre, Thackeray Road, SW8**

**Maintenance Engineer**

The Television Centre of the ILEA Learning Materials Service, situated at Battersea, has a vacancy for a maintenance engineer with specialist knowledge of professional studio and film sound equipment. The Centre, which produces programmes for over one thousand educational establishments, is provided with television and film production facilities at broadcast level, which are shortly to be converted to colour.

The successful candidate will join the maintenance section (four in number) and, with other members, will be responsible for maintaining a very wide range of vision and sound equipment which includes helical scan VTR's and cassette machines. He or she will be expected to be the department's expert in sound with particular knowledge of professional mixing desks, tape recorders and 16mm magnetic film recorders and reproducers (some involving digital techniques) and must have a number of years experience in this work. An HNC, the final City and Guilds' certificate or a similar qualification in relevant subjects is desirable.

Salary within the scale £4,864-£5,191 (Studio Technician 3).

Application forms, returnable within 14 days of the publication of this advertisement, from the Education Officer, Estab 2A/2, Room 4A, Addington St, Anexae, County Hall, London SE1 7UY. Tel: 01-633 7456.
Quick Quiz

Just a tick, that's all it will take you.

1. Can you fault find Electronic Circuits?
   - Yes
   - No
2. Do you know how to use an Oscilloscope?
   - Yes
   - No
3. Are you able to read circuit diagrams?
   - Yes
   - No
4. Can you use a Spectrum Analyser?
   - Yes
   - No
5. Do you understand the meaning of GHz?
   - Yes
   - No
6. Does V.S.W.R. mean anything to you?
   - Yes
   - No
7. Do you know how many “ohms” in a village?
   - Yes
   - No

If you score five or more “Yes” answers, then you could qualify for a really interesting career as a Test Technician with Marconi-Elliott Avionic Systems.

In our Mobile Radar Division at Borehamwood in Hertfordshire we're looking for men and women with a good basic electronics background to join teams working on the development, test and manufacture of a wide range of radar equipment and electronic surveillance and alarm systems.

It's challenging work and our Laboratories employ the most advanced techniques. Your experience, plus some training from us, will enable you to enjoy a satisfying future with a top company in the field of electronics development.

If you would like more details, get in touch now with G. Cock at Marconi-Elliott Avionic Systems Limited, Elstree Way, Borehamwood, Herts. Tel: 01-953 2030, Ext.3195.
COMMUNICATIONS ENGINEER
Newcastle upon Tyne  up to £4131

The Engineering Research Station at Killingworth is looking for a Communications Engineer to be involved in developing techniques which will increase the capacity of the Corporation's mobile radio channels. Work may be broadly split into two areas:

(i) investigation of the performance and implementation restrictions of wide area-coverage schemes.
(ii) investigations leading to more effective use of spectrum including problems associated with the transmission of digital information to mobile receivers.

A considerable involvement in discussions with user departments will be needed to ensure feasible integration of new techniques with existing systems.

Candidates should have a degree in Electronics, preferably with a specialisation towards communications.

Starting salary will be within an incremental scale rising from £2361 to £3819 plus a flat rate supplement of £312 p.a., with initial placing according to age, qualifications and experience.

Application forms may be obtained from the Manager/Management Services, British Gas Engineering Research Station Killingworth, Newcastle-upon-Tyne NE99 1LH quoting reference RD/539656/ERS (656) WW

BRITISH GAS

TELEVISION ENGINEERS
EXPORT OPERATIONS

Rediffusion Consumer Electronics is expanding its engineering team to give greater technical support to its customers with particular emphasis on export markets.

If you are a qualified television engineer with current experience in at least some of the following disciplines we should like to hear from you:

- Design and development of colour TV receivers
- Safety engineering, radiation measurements and test house submissions
- Quality Assurance in modern factory environments
- Customer service with particular emphasis on export markets
- Assessment of audio products from world-wide sources

The team is based at our engineering centre at Chessington, Surrey, but occasional visits to our factories in the North East of England and to our customers, home and abroad, will be required.

Salaries are attractive and assistance with relocation expenses will be offered if appropriate. If you feel you can make a real contribution towards the further success of our operation please write to

Mr. H. Brearley
Head of Technical Services
REDIFFUSION CONSUMER ELECTRONICS LTD.
Fullers Way South
Chessington
Surrey, KT9 1HJ
or phone 01-397 5411

TECHNICAL ASSISTANTS

Communications Department

Vacancies will exist for Technical Assistants in the Summer 1977 to work in the Communications Departments of the BBC based in Central London.

Technical Assistants will work under supervision on the maintenance and in some cases the operation of electronic equipment used in the distribution of radio and television programmes.

Duties

Technical Assistants will be concerned with the switching and routing of both television and radio programmes and in the provision and maintenance of all communication systems.

Training

Technical Assistants receive full-time training, which if successful should enable them to qualify internally as BBC Engineers in something over two years.

Qualifications

Applicants, who must be between the ages of 18 and 26 and have normal colour vision and hearing, should have had a good general education and be able to offer G.C.E. 'O' levels in English, Maths and Physics, or the equivalent, and have read up to 'A' level in Maths and Physics. Alternatively an ONC or Part I of the City & Guilds Telecommunications Technicians Course (No. 271) would be acceptable. In addition it is essential that they can demonstrate the ability to apply their knowledge of electricity and magnetism to related practical applications in the fields of communications, radio and television.

Salary

Depending upon experience the starting salary on appointment will be in the range £2514 to £2736 p.a. Additional payments will be made for those Technical Assistants who are required to work shifts or irregular hours. In addition a monthly pay supplement depending on total earnings of between £10.86 and £37.58 is payable under the current Incomes Policy.

For further details and application forms please write to The Engineering Recruitment Officer, BBC, Broadcasting House, London W1A 1AA quoting reference number 77.E.N(4) 4036-111 and enclosing an addressed envelope at least 9 ½ " x 4". Closing date for completed application forms is 14 days after publication.

GRAMPIAN TELEVISION LIMITED

ENGINEERS/TECHNICIANS

The Independent Television Company for North and East Scotland seeks electronic engineers or technicians for duties at its Studio Centre in Aberdeen.

The successful candidates will be employed in the operation and maintenance of modern electronic broadcast equipment.

Experience in this field is desirable but candidates without this experience, having a sound technical training, will be considered.

Salary is in the range £2689 to £4887 dependent on experience, with the prospects of later promotion through competitive interview to more senior posts.

Applications, in writing, to:

Mrs. E. A. Gray
Personnel Officer
Grampain Television Limited
Queen's Cross
Aberdeen AB9 2XJ

GRAMPIAN

SERVING THE OIL COUNTRY
SALES ENGINEERS

If you are looking for a stimulating and demanding job with the prospect of regular overseas travel on a world wide basis, why not join Pye TVT, one of the world's leaders in the design and manufacture of broadcasting equipment?

Continuing expansion has led to the need within the Technical Sales Department for Sales Engineers in the following fields:

1. Video Tape Recording.
2. Video Mixing, Switching and Assignment, including Station Automation and Computer Editing Systems.
3. Colour Cameras and Telecine.

In each case the successful candidate will be required to discuss advanced and sophisticated equipment at a high engineering level and to assist the regional and area managers in the marketing of these products.

A degree or equivalent qualification is desirable, but several years experience in the relevant field is more important.

These are very responsible posts and salaries will reflect the importance we attach to these appointments. Relocation expenses to this pleasant part of East Anglia will be given in approved cases.

Please write or telephone: Dave Barnicoat, Pye TVT Limited, PO Box 41, Coldhams Lane, Cambridge CB1 3JU.
Telephone: Cambridge 45115

Pye TVT Limited
The Broadcast Company of Philips

WIRELESS TECHNICIANS

There are vacancies at Home Office Wireless Depots throughout England and Wales for Wireless Technicians to assist with the installation and maintenance of VHF and UHF Systems etc.

Applicants must be able to drive a car and be in possession of a current United Kingdom driving Licence.

Salary
is £2010 (at 17), £2450 (at 21) and £2905 (at 25) rising to £3395, plus a 1976 pay supplement of £313.20 a year and a 1977 pay supplement of 5% of total earnings, subject to a minimum of £101.79 a year and a maximum of £208 80 a year.

A Secure Future
with a non-contributory pension scheme, good prospects of promotion and a generous leave allowance. There are opportunities for day-release to gain higher qualifications.

Qualifications
Candidates, male or female, must hold a City and Guilds Intermediate Telecommunications Certificate or equivalent qualification and have had good experience in Telecommunications.

Interested?
Then write or telephone for further details and an application form to: Mr C B Constable, Directorate of Telecommunications, Home Office, 60 Rochester Row, London SW1P 1JX. Telephone: 01-211 6420.

ELECTRONICS ENGINEERS

Are you a young flexible, electronics engineer preferably with HNC and some experience in design/development, able to analyse circuitry and modify existing equipment as well as creating original equipment?

Does the opportunity of joining a small Company in the forefront of scientific instrumentation where hard work and initiative are well rewarded appeal to you?

The job involves the on-site installation, commissioning and after-sales servicing of our range of complex instrumentation and requires a high degree of technical skill, initiative and responsibility.

In return we offer plenty of interest and travel (sometimes international) coupled with first-class working conditions. Salary is by negotiation and all travelling expenses are reimbursed.

Please apply in writing to:

R. F. LADBURY
BRUKER SPECTROSPIN LIMITED
UNIT 3, 209 TORRINGTON AVENUE
COVENTRY, CV4 9HN
Botswana
Telecomms
Engineer

For varied engineering and administrative duties to ensure the efficient functioning of telex, telephone, telegraph, and broadcast services for the Botswana Ministry of Posts and Telecommunications.

Candidates, under 55, must be MIEE or MIERE, preferably with a degree. 15 years' experience in telecoms operations is required, including responsibility for maintenance of telex, radio relay and multiplex systems, automatic exchanges, subscribers' equipment and distribution networks. A knowledge of electronic exchange working, exchange signalling systems, and broadcast transmitters is desirable.

Starting salary is equivalent to £6145-£7680 pa and includes a substantial tax-free allowance paid under Britain's overseas aid programme. Basic salary attracts a 25% tax-free gratuity.

Benefits include free passages, generous paid leave, children's holiday visit passages and education allowances, subsidised housing, appointment grant and interest-free car loan.

For full details and application form write quoting MX/1202/wd to

Crown Agents
The Crown Agents for Overseas Governments and Administrations, Appointments Division, 4 Millbank, London SW1P 3JD.

RADIO ENGINEER/TECHNICIAN FOR THE CARIBBEAN

Needed to work as technical adviser to the Radio Schools in Haiti; a non-governmental literacy development programme. Responsibility for the training of local counterparts.

A British Volunteer Programme Post; volunteer terms of service include free accommodation, living and other allowances, return air travel, language and orientation courses.

Write with details of curriculum vitae to

C U R O S
OVERSEAS
VOLUNTEERS

MTV
Best choice for used TV
• Largest stock and selection of colour and mono TV in Britain.
• 1976 exports exceeded 250,000 sets

Trade enquiries to
Midland TV Trade Services, Worcester Road, Kidderminster DY10 4NY, England. Tel: Kidderminster 88597 or 87398. Telex 337993.

MAGNETIC MICROPHONE SPEAKERS
41 inserts, ideal for all sound speaking and answering applications. Very rugged SC mic. 100 wattage. £6.95 each. "A" deep. 40p each 1 top P.A. £4 for £2.50 = 20 P.A. £2.50 for £1.50 P.A. £1.50 for £0.50 P.A. Bulk, various sizes and other items. Trade enquiries welcome.

R. S. SUPPLIES, 141 Shakespeare Street, Nr. LANCASHIRE, Kent CT1 7OZ.

ITN
SENIOR ENGINEER VTR OPERATIONS

Independent Television News Ltd. has a vacancy for a Senior Engineer in the ITN Facilities Centre in Central London, able to operate and maintain a tape transfer area of, at present, 18 Helical Scan Video recorders.

Candidates should have several years' experience with such equipment, and experience of broadcast 2nd quad recorders would be an advantage.

Salary £5712 per annum.

Contributory Pension Scheme and free Life Insurance.

Please telephone the Personnel Officer on 01-637 3144 for an application form, quoting reference 8312.

ASSISTANT ELECTRONICS ENGINEER

Required for a Research and Development company in West London.

A vacancy exists for a young engineer educated to HND standard to join a design and development section working on the control of vehicle engines. Experience in industry is desirable but not essential as the applicant would be at a junior level in the first instance.

Please apply, giving details of age, qualifications and experience to:

1 The Development Manager, SGRD Limited
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Even if we didn’t make it, we’ll make it work.

Bradley Services have the expertise and manufacturing capability necessary to make the most sophisticated electronic systems and electro-mechanical devices. However, equally important are the facilities we have for repair and calibration. We can handle virtually any type of instrument within the frequency range DC to 36 GHz — irrespective of manufacturer.

We also have a Post Design Services Group which provides every type of after-sales engineering support, from the provision of technical literature to the upgrading of complete systems. These facilities all approved to MOD Def. Stan. 05-21, have been developed over more than 20 years and during that time we’ve handled practically every type of instrument in use. So, if you’ve got a problem with some equipment, the chances are that, even if we didn’t make it, we can still make it work.

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Even if tin prices stabilised, a change from 60/40 alloy to Savbit Solder could save you £100/tonne, ensure a better job...

The reason is that Multicore Savbit not only solves the problem of fine copper wires and thin foils deteriorating during soldering, but also contains less tin than 60/40 alloy. We make both so we are just offering to alleviate your rising metals costs.

During normal soldering, a dissolving action causes the wire to weaken and embrittle—often to break during subsequent field use.

Savbit, however, is a rosin based, 5-core wire solder comparable in joint quality to standard high performance alloys, but capable of dramatically inhibiting the copper dissolving action.

As this diagram shows, compared with a 60/40 alloy, Savbit can reduce the dissolution of copper by as much as 100 times. Yet wetting rate, flow, conductivity and capillary force are almost identical—with creep strength and shear strength actually increased.

*(Indicative of product advantages only; not to scale)*

...and more

Some people think Savbit alloy is only usable with plain copper soldering iron bits, but this isn’t true.

As these photographs illustrate dramatically, Savbit also saves significantly on the cost of iron-plated soldering iron bits, which have a copper core. This is exposed through cracks in the plating.

Add this advantage to the increased reliability and joint quality Savbit offers, and you'll understand why more and more 60/40 users are making the change—and profiting. The Ministry of Defence have given a special new Approval No. DTD 900/4535A for Savbit alloy with ERSIN 362 flux to be used in lieu of Solders to B.S. 219 and B.S. 441.

ERSIN
Multicore

For full information on Savbit or any other Multicore products, please write on your company's letterhead direct to:

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Maylands Avenue, Hemel Hempstead, Herts. HP2 7EP
Telephone: Hemel Hempstead 3636 Telex: 82363.