Wind meter

'Just detectable' distortion

Morse decoding program
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Cutaway model of a capacitor measuring microphone from Briel & Kjaer (UK) Ltd. Symbolically introduces the article on 'just detectable' distortion in this issue.

IN OUR NEXT ISSUE
A range of counters for construction based on the versatile Intersil CM7516 IC. From a set of modules a variety of instruments can be assembled.

Magnetic recording progress. Tape recording has developed rapidly, urged on by the popularity of hi-fi reproduction. James Moir reviews advances in equipment and tape coatings.

Guide to a.s.w. devices for the professional applications engineer, covers electrical characteristics and applications of three a.s.w. types: bandpass filters, delay lines and oscillators.

Open channel frequencies
Commerical broadcasting
The speed of light

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### Latest Test Equipment

**February 1981**

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L.F. RANGES
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In the 1940s the construction of computer memory was difficult and expensive. So was the construction of a processor (then called a mill, or arithmetic unit). It was out of the question to cope with the technical problems of building a combined unit. The Von Neumann architecture was a creature of these historical engineering constraints. The result was a list processor, and all problems to be solved by digital electronics had to be converted into a list of sequential steps. The people who did the conversion were called 'programmers'.

It is historically unfortunate that this Von Neumann architecture proved to be so versatile that it remained fixed long enough (1944-1980) for a glamorous mythology, and also a client society, the programmers, to develop around it, innocent of technology and also rather lacking in knowledge of the nature of the problems to be solved. This architecture has now been carefully copied, without improvement, into today's microprocessor. The resulting situation, which we are embroiled with, is similar to the man at the information desk in a railway station. He knows nothing about the technology of trains or railway line networks, or that train times can be altered, neither does he know the reasons why you want to make your journey. All he can do is advise you on how to use the existing schedule, which is very awkward indeed.

The programmer class became powerful enough to insist that the computer remain unchanged, and there has been no change in computer architecture for 56 years. Similarly, the railway information man would prefer the time-table and network of lines to remain unchanged, but, unlike the programmer, he does not always have his way.

Programmers developed a glamorous view of themselves, and made heavy inroads into the media. From the beginning they were very well paid, to say the least. Borrowing from Marshall McLuhan's philosophy, they caused society to think that the essence of modern society was 'information processing', and even that the human brain was an 'information processor' following their own baroque, bureaucratic procedures. This left them free to remain ignorant on the one hand of the technological nature of their machines, and on the other hand to take little interest in the customer's real problem, for which he wanted a mechanised solution. In classic style, the programmer introduced an informational bureaucracy between machinery and problem to be solved, and insisted that any link between the two must be via the mandarin language which was devised in the 1950s to try to make the best use of the slow, awkward Von Neumann machine architecture of that time.

This incursion of an informational bureaucracy between social needs and technological solutions is now likely to be institutionalised by the setting up of a 'Minister of Information Technology' (December 1980 issue, News, p. 46). In fact, there is nothing technical about the information explosion that technically unformed programmers are busily creating around themselves and us.

Digital electronics is a very powerful branch of engineering with massive potential for social benefit, but it will be hampered in contributing to society's needs until the technically uneducated, bureaucratic varnish variously called 'information technology', 'computer science', 'information science' gets off its back and lets get on with the job.
Just detectable distortion levels

Attempts to arrive at a practical criterion for assessing audio equipment by James Moir, F.I.E.E. James Moir & Associates

Are distortion levels of 0.1% really detectable? Are all harmonic distortions of equivalent material being reproduced? Is an individual's ability to detect distortion levels of 0.1% really detectable? When programme music is being reproduced, is the amplifier having 0.005% or 0.001% distortion audibly 'cleaner' than one having a t.d. of 0.5%? This is the problem to which the present discussion is directed. It would be unrealistic to suggest that zero distortion should be the target. A more realistic approach would be to try and define the level of distortion that is 'just detectable' without using modern equipment and critical listeners.

The 'just detectable' level is a function of so many variables that a precise specification, a single figure such as 0.1% or 0.5%, is unlikely to emerge from the discussion. Even in the simplest situation where the test signals are single-frequency tones it is impossible to specify a single figure without setting wide limits. An experienced observer will detect the addition of a second or third harmonic when this is less than 0.1%. But, given the opportunity to make repeated comparisons of the distorted and undistorted tone, he will lower the detection level by a factor of at least 0.01% distortion beyond the 'just detectable'.

The 'just detectable' level of distortion in sinusoidal tones is merely of academic importance and will not be given further consideration. However, the same problem exists when attempting to detect the presence of distortion in a musical programme, if the test facilities allow a smooth variation of the distortion content the 'just detectable' distortion (JDD) level remains to decrease with increasing extent of distortion, 3% to 8% being average values, even for professional personnel, the reasonable assumption that low levels of harmonic distortion are detectable if 'clean' would seem to be in conflict to the usual information about the t.d. is desirable.

The adoption of t.d. as a practical measure of the 'just detectable' level for commercial purposes follows the international standardisation, though it is appreciated that is almost certainly the accompanying intermodulation components that are responsible for the 'detectability'.

In the majority of situations the total intermodulation distortion is directly proportional to the total harmonic distortion, the relative values depending only upon the ratio of the amplitudes of the two test signals.

However, the value of the manufacturers' t.d. data would be greatly increased if information on the levels of distortion that are just detectable or just acceptable were available in addition to the 0.1% really detectable when programme music is being reproduced or a normal 0.5% amplifier having 0.005% or 0.001% distortion informations on the complete programme material. A number of authors have attempted to provide full information on the test routines.

The specification of the 'just detectable distortion' in programme material is inherently more difficult, for the signal is continuously varying in amplitude and in consequence the instantaneous value of the distortion is also varying continuously. In Figs 1 and 2 the JDD level is taken as that point of the spectrum where the signal to noise ratio is reduced by a factor of 20 dB from the level at the low frequency end of the spectrum. The data quoted later suggests that the just detectable level of distortion is not a constant for a period of at least 10 seconds but varies through the frequency range, to a maximum in the region of the level when the peaks of the same amplitude, but of short duration, even though the total duration of the peaks is the same for both cases.

However, there are other factors that are of significance. It is well established that distortions of the simple amplitude distortion (Harmonic distortion) are less obvious when the distortion is present at a frequency range and level of the spectrum. The data quoted later suggests that the just detectable level of distortion is not a constant for a period of at least 10 seconds but varies through the frequency range, to a maximum in the region of the level when the peaks of the same amplitude, but of short duration, even though the total duration of the peaks is the same for both cases.

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15% to 25% if it is confined to the frequency band below 100Hz. Odd order harmonic distortions were found to be more subjectively annoying than the even order distortions. Some fifteen years later (1950) D.E.L. Shorter of the BBC Research Department compared the sound quality of a number of systems for which the measured harmonic spectra were known. Comparing amplifiers having different harmonic spectra he found that the just perceptible distortion was 0.4% in one instance and 2.6% in another, an illustration of the wide spread of distortion values to be expected in any quotation of a just detectable value. He obtained better agreement between subjective opinion and the objective measurements when he multiplied each harmonic amplitude by \(n^2\) before taking the r.m.s. sum. (\(n\) is the harmonic order.) The spread of just perceptible values was thus reduced to 0.8% to 1.3% but it should be remembered that weighting in this way prevents his values being directly compared with the unweighted values obtained by other researchers.

Wigan (1961) made a very comprehensive investigation of the problem and came to the conclusion that the subjectively judged unpleasantness is a function of the time-rate-of-change of the departure of the signal from normal. All his results are difficult to apply to a practical case where only the harmonic data are available. They do, however, confirm the earlier suggestions that there are likely to be wider limits on any suggested value for the JDD.

More recently Fryer made a very thorough investigation of the problem using a distortion producing technique that introduced only the first order intermodulation distortion components into a clean signal. Skilled male listeners could detect the presence of total distortion components of about 2% to 4% in piano music and 4% to 5% in other types of programmes. However his circuitry did not introduce the harmonic distortion that would inevitably accompany the intermodulation products if they were produced by curvature of the transfer characteristics of an amplifier or other circuit component. If the harmonic components had been included the r.m.s. sum would probably have been near the top end of the quoted JDD range of 4%, but, as with Shorter's weighted data, his JDD percentage cannot be directly compared with the data obtained by others.

Recently we took the opportunity of making a re-assessment using modern equipment. A 15W master tape recording of a concert orchestral programme was used as a source signal, the amplifier output being fed to a pair of headphones chosen for their good frequency response and particularly low distortion. We were specially interested in the audibility of cross-over distortion, a particularly annoying form of distortion. A simple addition to the bias circuit in a good amplifier allowed the bias on the output stages to be smoothly varied by a single knob control from the under-biased to the over-biased condition, thus varying the amount of cross-over distortion over a wide range.

The amplifier output signal was monitored by an oscilloscope to show up any amplitude limiting and to reproduce the calibration waveforms. Bias on the output stages was adjusted until distortion on the programme material when subjectively judged was just detectable, each sound spending as much time as he wished in finding the point at which the distortion was just 'detectable'. The bias control knob carried calibration markings and those were recorded for each headphone and averaged over about twenty determinations to obtain the quoted JDD value. Additional readings were taken at the bias setting level well below the 'just detectable' to confirm that the residual distortion 0.13% in the equipment was unlikely to affect the results obtained.

This is a sensitive technique for determining the 'just detectable distortion' for after a few comparisons the subject begins to recognize the particular form of distortion introduced into the music by the bias change. During subsequent comparisons the subject becomes increasingly sensitive to that particular distortion. After 10-15 minutes experience his sensitivities to the distortion is probably increased by a factor of at least ten times.

In the earlier discussion the actual distortion content in the reproduced music cannot be directly measured but it can be approximately indicated by the peak-to-peak amplitude of the programme material at which the distortion was just detectable was marked on the oscilloscope face and a sine wave value of the same peak-to-peak value substituted. This sine wave signal across the headphones was then analysed in the conventional manner using a Marantz Type TF2330 narrow band analyser, all components up to about the 20th being separately measured. Fig. 4 indicates the amplitude of all the harmonics that were present and also reproduces the waveform of the sine wave signal having the same peak-to-peak amplitude as the programme signal. If the r.m.s. value of the programme is multiplied by \(n\) this is approximately a factor of at least \(n^2\). If the waveform is of a conventional type it is 1.2%, or if waveforms are non-conventional multiplying each harmonic by \(n^2\) then it is 15%. It is an interesting observation that while distortion on the sine wave signal was 'just detectable' visually it was also 'just detectable' audibly.

On examination of the data from all the investigations and rather naturally given rather greater weight to our own results over any view of the relatively recent date of the investigation, it would appear that the 'just detectable' distortion is about 1% of the lower harmonics. Indeed in view of the critical nature of our test technique, smoothly adjustable distortion was introduced in waveforms using the same test passage, it would seem unlikely that even experienced observers listening to a normal programme presentation could detect the effect of adding 1% distortion to the signal. It would seem reasonable to suggest that Fryer's value of around 3% distortion represents the 'just detectable' level in practice with limits in the range between 1% and 5%. If it is intended to be ultra-critical out 'well below the detectable distortion' value of 0.13% could be accepted as the desirable target.

With these values in mind it is interesting to see how all the individual items of equipment in a system measure up to this standard. Amplifiers are not the only system component that have a performance that conforms to the 'just detectable' standard. Reasonably priced units can introduce distortions that are below 1% (4dB down) at half their rated output power. Amplifiers in the very top class, but still in domestic usage, have distortions in the 0.003% to 0.005% class (60-80dB down).

Wind speed and direction meter

Digital and analogue indication for racing yachts or met. stations

by N. Pollock

A wind speed and direction measuring instrument suitable for amateur construction is described. Although specifically designed for yachts masthead use it is also suitable for land-based meteorological applications. The novel masthead transducer unit avoids the use of expensive expensive measurement components and can be constructed relatively easily by anyone with access to a small workshop.

A cockpit display of masthead wind speed and direction has become an essential for offshore racing yachts and is very useful for fastening yachts. A number of commercial instruments are available, but they tend to be very expensive. The main requirements for such an instrument are as follows:

- the masthead unit must be small, light and weatherproof.
- the wires of wires coming down the mast must be reasonably small.
- both speed and direction systems should work over a speed range of about 1 knot to 60 knots. At lower speeds, boat motion makes the indications unreliable, while at higher speeds it is too evident what the wind is doing.
- the direction display should have a resolution of 1°, at least, which could be achieved with a potentiometer and starboard of head-to-wind. This is needed for fine tuning when beating to wind.
- there should be a continuous 360° analogue type display of direction which can be used as a glance in moments of stress, such as when gybing in a strong breeze.
- the system should operate from a 12V accumulator with a low current consumption.

To the best of the author's knowledge, no instrument suitable for amateur construction which meets all the above requirements has been described previously. A number of wind direction indicators using simple 3 or 4-bit optical encoders have appeared over the years, but they have inadequate resolution. A high-resolution direction indicator with a limited angular operating range, suitable for close hauled use, is described in Reference 1.

Operating principle

The most difficult problem in designing this type of instrument is the selection of the method of encoding the wind direction information. Commercial 360° rotation, low-friction potentiometers, selsyns, resolvers and non-contacting digitizers can all be eliminated due to cost and availability problems.

The encoding technique adopted is one originally described by Tysoe. The principle of operation will be described with reference to Fig. 2. A cup anemometer and a wind vane, shown in Fig. 1, are mounted on a pair of coaxial shafts, which carry a pair of opaque discs with a small clearance between them. A fixed annular disc surrounds the small-diameter direction disc. These three discs are shown separated in Fig. 2, for clarity. A light source is located below the disc assembly. The clock photometer, fitted above a hole in the fixed annulus, produces a pulse train as the disc rotates in the annulus of the anemometer disc.

Fig. 2. Operation of transducers. Annulus and upper disc are normally in same plane.

...continued on page 38
Mechanical design of masthead unit

This article is primarily concerned with the electronics of the system, but to assist potential constructors, some hints of the mechanical design will be included. A cross-section view of the prototype masthead unit is shown in Fig. 3 and photographs of the various components are reproduced in Figs. 4 and 5. The unit was constructed inside a piece of 50 x 1.6mm aluminium tube, the various discs being cut from glass-fibre printed-circuit board. The clock track has 36 holes 1.7mm diameter, equally spaced on a 40mm diameter circle, the clock photodetector window in the fixed annulus is 1.0mm diameter and all the other holes in the discs were about 1.7mm square. The light source consists of two tubular, linear-filament, automotive tail-light bulbs with the end contacts removed to fit them in the available space. Ball bearings are secured in the end fittings and the shafts fixed in the bearings with an adhesive such as "Loctite Bearing Adhesive". The spacing between the discs (about 0.4mm) was set using temporary spacers between them while the adhesive on the shafts cured. This procedure avoids the need to accurately machine bearing-locating shoulders. Adjacent faces of the discs were painted matt black, while the rear faces of the discs and the rest of the interior was painted white.

The wind vane can be constructed from a variety of materials; the major requirements being that it should be of light weight and accurately balanced about its axis of rotation. A strong, well-balanced cup anemometer is difficult to make, so a commercial unit, manufactured by VDO and obtainable from chandlers was adapted. This anemometer, which had a mean cup radius of about 44mm, was found to give a clock calibration factor of 22.5 hertz/knot. Since the system speed calibration is adjustable, any convenient commercial or home-made anemometer could be substituted.

Power supply

A 9V supply was selected for the instrument, since it can conveniently be derived from a 12 volt battery system. The circuit of a suitable regulator is shown in Figure 7.

Masthead circuit

To provide high-level, low-impedance signals to drive the long wires down the mast, the three photodetector outputs are amplified in the masthead transducer unit. The necessary circuitry conveniently fits on a circular printed-circuit board which mounts on the direction end fitting, as shown in Fig. 5. The circuit of the masthead system is shown in Fig. 8. The two 12V bulbs in series are operated so far below their rating that they should have a very long life. It is desirable that the clock and coincidence amplifiers just swing to full output when the anemometer disc is rotated slowly and the direction disc is in...
Wireless World February 1981

**WIRELESS WORLD FEBRUARY 1981**

**Adamic barrier**

For British amateurs (as for Marconi) the Adamic barrier is the single most important hurdle for radio signals. The ability to bridge the Adamic on earth is as valuable to an amateur as to the most important hurdle for radio signals. The ability to bridge the Adamic on earth is as valuable to an amateur as to the most important hurdle for radio signals. The ability to bridge the Adamic on earth is as valuable to an amateur as to the most important hurdle for radio signals. The ability to bridge the Adamic on earth is as valuable to an amateur as to the most important hurdle for radio signals. The ability to bridge the Adamic on earth is as valuable to an amateur as to the most important hurdle for radio signals. The ability to bridge the Adamic on earth is as valuable to an amateur as to the most important hurdle for radio signals. The ability to bridge the Adamic on earth is as valuable to an amateur as to the most important hurdle for radio signals. 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Satellite for business communications

Now in orbit is the first of a group of three communications satellites designed to provide voice, video, high-speed data and facsimile services for American business firms and industries. Launched in November 1980, the satellite is called SBS, which stands for the name of its owner, Satellite Business Systems, a private company jointly owned by IBM Corporation, Comsat General Corporation and Aerovox Life and Casualty. It is expected to begin commercial operations early this year.

The spin-stabilized satellite was built at Hughes Aircraft Company's space and communications group at El Segundo, California, and was launched by NASA on a Delta rocket into a geostationary orbit at 120° West longitude roughly 40,000 miles above the Earth. It is 74 feet in diameter and has 39 high in its " squared" position, but when, in space, its solar panels are fully extended and its communications aerial is raised it has an overall height of 215 feet. The solar panels take the form of two concentric cylinders, the outer of which extends nearly six feet downward in space. This capacity of expanding to space doubles the spacecraft's solar power generating capacity over many previous satellites. Expansion is necessary to meet the demand for the 121 MHz band. The solar panels take the form of two concentric cylinders, the outer of which extends nearly six feet downward in space. This capacity of expanding to space doubles the spacecraft's solar power generating capacity over many previous satellites. Expansion is necessary to meet the demand for the 121 MHz band.

Levy on blank video cassettes?

At the first meeting of the British Videogram Association's Council of Management, Donald MacLean of Thorne-Dani was elected Chairman and Maurice Obersch of CBS, Vice-chairman. Peter Scarpino will act as Secretary while the Association is becoming established.

Videogram manufacturers have evidently experienced roughly the same problems as those in the audio recording industry. The Association includes consideration of the "commercial piracy problem" and "an approach to Government for a levy on the sales of blank video cassettes.... with a view to combating the spread of pirating on domestic video recorders. When asked whether such a tax was, perhaps, a little unfair on people who intended to use the tapes for other purposes, Michael Collins of Polygram, who claims the working party on industrialization and copyright, expressed the view that "there's a case for saying "too bad." Alternatively, he suggested, such purchases could be exempted from tax if the buyer signed a form at the time of purchase to the effect that they had no intention of using the tape for piratical purposes. Such a provision, he pointed out, was common in libraries where copyright photocopying was permitted for the purpose of study.

The second satellite in the series is scheduled to launch on a Delta vehicle in April this year, and the third, Boeing's launch from the Space Shuttle in late 1982. By 1983 Satellite Business Systems also plans to establish an inter-city satellite telephone service connecting up to 1,000 metropolitan calling areas. For use with the satellite's 100 earth terminals are being built, also by Hughes. They will be installed on the roofs of customers' buildings or on adjacent ground. Delivery has already started and is expected to be completed in 1982.

Voice recognition for mariners

Because senior officers on ships don't usually take to the idea of pressing buttons on keyboards but are used to backing orders at subordinates, a seagoing version of Prestel video has been equipped with a voice recognition system instead of the usual keypad for interactive communication. The seagoing Prestel is called Sirrus and its purpose is to give ships' officers immediate access to information available in shore-based data services. Developed by a consortium of British Telecom, the Home Office, the Departments of Trade and Industry and Liverpool Polytechnic, the Sirrus system consists of a satellite telecommunications system to be fed into a computer terminal aboard the ship. The terminal consists of a display screen, a voice-band modem, a microphone and a button. The modem, which uses standard telephone channels, can copy text from the screen onto an exercise. On the ship's voiceband modem, the button is linked to a program designed to recognize 200 different voice commands. If the voice command is recognized, the button is pressed, and the computer terminal is fed the required information. A voice command is deemed to have been recognized if the 'Dover test' is passed. The computer will interpret the voice command as meaning that the user wishes to request information and will then search through its database for the relevant information. If the voice command is not recognized, the computer terminal will ask for more information until the command is recognized. The voice command is then passed to the database and the relevant information is displayed on the computer terminal.

The 'Dover test' consists of asking the user to press the button after each voice command. If the user presses the button after the voice command, the computer will assume that the user has recognized the command. If the user does not press the button, the computer will repeat the voice command. The 'Dover test' is named after the Dover Ferry, which is one of the most dangerous routes in the world for mariners. The test is based on the idea that the user will press the button if they recognize the voice command, and will not press the button if they do not recognize the voice command.

Data convention in Europe

In the past few months a European convention on the danger of data protection legislation in force in some countries has been signed up and has been approved by the committee of ministers of the Council of Europe. At the time of writing it is due to be formally signed by the Member States during the first half of April. The convention aims to avoid obstacles to the free passage of data between participating countries by encouraging them to treat each other's data protection. It specifically requires that each country must treat data protection legislation in force before it can ratify the convention. What form that legislation must take is not stated, but a set of principles to be followed has been provided. These include the right of single data subjects to files, rectification of mistakes and publication of the files.

The convention will come into force in 1980, but will not become legally effective until 1982. The convention is not intended to require that member states should adopt the same policies as the convention, but merely to encourage them to adopt similar policies. The convention has been welcomed by the European Commission and has been endorsed by a number of trade associations, including the European Telecommunications Standards Institute (ETSI), which represents the interests of the European community in the field of telecommunications. The convention has been welcomed by the European Community and has been endorsed by the European Union. The convention has been welcomed by the European Community and has been endorsed by the European Union. The convention has been welcomed by the European Community and has been endorsed by the European Union. The convention has been welcomed by the European Community and has been endorsed by the European Union.
**Computer network aids astronomers**

A network of computers has been set up at six centres in the UK to provide a cost-effective image processing and data reduction for British astronomers. Called the Science Research Council's (SRC) National Astronomy Image Processing System, the network is controlled from the Science Research Council's Information Processing Laboratory in Chilton, Didcot, Oxfordshire.

Astronomers in Britain now have access to a wide range of telescopes operating in different parts of the sky. The new system, which is expected to be in full working order by the end of the year, will enable astronomers to access data from the whole range of telescopes without having to wait for their actual visit. The system will be available to astronomers in the UK as well as those in other countries, such as the USA and Canada.

**Venus**

The Venus probe will be launched in 1984 to study the planet, which is the second closest to the Earth. The probe will be carried by the European Space Agency's (ESA) Venus Express spacecraft, which is scheduled to be launched in 1983.

**Jupiter probe**

The Galileo probe will transport an atmospheric entry probe (AEP) to Jupiter. The AEP will descend through the Jovian atmosphere and then be recovered by the main spacecraft. The AEP will be equipped with a suite of instruments to study the planet's atmosphere and surface.

**Radar simulators needed to help train operators**

The Radar simulator is needed to help train operators in the use of radar systems for communication purposes. The simulator will be used to train operators in the use of radar systems for communication purposes.

**Racal-Decca in Transit**

The cost of marine navigation by satellite is drastically reduced by the introduction of Racal-Decca's new Doppler satellite navigation system. The technique can now be used by small ships and vessels at sea, and will be particularly useful for those who are at sea for long periods.

**Intelsat V launched**

Intelsat V, the first in a new generation of geostationary communications satellites, was launched by NASA on December 6. It is placed in its permanent orbit, will take up a position 21° west over the equator.

**C.B Green Paper**

C.B Green Paper - CBA's response

In response to the invitation extended by the Home Office, the C.B. Green paper discusses the need for increased communication capacity and the role of the new satellite communications technology.

**More satellite communications for shipping**

A new global satellite communications system is being set up to meet the growing international telecommunications needs of the world's shipping and offshore industries during the 1990s. The system, which will be known as Iridium, will provide coverage of the Atlantic, Pacific and Indian oceans.

**News in brief**

The BBC has announced that it will open its new 22nd local radio station, which will be located in the city of Bristol. The station will be launched on March 1, bringing the total number of BBC local radio stations to 23.

**Computer network aids astronomers**

A network of computers has been set up at six centres in the UK to provide a cost-effective image processing and data reduction for British astronomers. The network is expected to be in full working order by the end of the year.

**Jupiter probe**

The Galileo probe will transport an atmospheric entry probe (AEP) to Jupiter. The AEP will descend through the Jovian atmosphere and then be recovered by the main spacecraft. The AEP will be equipped with a suite of instruments to study the planet's atmosphere and surface.

**Radar simulators needed to help train operators**

The Radar simulator is needed to help train operators in the use of radar systems for communication purposes. The simulator will be used to train operators in the use of radar systems for communication purposes.

**Racal-Decca in Transit**

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Morse decoding

A machine-code program for decoding Morse transmissions on a home computer

by N. Kyriazis

Decoding Morse by means of a computer is a fairly simple matter and many programs have already been produced for home computers such as the TRS 80. This article describes such a program, which was written in machine code for the Z80-based Wireless World scientific computer.

The main advantages offered by this program are that it can be used to decode either machine or manually produced Morse and that it provides a certain amount of immunity to the effects of noise and interference associated with short-wave reception, which would normally cause unacceptable decoding errors.

To minimize the effects of poor sending and to ensure reliable decoding of the typical short-wave reception, the following features have been included in the program:

- The ability to recognize and reject the effects of short-lived interference, such as that generated by ignition systems.
- The ability to recognize and reject short gaps in the transmission which may occur as a result of a type of interference described above. (These gaps may occur in more advanced receivers which have effective noise limiters.)
- Generous tolerance for the definition of dah, dots, characters, spaces, etc., to cater for the different "fists" of various CW operators.
- The provision of simple 'filtering' of the input from the receiver to reduce the effects of noise on weak signals during fades.

Program description

The program compares the time lengths of mark periods, i.e., periods of tone output from the receiver, and space periods, i.e., periods of no tone output, with a predetermined minimum time unit. The tone mentioned here is, of course, the audio frequency generated by the receiver in the CW mode, usually around 750-1000Hz. This audio output from the receiver must be converted to a logic-compatible signal, so that it can be fed into the computer via one of the five serial inputs. But I was used in this application, any other bit may be used if required by modifying the marking instruction following the IN instruction, details of which will be given later. The various elements of Morse characters are defined as follows:

A dash has a duration of one unit of time.
- A dot has a duration of three units of time.
- Elements of the same character are spaced one unit apart.
- Characters are spaced three units apart.
- Words are spaced at least five units apart.

To make the program tolerant to sending errors (bad "fists") and to minimize the effects of interference, as mentioned earlier, the time unit values for the elements of the Morse characters are modified as follows:

- A dash becomes a mark period which is between one half and two units long.
- A dot becomes a mark period which is two or more units long.
- An inter-element space is from one half to one and a half units long.
- The space between characters is from one half to four units long.
- Words have a space between them of four units or more.

A maximum limit of eight units length is placed upon the dash by the program as will be described later. Mark or space periods less than one half unit long are regarded as the result of interference and are dealt with accordingly by the program.

It may seem initially that there is too much tolerance in the definition of these basic Morse elements as, for example, a dot has a range of 6:1 in time duration. It has been found, however, that this method works well in practice and most hand-sent Morse is decoded accurately. The regarding by the program of mark units of less than one half unit as interference reduces to a large extent the tendency to display the letter E as a series of Es under interference conditions. Similarly, the minimum limit of one half unit for a space results in fewer errors during periods when the output signal from the receiver is weak and reaches the minimum limit required to operate the interface circuitry.

Before giving the detailed description of the program, here is a list of definitions of the terms used in the accompanying flowchart: MARK - a counter used for measuring the duration of "tone" output from the receiver which corresponds to the key-down time and is represented by the H register of the Z80. SPACE - a counter used for measuring the "no-tone" or key-up time which is represented by the L register of the Z80.

The program in machine code

<table>
<thead>
<tr>
<th>Operation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>OC00 11 00 B1 01 O1 0C 21 00 0D 95 0C 30 24 24 7C</td>
<td>Start</td>
</tr>
<tr>
<td>OC01 CB 3F CB 3F CB 3F BB 3B 07 9C 0D 35 1F 18 F9</td>
<td>MARK = 00</td>
</tr>
<tr>
<td>OC02 CD 95 GC 3B 09 2C 78 CB</td>
<td>MARK = 00</td>
</tr>
<tr>
<td>OC03 F4 7C 85 67 2E 00 18 0D 7C CB 3F BB 8B 11 26 00</td>
<td>SPACE</td>
</tr>
<tr>
<td>OC04 18 09 2C 7D CB 3F CB 3F BB 3B 18 1D 95 0D 35 09 F9</td>
<td>SPACE = 00</td>
</tr>
<tr>
<td>OC05 24 78 CB 3F BC 3B 29 2D CD</td>
<td>SPACE = 00</td>
</tr>
<tr>
<td>OC06 00 18 DF 7D FE 01 2B 08 CD</td>
<td>SPACE = 00</td>
</tr>
<tr>
<td>OC07 26 00 CD 95 0C 30 29 F4 2E 8B CB 3F</td>
<td>MARK = 00</td>
</tr>
<tr>
<td>OC08 78 CB 3F BB 3D 06 3D 07 7B</td>
<td>MARK = 00</td>
</tr>
<tr>
<td>OC09 00 18 DF 7D FE 01 2B 08 CD</td>
<td>SPACE</td>
</tr>
<tr>
<td>OC10 CC 3F BB 00 18 BB CS</td>
<td>MARK = 00</td>
</tr>
<tr>
<td>OC11 CD 36 03 0F 10 F4 79 FE</td>
<td>MARK = 00</td>
</tr>
<tr>
<td>OC12 7B EF 3B FE 3B 20 19 13</td>
<td>MARK = 00</td>
</tr>
<tr>
<td>OC13 08 02 16 B1 CS 05 06 80</td>
<td>MARK = 00</td>
</tr>
<tr>
<td>OC14 3E 05 79 01 02 00 21 B8</td>
<td>MARK = 00</td>
</tr>
<tr>
<td>OC15 CE 13 E1 C1 0E 01 00 0D</td>
<td>MARK = 00</td>
</tr>
<tr>
<td>OC16 1F 07 1B 0A 1B 04 0B 0F</td>
<td>MARK = 00</td>
</tr>
<tr>
<td>OC17 16 14 13 30 3C 3E 3F</td>
<td>MARK = 00</td>
</tr>
<tr>
<td>OC18 0D 4C 35 BA 7A 73 47 55 52</td>
<td>MARK = 00</td>
</tr>
<tr>
<td>OC19 37 00 21 00 0D 02 03 04 05</td>
<td>MARK = 00</td>
</tr>
<tr>
<td>OC20 0D 07 08 09 0A 08 CB 3C 0D</td>
<td>MARK = 00</td>
</tr>
<tr>
<td>OC21 0D 17 18 19 1A 31 32 33</td>
<td>MARK = 00</td>
</tr>
<tr>
<td>OC22 0E 29 2C 23 20 2C 3F</td>
<td>MARK = 00</td>
</tr>
</tbody>
</table>
MARK sequence as far as the handling of short mark periods is concerned but when a valid mark is encountered, i.e. a mark of more than a half unit long, it checks whether the SPACE count is less than one and the SPACE length is greater than one unit.

If less than one and a half units long, the space is regarded as an inter-element space. A valid SPACE is added to the unit, the sum divided by two and the result entered in UNIT again.

This results in an enlargement of the UNIT towards the value representing the increasing spacing program to adapt automatically to the speed of the sender, provided it is not less than two thirds or greater than two and a half times the present speed (about 17 w.p.m.). If the space is greater than one and a half units then it is regarded as a character space, the display subroutine is called.

To give a logic "1" for no tone and a logic "0" when a tone is detected) Taking five uses a Jump on Carry (JRC) to go to the input changes state during sampling then the bit 1. Next, the contents of the SPACE count at block B.

If the SPACE count reaches four units then it is regarded as a word space and if the content of CHAR is not (01) (no element inserted) then the character is displayed and is followed by a space on the print. The SPACE count is set to 00 and then the program proceeds to display the next character. This is to avoid the occurrence of up to five words under certain interference conditions that cause the space to reach four units without any elements being inserted into the buffer.

And now, here are some details of the two subroutines used by the main program. All the characters blocks use a subroutine that has the following format: the output from the receiver interface is input to the character generator and masked by an AND instruction to retain only bit 1. Next, the contents of the accumulator (which will be either 00 or 02) are added to the C register which was originally pushed onto the external stack and then set to 00 on entering the subroutine. This is to be changed to be printed.

A simple receiver interface was made by using a 7446 decoder using an Intel MK67 to give the t.t. input with logic "0" when a tone is received and a logic "1" when the tone is removed. A hand-key with a 1k resistor tied to the +5 supply can be used for testing another subroutine which checks to see if the v.d.u. address points to the last eight positions of a line, which case if the character is a space the next two lines are cleared and a new line called to avoid splitting words and to keep the display tidy.

Next a search is made through the Morse table to find the ASCII equivalent of the HEX code for the converted character which is then sent to the v.d.u. for display. If a HEX code outside the table is presented an asterix will be printed. The Morse table contains characters from A-Z numbers from 0-9 and the following auxiliary characters; full stop, comma, question mark, question mark, semicolon, omicron (.), break (=), double-break (=), end of transmission (\), end of word (<), wait (\), color and parenthesis.

A machine language listing in given in the standard W.C. scientific computer form. The program contains 455 lines of code and is written in assembly.

Three test transmitters for 192, 196, 198 MHz were installed in the lab. The 192 MHz equipment was the same as the 172 MHz equipment but the 196 MHz equipment was simple monopole on the roof of the lab.

An empty car was fitted with receivers for each band, such signals as were recorded to the tapes. Transmission to the empty car were also made from a base station, where the power was approximately 35 above ground level.

At 190 MHz, the useful range in an urban environment was about 1.5 miles when operating to mobile and 1/2 miles to mobiles. Listening tests showed that the coverage was patchy, but it was found that reception was relatively unaffected by buildings and bridges. A test in an open country, with a near line-of-sight path, revealed that the mobile range was about 3-5 miles. Under more urban conditions mobiles could usually be heard from within half a mile due to the presence of trees and hedges.

A summary of the results is shown in the chart.

Useful range in miles for a 3W transmission

Frequency MHz Base-mobile Mobile-mobile

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Base-mobile</th>
<th>Mobile-mobile</th>
</tr>
</thead>
<tbody>
<tr>
<td>192.5</td>
<td>4.6</td>
<td>3.5</td>
</tr>
<tr>
<td>196.5</td>
<td>4.6</td>
<td>3.5</td>
</tr>
<tr>
<td>198.5</td>
<td>4.6</td>
<td>3.5</td>
</tr>
</tbody>
</table>

Finding was noticeable at 456MHz, very noticeable at 1272MHz, but virtually absent from the 195 and 273MHz bands. The results at 1272 MHz were due to heavy interference from overseas stations.

By use of the inverse of the above law, the range predictions cited in the Open Channel discussion, decreases from 500 MHz down to 10 MHz, and are shown below.

Base to mobile range in miles

Frequency | Distance (km) | Base-mobile | Mobile-mobile |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>150</td>
<td>0.8</td>
<td>0.8</td>
</tr>
<tr>
<td>1000</td>
<td>250</td>
<td>0.4</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Now keeping on one of the clocks at the point A, then the clock will be compared to the point B. A time difference of 1 second is considered to be a large error, while a time difference of 10 microseconds is a very small error. However, it is impossible to use a clock to measure time intervals of four orders of magnitude greater than this in the Michelson-Morley experiment and thus it would be entirely unnecessary to distinguish between the two divisions, length and connection means.

Two clocks will be required, able to measure time down to 100 picoseconds, and most important, able to synchronize within the same accuracy. Microwaves are often used for this purpose by comparison with some appropriate technique while keeping one at a point in space.

Now keeping out of the clock at the point A, the clock will be transported to the point B. A distance in the order of a few seconds.

Returning to the above law, the time difference between the two sources, which is approximately 10 seconds, is the time difference due to the presence of trees and hedges.

In the Michelson-Morley experiment at 1300 MHz, using the same numerical values for d and a, the second derived from the above law, with an accuracy to ±20 picoseconds (approximately), it is clear that the above law is valid only with tolerances of a hundred or hundred-thousand.

One remaining issue has been quite consistent with the theory of relativity. The two clocks should be synchronized by the theory to be described by the following by (\(\Delta\)\)\(n\)\(\Delta\)\(t\))\(\Delta\) for a constant amount of time. We see that the two clocks are synchronized exactly, as the above law is the theoretical law and so the synchronization is perfect.

Now we see how to synchronize the clocks, we use the following formula:

\[ \Delta t = \frac{c}{2} \Delta x \]

Now if the distance is in the range of a few nanoseconds, then the clock will be synchronized exactly, as the above law is the theoretical law and so the synchronization is perfect.

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Now if the distance is in the range of a few nanoseconds, then the clock will be synchronized exactly, as the above law is the theoretical law and so the synchronization is perfect.
Clara clearly your editorial “Save our public service broadcasting, you can see the communist countries leaving us in peace or for that matter, you can sell it all out for the sake of the state,” I thought that you were actually asking that we leave the country as a whole and... think that.

So seems to me we keep our 'gooseoids' or go for world wide communism complete with its psychiatric hospitals for dissidents - I know what I think.

D. A. Barlow

We, the Central London Medical Branch of the Association of Scientific, Technical and Managerial employees of the British Broadcasting Corporation and the World Wide Radio League believe that the initiating and leading article “Microchips and megadeaths” published in your issue of 20th February is a travesty of the facts and we cannot allow this false picture to be portrayed as a serious and objective comment on a subject of this nature.

We hope that this article is part of a general policy to ridicules the work of experts and experiments. Scientists and engineers seem to have a tradition of being non-political and the World Wide Radio League article correctly points out that this must stop.

Technically we consider that the work of the experts and engineers and scientists can devote more time to the and the dwindling world resources to the purpose of reducing the "per cent" to the whole human race.

E. C. Brad (Branch Secretary)

STMLS (Central London Medical)
London WC1

"ANATOMICAL" LOUDSPEAKER

I fully agree with Mr. R. H. Harcourt ("An anatomically small loudspeaker") October 1980) who draws attention to the importance of the loud loudspeaker for the reproduction of certain sounds. But I have found that some of the few that have never seen an audience affected by a demonstration of this device in the presence of a demonstrating is not an easy thing. The O. B. T. recognized the 500kHz equipment and properly means of salvation, and indeed required that an instruction could be displayed as suitable any ship's officer's emergency. It would not be necessary for Mr. Boyes to demonstrate the practical potential of $10,000 for a martrernal." Observation. In many shows it seems to be a good idea to have a set of this sort on this," I am sure your tone will find us as much as you bottle loudspeaker for the reproduction of certain sounds, especially if the listener's stress is more pronounced. I have seen some years that to reproduce a good sound is no substitute for the right kind of equipment. I am not going to say that my infinite. But it can also be a loudness unit which is near enough the same as that of the experts, obviously, one cannot take this principle very far. It would be impossible, for instance, to reproduce the sound from a whole orchestra by assembling an equivalent number of instruments, and to make the case distinct perfectly the individual instruments, and to accommodate these in the living room. But we cannot do this. There are not enough of the human voice, the sound which is most interesting and which is not so easy to achieve as any other. For myself I cannot say that I have ever heard a sound that I would not find a good subject: people (not just do not speak with books round their heads). I think that may be a few years ago... I have made the point that the "microphones and megadeaths” is an echo of "anatomical" loudspeakers. My argument was that even the sound of a voice comes primarily from the lungs and not from the mouth, leading to the mouth. The other embellishments are added for aesthetic convenience.

It occurs to me that it would be fitting to place the instrument in the likeness of one’s nearest and dearest - what a fine thought, or sentimental, it might be to think of the joy of others.

Lena the loud-talker

This is based on my own experience of the audience. I think it is obvious to... how on the right line.

Firstly, it will be noticed that she has no chest. Actually she has, in fact it is hard to indicate that the whole thing is wrong and the chest, in fact consists of a partly transparent chest and part of it is..." "the chest and lungs. On the top of the chest I placed a little button that when these two buttons were pushed together they produced a sound (b) and hence another... by the human voice, and to all intents and means, she is not hurt by the sound of a voice comes primarily from the lungs and not from the mouth.

Thomas J. Lloyd

Department of Philosophy
University of Glasgow

ELECTRONIC ORGAN TONE FILTERS

Many thanks to your magazine and Dr. Pykett for the much-needed basic guide to tone filters for the amateur radio equipment constructor. I feel that it would certainly agree with Dr. Pykett’s reply to Dr. T. D. Young’s report of having the possibility of using a computer or... the musical instrument to the music the user has available. By this I do not mean gimmicks but practical devices for improving the sound quality.

We are now a step closer to putting loud sound by giving a slightly more powerful amplifier, very little power, the radio of the film. I can see this computer, of course, keeps one foot glued firmly to the floor and is the discriminating classicist can use it to argue against the argument of Mr. Young’s article, his point is in no way affected by the article.

B. Harold Jones

I believe that pipe organs can only get more expensive. I prefer to say that they are only expensive in appearance, but not the organs themselves, especially at such a time of rapid development as the industry is going through now. However, really, a few of these "phase" oscillators, almost any valve amplifiers. Two or more oscillator are used, each driving its own amplifier and speaker mounted in a wooden cabinet enclosed to the weight of extending wave for some time.

M. R. Berrin

Middlesex

WW’s FIELD OF INTEREST

I have been following with interest the recent... seeing the ground of relativity theory in commenting on the role of the electronics and telecommunications industry in providing the appropriate policies, which are the most important.

It seems to me that some readers will be disturbed by suggestions that their leaders are not sufficiently broad, or may be greater if they have previously considered the issue of radio and television in undue light to the interests of these technologies in technology. May I refer briefly to a few of the comparisons in this issue.

Dennis Thacker is involved in a few different fields. He is known by many as a friend and retains the ground of relativity theory in commenting on the role of the telecommunications industry in providing the appropriate policies, which are the most important.

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LEVY ON BLANK TAPES

As one of the relatively few holders of the Amatore
Recording License, I found myself totally unable to support the proposed levy on blank tapes and those who have studied the case for a levy must at least be alleged to be at stake a levy of several pounds per annum would be called for.

As far as I can recall, no one knew of the wide field of interest, even if I may sometimes be unmasked or confused, or find it weighted with "commercial" after all, I don't have to read them at all. What I have to do is to obtain information and extract it from there. By then it should be evident that I have not been misled. This is the most obvious part of me. The more people who have used up or confused, or find it weighted with "commercial" at least that's why I would have thought. If fair com-

TV SETS FOR THE HARD OF HEARING

I was interested in the plight of your correspond-
ent Mr Holloway (October letters), who had a
problem finding a television set with a

logic probe

The probe described is unusual in that it will detect and indicate the presence of propagation delays in logic circuits. In addition to the usual static testing it also shows negative coincidence in two pulse signals.

Circuit operation

Protection circuit. The protection circuit shown in Fig. 4 has been incorpo-
rated to prevent damage to the probe due to incorrect supply voltages. In addition, D3 is illuminated when the supply voltage is incorrect, i.e., when the applied voltage to the circuit is 4.5-5.5 V. This feature is very useful, as it too often the most obvious fault of incorrect supply voltage is overlooked and much time can be wasted investigating "suspect" digital circuits.

Under normal operation, T1 is off, T2 is on and hence SV is applied to the probe circuit via RLA. However, above 5.8 V, D3 conducts and T1 is based on this

I, for one, welcome the widening of W.F.'s field of interest, even if I may sometimes be unmasked or confused, or find it weighted with "Commercial" after all, I don't have to read every word if I don't want to; I can even manage without an "off" switch.

with Mr. Casser's modified symbols as shown in
by A. J. Jameson, B.Sc.

The probe is a useful aid to testing and fault-finding digital systems. The many commercial and amateur designs currently available provide information about the static and dynamic behaviour of circuits, but have the disadvantage of providing 'coincidence-detection' and cannot indicate the presence of 'glitches' in the wave form under investigation.

For example, in the simple case of Fig. 1, a 'standard' probe would indicate pulses at A and B, but the output C would remain high, leading to the conclusion that either the gate is faulty or the pulses are not coincident. The next step in the exercise would probably require the use of a dual-beam oscilloscope to prove whether or not A and B are coincident. Even so, if the pulses are of different frequencies, the task of 'coincidence proving' may be impossible using an oscilloscope. In addition, the use of an oscilloscope makes the test expensive and time consuming.

Another example encountered all too often, despite careful design, is that of 'glitches' produced by static and dynamic race-hazards. In the example of Fig. 2, a negative-going 'glitch' is produced due to the propagation delay through the JK flip-flop. This example is also shown in Fig. 5, when a 20nS pulse has been produced using the circuit shown in Fig. 2.

The use of a logic probe on such a circuit would reveal no faults whatsoever. Even an oscilloscope with delayed-sweep facilities would probably show nothing unless the pulse width of A was greater than 1MHz. However, the presence of such a circuit with a window generator provides conscious and quite often diagnosed as an "elusive dry-joint".

The logic analyzer probe now described, solves these problems whilst providing the features of the standard probe. It should be mentioned that the t.l.i.c.s. used in the probe are operating with pulse durations shorter than those by manufacturers. Although two probes have been made without trouble in this respect, it may be necessary to experiment with several l.c.s. The total cost of the unit is about £10.

selves with the techniques of communication and control.

What proportion of the W.F.'s readership, one wonders, wants only information on bare tech-
nicalities, well-embellished jobs that are neat, and perhaps a few words on how wonderful everything is going everybody.

Yes, we pay 60p a month to be informed, to retain ourselves in the activities of our fellows, and to have our view of life expanded; at least that's what I have thought. If fair com-

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Under normal operation, T1 is off, T2 is on and hence SV is applied to the probe circuit via RLA. However, above 5.8 V, D3 conducts and T1 is based on this

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Thus is present at the input to IC5, point A will be high. This in turn is inverted by IC4, and a low is therefore present on IC2. Thus D1a is conducting and the red LED D1 is lit. These latches are reset by narrow pulses produced by the unijunction oscillator T5.

If a permanent 1 or 0 is present at the probe, it overrides this reset pulse and therefore either D1a or D1b remain lit.

Positive going glitches are detected by the circuit comprising IC4a, IC4b, and IC4c, which indicate the logic level at the probe. If a 1 is present at the input to IC4, point A will be high. This in turn is inverted by IC, and a low is therefore present on IC2, Thus D1a is conducting and the red LED D1 is lit. These latches are reset by narrow pulses produced by the unijunction oscillator T5.

IC5 provides the ANDing circuitry needed to facilitate the coincidence detection mode of operation. The latches comprising IC4a, IC4b, and IC4c indicate the logic level at the probe. If a 1 is present at the input to IC5, point A will be high. This in turn is inverted by IC, and a low is therefore present on IC2. Thus D1a is conducting and the red LED D1 is lit. These latches are reset by narrow pulses produced by the unijunction oscillator T5.

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Phase-comparator detectors
This type of detector also makes use of the varying phase relationship between two input signals, nominally in quadrature, such as the voltages across the primary and tuned secondary windings of a transformer but it does so in a manner quite different from that of the detectors described earlier. In Seeley-Foster and ratio detectors the two input signals are added to produce resultant voltages (the amplitude of which varies with the phase difference) which are applied to amplitude detectors, the combined output giving the required modulation-frequency signal.

In phase-comparator detectors the two input signals are limited so as to form rectangular pulses. Limiting may be carried out in separate stages preceding the phase comparator or in the phase comparator itself. The degree of overlap of these pulses varies with the phase difference between the two inputs and determines the output current of the comparator which is therefore a copy of the modulation wave-form. The output of the comparator thus depends on the relative timing of the two sets of pulses and is independent of the amplitude of the input signals provided this is sufficient to give satisfactory limiting.

To summarise: in the detectors described in the first article the amplitude of the primary and secondary voltages is the significant quantity whereas in the phase comparator it is the timing of these voltages which matters.

The general form of a phase-comparator detector is illustrated in the block diagram of Fig. 13(a).

Self-limiting phase-comparator detectors.
In an early form of phase-comparator detector the two input signals are applied to the two input grids of a special valve. The grids are required to give limiting action: in other words positive-going signals are required to increase anode current up to a particular value whereas further positive excursions should produce no change in anode current. This is the type of control achieved by the suppressor grid of a pentode. Signals applied to such a grid deflect cathode current from anode to screen grid or vice versa but cannot increase or decrease cathode current which is determined by the screen grid and control-grid potentials. Thus the ideal value for this particular application is one with two suppressor grids.

In addition it is important to minimise damping of the input-signal source (normally the primary and tuned secondary windings of a transformer) by the input grids when they are driven positive with respect to cathode and, to this end, input-grid current must be kept to a low value. This is achieved by so constructing the valve that each input grid is situated between two positively-charged screen grids where there is no space charge to support grid current. Finally therefore the valve required consists of three screens, two input grids, a control grid and a suppressor grid next to the anode to suppress tetrode kink.

Thus was the nonode derived and Fig. 13(b) shows the circuit diagram of an f.m. detector using a nonode. Its operation is illustrated in the waveform diagrams of Fig. 14 which show that anode current can flow only when grid g and grid g₂ are both positive i.e. when the pulses derived from primary and tuned secondary windings overlap. As the degree of overlap varies with frequency modulation the anode current varies accordingly and so contains a strong modulation-frequency component.

There was a simpler valve which was used in a similar way to the nonode. It was a pentode in which the two input signals were applied to the control grid and the suppressor grid but the geometry of the electrode structure was quite different from that of a conventional pentode in order to achieve the type of limiting action required at the two grids. It was known as a gated-beam valve.

Transistor phase-comparator detectors.
In its simplest form a transistor equivalent of the nonode or gated-beam tube could take the form shown in Fig. 15. One of the disadvantages of such a simple circuit is that the output would contain a large component at the input frequency in addition to the wanted modulation-frequency component and in practical forms of phase-comparator detector precautions are taken to minimise this unwanted component. In integrated circuits, for example, extensive use is made of the push-pull principle and a simplified version of a typical circuit is given in Fig. 16. The output of the i.f. amplifier (also included in the i.c.) is applied to the push-pull pairs to 54 Tr₁ and Tr₂ so that when one of these transistors is driven into conduction the other is cut off. The qudrature signal is derived from the i.f. output by use of an external LC circuit and associated reactance (one possible arrangement is shown in dashed lines) and is applied also to pulse form to two push-pull pairs Tr₃ and Tr₄ in a circuit which ensures that none of the quadrature component appears across the output terminals. Suppose Tr₁ base is driven positive by the quadrature signal at an instant when Tr₂ is conductive. The effect is to promote conduction in Tr₁ and thus to cut Tr₂ off, producing a net output between the output terminals. Half a cycle later, when Tr₂ is conductive, Tr₁ and Tr₂ behave similarly and again there is a net output. The duration of these outputs depends, of course, on the extent of the overlap between the i.f. and quadrature inputs and varies with the phase difference between the two inputs. The output can be used as a i.f. in a.f.m. receiver or for a.f.c. purposes.

Tr₃ is included to stabilise the mean current through the detector and is one of the many auxiliary components included in a.c. to ensure that the performance is substantially unaffected by variations in ambient temperature or in supply voltage. A number of i.c.s designed for use in f.m. receivers incorporate detectors with a circuit similar in spirit to that of 16 and they are often described as balanced, symmetrical, quadrature or product detectors.

Counter discriminator
This is the most common type of the many different types of counter detector that have been developed. It is based upon the fact that any potential present upon the input circuits to which the detector is connected is amplified and the output appears at the collector of the transistor that is driven into conduction. Use is made of the fact that the collector current is very sensitive to small changes in the collector voltage when the transistor is operating in a region close to cutoff. The output, therefore, is very small and provides a means of varying the sensitivity of the circuit by means of the collector voltage or by changing the base-emitter voltage. The output voltage is thus a measure of the signal applied to the detector.

In conventional f.m. receivers the signal is often applied to a series of differentiators with a gain of about 30 to 40 and its output is applied to a number of transistor discriminators. The output of each discriminator is then applied to a low-pass filter and the relative output of the filter is indirectly proportional to the frequency of the input signal. The relative output is then used to vary the gain of the i.f. amplifier or to operate a side band detector. The frequency is limited by using a low-pass filter in the discriminator output and the output of this filter is then applied to the low-pass filter that is used to limit the signal to a frequency component of the input signal. The output of this filter is then applied to the i.f. amplifier and the gain of the i.f. amplifier is thus controlled by the frequency of the input signal.
Early pulse-counter discriminators were fed with square waves from the final limiting stage in the i.f. detector where the wave was differentiated in an RC circuit which, as shown in Fig. 17, incorporated diodes to eliminate the going-bipolar. The resulting train of positive-going trips was passed through a low-pass filter, a cut-off frequency of say 30Hz. A simple RC filter is shown in Fig. 17 which is taken from an article published by M. G. Scrogie in 1956.*

In more recent pulse-counter discriminators the positive-going pulses are used to trigger a multivibrator giving, for example, 1-up pulses which are passed through a square-trap (to eliminate any overshoots) before being applied to the low-pass filter.

Pulse-counter discriminators are used in applications where linearity is important e.g. in f.m. receiver and in f.m. deviation meters.

Locked-oscillator discriminators

At the title suggests this last type of f.m. discriminator is based on an oscillator which is synchronised by the f.m. signal so that its frequency follows any change in that of the input signal. Such a system can be expected to have two useful properties. Firstly, the amplitude of the output signal put can be many times that of the input signal, implying a high degree of effective synchronising: in other words the discriminator should be frequency selective. Thus the oscillator can be used as a source of amplified and amplitude limited f.m. signals which have many of the types of characteristics of the described above. Used in this way, the oscillator is not itself a discriminator but a source of input signal for a discriminator. Circuits of this type were described as early as 1944.

The synchronised oscillator can, however, act as a discriminator. If it operates in class C, taking one burst of current from the supply per cycle of oscillation, the frequency of the bursts produces a signal which is independent of that of the input signal and so contains a modulation frequency component which can be used as detector output. For the reasons given under the previous section, however, a low value of intermediate frequency (and hence oscillator frequency) is necessary to give a worthwhile performance from such a circuit.

Phase-locked-loop circuits. In this more recent application of the principle the frequency of the oscillator is controlled not by direct detection of the i.f. signal, but by a control voltage dependent on the difference between the phase of the oscillator and that of the i.f. signal. The circuit, illustrated in principle in Fig. 18, is so designed that the error signal, which is the control voltage which is to minimise the phase

* — Low-distortion f.m. discriminators, Wireless World, April 1956.

The use of batteries as the power source for small electronic instruments and equipment is often considered essential. The absence of a trailing mains lead (especially when there is no convenient outlet) precludes their use. However, there is a lack of nickel/cadmium batteries which are not damaged by complete discharge. Indeed, under such conditions, Nickel-cadmium "batteries" are being assembled from individual cells they should all be in the same state of charge, one may be exhausted before the rest and therefore be dogging "reverse charging".

A really effective indicator on a battery-powered instrument might prevent this lamenteable waste of batteries. However, of the many types of "toy" indicator used, nearly all have proved of very limited effectiveness. One well-known manufacturer uses a red/yellow/orange/red, the transparent part of the knob showing fluorescent orange when in the red" position and this is reasonably effective when the front panel is in bright light. Indicator lamps have also been used but usually with intermittent operation to save current. Examples are a blocking oscillator causing a neon lamp to flash, and a flasher circuit driving an LED. Unfortunately, the price that can be charged for a battery is very limited. The flashing rate cannot be more than one per second or may fail to catch one's attention. The other hand, the eye integrates over about 100ms, so flashes much shorter than this must also be much brighter to give the same visibility. Thus a saving of about ten to one in energy (ignoring any "no bouncing between"..."s point drawn by the flasher circuit") about the limit in practice.

The author has amused many as most batteries as most people by inadvertently leaving equipment switched on when not in use, and decided many years ago that the only effective remedy was to replace the

**Battery-powered instruments**

Choosing and using dry batteries, with some suggestions for improving service life

by Ian Hickman

The very small cost of main batteries for rechargeable nickel/cadmium types thus has come into question. (All the batteries, including the nickel/cadmium types discussed in this paper, must be recharged at the end of the day.)

Rechargeable types

Rechargeable batteries offer considerable economies in running costs, though the initial cost is high. For example, comparisons can be made between certain layer-type batteries, e.g. Pt/Pt, and also certain single cell types, e.g. AAG, C and D size primary cells, where, mechanically ininterchangeable, rechargeable nickel/cadmium batteries are available. These cost about ten to twenty times as much as the corresponding zinc/carbon (Leclanché) dry battery or cell, and as much or more again for a suitable charger. This is because almost all have proved of very limited effectiveness. One well-known manufacturer uses a red/yellow/orange/red which, the transparent part of the knob showing fluorescent orange when in the red position and this is reasonably effective when the front panel is in bright light. Indicator lamps have also been used but usually with intermittent operation to save current. Examples are a blocking oscillator causing a neon lamp to flash, and a flasher circuit driving an LED. Unfortunately, the price that can be charged for a battery is very limited. The flashing rate cannot be more than one per second or may fail to catch one's attention. The other hand, the eye integrates over about 100ms, so flashes much shorter than this must also be much brighter to give the same visibility. Thus a saving of about ten to one in energy (ignoring any "no bouncing between")..."s point drawn by the flasher circuit") about the limit in practice.

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The on/off switch by an 'on' push-button. This switches the equipment on and initiates an interval at the end of which the equipment turns itself off again. Clearly, it would be most annoying if just at the wrong moment—say when about to take a reading—the instrument or whatever switched itself off, so the push-button should also, whenever pushed, extend the operation of the instrument to the full period from that instant. One can thus play safe, all in all, by pressing the button again, 'just in case'.

The period for which the instrument should be left on may be of course determined on its use and the inclination of the designer. However, a very short period—a minute or less—would generally be rather pointless; provided one had one hand free could be obtained with a stringy-a-way "on what pressed button", which is also cheaper and simpler. For many purposes, ten or fifteen minutes is a reasonable period, but clearly it is not critical unless the equipment is exceedingly current-hungry. After all, it is being left on overnight (or a week-end) that ruins batteries controlled by an ordinary switch, not the odd half hour or so.

In the late 1960s, when the author first used a ten-minute timer to save batteries, producing such a long delay economically and with little cost in "housekeeping" current was an interesting exercise, especially as monstrously high resistances were ruled out as impractical and expensive. So the circuit of Fig. 1 was developed and proved very effective. The preset potentialometer was set to pick up a voltage a little higher than 221 (11 preset point on) and was in good condition. The resetting of the complementary latch, turning on the instrument and initiating a bootedstrapped energy at the preset point, is, of course, entirely turned off the latch and hence the instrument, unless the battery was pressed again first, when the capacitor was discharged again via R, and the interval initiated. This made saving batteries, although the exact period was rather vague due to variation of the base voltage of the base-emitter circuit. Incidentally, the purpose of the 0.1µF capacitor was to enable the preset potentialometer to be set for a 6 second period before the 2µF capacitor was connected in circuit. This made setting up the 600 second period much less tedious.

An even simpler circuit is possible with the use of the VCC timer, which is illustrated in this Fig. 2. The circuit undoubtedly works well in practice, but whilst it is not the simplest one can imagine in a piece of home-made gear, it has major advantages. Firstly, the whole circuit is contained on the face of the VCC timer. Secondly, there is a clear turn-off point.

As a general guide the currents are shown here as +2V, the drain resistance rises progressively, greatly starvating the load of current in saturation. On reaching a count of 20, the output, or escape, goes to the positive rail, turning off the p-n transistor and hence also the n-p-n transistor and -the output. Clearly, by increasing the timing resistor and capacity at points 10 and 9 respectively, delays of many hours could be obtained if required.

Such a timing circuit is reasonably cheap to incorporate in any instrument and requires no setting-up. As shown in Fig. 3, it is capable of supplying up to 10mA or more load current; larger load currents simply require the 100kΩ resistor in the base circuit of the BC109C transistor to be increased in value. For the latter, the current in the base of the BC109C, in particular, can be the basis of a timer providing an output of up to an hour with only a 0.1µpF timing capacitor, as in Fig. 3. Here, on operating the push button, the complementary latch is set, in the output of the base of the transistor which, starting from 0.1µF, all but the zero at the divide by 20 output, or 20 times this is therefore at logic 0, holding the n-p-n transistor and hence also the p-n transistor and -the output. Clearly, by increasing the timing resistor and capacity at points 10 and 9 respectively, delays of many hours could be obtained if required.

Choosing the battery size

Using one of the above circuits can reduce the average daily running time of an instrument with a current consumption of the overnight run-down, but the question still remains — 'which dry battery to use?'. To answer this question, we first estimate the minimum appropriate supply voltage. If a 6V nominal supply is used, there is a wide choice of cells, but in order to use four single cells rather than a layer battery, for many purposes, an end of life voltage of around 4V is too much. This would require 10.2V battery, but it would be more useful end of life voltage, whilst if a higher voltage is required, the choice of batteries in series can be used, 6V or 9V types as required.

To decide what size battery of a given voltage to use, refer to the battery manufacturer's data. Tables 1 to 3 give the service life operation of the batteries in series (at 20°C) for three different types of layer batteries. The top value PP1 is one of the best batteries in service; this is followed PP4 and PP7 in order of increasing capacity, which -whilst relatively new, are not quite so commonly used. It is important to note that the values given the service life in hours for the PP1, at 9V, i.e., for a constant resistance load. Thus the current provided at for example a 6V end point must be spread over the cells of the left-hand column of the table.

The first fact which strikes one is the much greater milliamp-hour capacity of the PP1 the PP4 and of the PP7, in each case double of 6.1. Yet the price differential (by comparison) is tiny. It would therefore appear at first sight that the A1 for PP1, or at least the largest battery capable of being accommodated within the case of the circuit. In general, for an equipment for an equipment of using only a very small current and/or receiving occasional use. Under these circumstances a battery would be partially used before giving of "lifeline", and saving the cheaper battery would be a more sensible choice. Except for the current of the small micromamps up to a milliamp or so —it is worth considering saving the cost of a switch entirely and letting the current run continuously. It is in any case good if one can to practice a layer battery type, for the vegetable, but largely because of little use it has had, although in a temperate climate it will often remain serviceable much longer than the more temperate climates routine replacement after 6 to 9 months is usual.

The circuits of Figs. 3 and 4, when on, apply the full battery voltage to the load circuit, except that it is not to the instrument to the collector saturation voltage of the series pass transistor. This being so, load current can be very much lower, or small circuit and yet be enough useful life, and in good condition. The voltage falls to an unservicable one and whilst the measurement is made, the i.e.d. will illuminate again.

By connecting the monitor circuit across the output of the delayed switch-off circuit, the monitor draws housekeeping current drawn by the circuit of Fig. 4 means of course that whilst 'on', the battery is actually being run down.
### PP3 Estimated Service Life at 20°C

<table>
<thead>
<tr>
<th>Milliamps</th>
<th>Service life in hours to endpoint voltage of 6.6V, 6.0V, 5.4V, 4.8V</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>28 32 34</td>
</tr>
<tr>
<td>15</td>
<td>17 19 21 23</td>
</tr>
<tr>
<td>25</td>
<td>9.2 11.2</td>
</tr>
<tr>
<td>50</td>
<td>2.3 4.1 5.1 6.8</td>
</tr>
</tbody>
</table>

**Discharge period 30 min/day**

- 15: 222 265 295 312
- 25: 215 248 280 277
- 50: 63 77 71 77

**Discharge period 12 hours/day**

- 1.5: 180 196 200 205
- 2.5: 112 122 132 136
- 5.0: 69 89 92 92
- 10.0: 24 28 31 34
- 15: 15 17 23 30 33
- 25: 15 12 17 19

**Note:** Also available are the higher capacity PP3P for miniature dictation machines etc. and the PP3C for calculator service.

### PP9 Estimated Service Life at 20°C

<table>
<thead>
<tr>
<th>Milliamps</th>
<th>Service life in hours to endpoint voltage of 6.0V, 5.4V, 4.8V</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>24 25 44</td>
</tr>
<tr>
<td>15</td>
<td>16 28 33</td>
</tr>
<tr>
<td>25</td>
<td>10 44 54</td>
</tr>
</tbody>
</table>

**Discharge period 30 min/day**

- 15: 260 275 295
- 25: 190 220 249
- 50: 67 78 89

**Discharge period 12 hours/day**

- 0.75: 2075 2200 2325
- 1.5: 1690 1860
- 3.5: 532 620
- 6.0: 214 263
- 7.5: 117 147
- 15: 38 50

### WP3 Estimated Service Life at 20°C

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<td>165 190 215</td>
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<tr>
<td>25</td>
<td>100 125 145</td>
</tr>
<tr>
<td>50</td>
<td>35 50 69</td>
</tr>
</tbody>
</table>

**Discharge period 12 hours/day**

- 0.75: 2075 2200 2325
- 1.5: 1690 1860
- 3.5: 532 620
- 6.0: 214 263
- 7.5: 117 147
- 15: 38 50

### PP3 Estimated Service Life at 17°C

<table>
<thead>
<tr>
<th>Milliamps</th>
<th>Service life in hours to endpoint voltage of 6.0V, 5.4V, 4.8V</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>26 30 32</td>
</tr>
<tr>
<td>15</td>
<td>17 19 21 23</td>
</tr>
<tr>
<td>25</td>
<td>9.2 11.2</td>
</tr>
<tr>
<td>50</td>
<td>2.3 4.1 5.1 6.8</td>
</tr>
</tbody>
</table>

**Discharge period 30 min/day**

- 15: 222 265 295 312
- 25: 215 248 280 277
- 50: 63 77 71 77

**Discharge period 12 hours/day**

- 1.5: 180 196 200 205
- 2.5: 112 122 132 136
- 5.0: 69 89 92 92
- 10.0: 24 28 31 34
- 15: 15 17 23 30 33
- 25: 15 12 17 19

**Note:** Also available are the higher capacity PP3P for miniature dictation machines etc. and the PP3C for calculator service.

### PP9 Estimated Service Life at 17°C

<table>
<thead>
<tr>
<th>Milliamps</th>
<th>Service life in hours to endpoint voltage of 6.0V, 5.4V, 4.8V</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>24 25 44</td>
</tr>
<tr>
<td>15</td>
<td>16 28 33</td>
</tr>
<tr>
<td>25</td>
<td>10 44 54</td>
</tr>
</tbody>
</table>

**Discharge period 30 min/day**

- 15: 260 275 295
- 25: 190 220 249
- 50: 67 78 89

**Discharge period 12 hours/day**

- 0.75: 2075 2200 2325
- 1.5: 1690 1860
- 3.5: 532 620
- 6.0: 214 263
- 7.5: 117 147
- 15: 38 50

---

**Fig. 7.** Circuit of Fig. 3, modified to act as stabilizer.

**Fig. 8.** Use of a low-voltage indicator with a stabilizer.

---

**Amateur radio and illegal c.b.**

Police investigation of illegal 27MHz "citizens' band" activities continues to in-
clude the mapping of vehicles carrying un-
usual-looking aerials, sometimes resulting in radio amateurs experiencing conside-
rable difficulty in proving that their trans-
mitters are legal. Since amateur licenses are not computerized, immediate confirma-
tion cannot be obtained through the police data networks, although it seems likely that this information will be time-
stored on a Home Office computer and thus become part of the amateur's "electronic
dossier".
Programmable bandpass filter

This design simulates a resistor, $R_{eq}$, by switching a small capacitor, $C$, at a clock rate $f_c$ in the frequency range of 50kHz to 500kHz. The size of the equivalent resistor is $1/2f_cR$, and a multivibrator circuit for simulating $R_{eq}$ is shown in Fig. 1. The s.p.s.t. analogue switch can be replaced by a dual switch, type TL 191 CN. Clock frequency is set by the RC networks to, say, 100kHz and this circuit replaces resistors $R_1$ and $R_2$ in Fig. 2. Centre frequency of the filter $f_0$ is $1.592\times10^6/R_{eq} = 1.592\times10^6/1.592\times10^6 = 1$. Under this condition $Q$ depends on $R_4$, $R_5$, and $R_6$. Gain, $A_{eq}$, for the pass band is $5.10^6/R_2$, so $R_2 = 5.10^6/A_{eq}$.

T. Williams

Fig. 3.

Improved audio-visual circuit

Where several locations or sub-systems are monitored, for example in an alarm system, it is common to have an audible alarm, which is activated if a monitor point is triggered, and an array of visual indicators to show the particular location(s) involved. Because the audible alarm has a large number of inputs, this system can be costly in terms of wiring and connectors.

A simpler solution is to use the i.e.d. as an OR gate, with the output as a current to ground which can be detected by a current mirror. Because the current can become reasonably high, $T_3$ must be a medium-power type. Although this unbalances the current mirror, linearity is not important in this switching application. The final design used a p-n-p switch as an active pull-up. With this arrangement only one input connection is required for the audible alarm.

K. Kraus

Fig. 2.

Wide-range p.p.m.

By using the exponential conduction characteristic of a silicon diode, i.e. d. bar or monolayer display of audio level over a range of 40dB can be achieved.

The collector load of $T_3$ is bootstrapped by $T_4$ and $C_4$ to produce a near constant-current drive to $D_1$ and $D_2$. The clipped signal is then amplified to drive a receiver transformer, and $T_5$ maintains a constant current through the rectifier bias diode $D_2$. Capacitor $C_5$ and $R_4$ determine the rectifier discharge time-constant, and $C_6$ buffers the output. The i.e.d. driver, $I_D$, supplies 15mA through the display diodes, and $R_2$, $R_3$ limit the dissipation of $R_4$ during large input signals.

To adjust the circuit, set $R_8$ for maximum input, $R_9$ to the mid-position and $R_{10}$ to maximum resistance. Apply 12V and feed a 1kHz signal of at least +12dBm to the input. All of the i.e.d.s should turn on. Reduce the input to 0dBm and adjust $R_8$ until l.e.d. 1 is just extinguished. Increase the input to +12dBm and adjust $R_8$ until l.e.d. 10 is just on. Repeat the last two adjustments as necessary. Reduce the input to −30dBm and adjust $R_7$ until l.e.d. 10 is just on. Re-adjust $R_8$ and $R_7$ if necessary.

The calibration should now be within 1dB over the range 80Hz to 15kHz. The lower sensitivity limit can be extended by connecting a 351 resistor in series with $D_3$; $R_3$ can then be adjusted so that l.e.d. 1 turns on with an input of −55dBm, but the scale below l.e.d. 8 will need to be recalibrated.

The circuit is fairly sensitive to temperature variations, due to the characteristics of $D_1$ and $D_2$, but it is nevertheless useful in studios and other controlled environments.

T. M. Forcer

Fig. 1.

Ringing-tone generator

A reasonable approximation to the standard telephone ringing tone can be achieved with two i.e.d.s and two transistors. A c.m.o.s. oscillator/binary divider generates both frequencies, and the gating signals so, in the quiescent state, only c.m.o.s. current and transistor leakage current is drawn. The output-stage values are appropriate for a $V_{DD}$ of 10V and a low voltage supply of 4V. Repeater $R_1$ gives a f.m. warble on the tone and can be omitted if this is not required.

T. Williams

Fig. 1.

Circuit Ideas
Gate tester

Fig. 1 tests quad dual-input type gates by comparing the logic operations of a reference i.c. with the device under test. Input signals are provided by a square-wave generator and divider.

Two alternative circuits are shown for testing 3-input and 4-input gates, using the same output arrangement.

K. Wright
Colchester
Essex

If everything were perfect...

It is rarely necessary to have to boost the bass response of a top quality high-fidelity system, although the Quad 44 tilt control does enable subtle changes to be made to the overall balance of the programme, but there are a number of high-quality loudspeakers on the market, which because of their Lilliputian dimensions, necessarily have attenuated low frequency response and the Quad 44 is fitted with a bass control which in the lift position provides optimum equalisation.

Considerations of domestic harmony frequently dictate loudspeaker placement that is less than ideal. The almost inevitable result is the excitation of the fundamental eigen tones of the room and music reproduction with a characteristic and unpleasant honk.

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Telephone: (0480) 52561.

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QUAD is a registered trade mark.
Teledyne Semiconductor has introduced two evaluation kits for the new 7106/7107 3½ Digit Monolithic CMOS A/D Converters. The kits are simple to use and will measure AC and DC voltages, multi-range DVMs, resistance currents, temperatures and other physical dimensions.

The 7106 kit uses a liquid crystal display and is normally powered by a single 9V battery. It is portable, can be used inside or outside and will not fade in sunlight. The 7107 kit uses light emitting diode displays and requires an external power supply. It operates under normal indoor ambient light conditions. Both kits include parts for 200MV full scale. The kits use the I.C. internal reference, which at 100ppm is adequate for most applications. However, they can be modified to operate from an external reference where higher stability is required.

Each evaluation kit contains one I.C. (either 7106 or 7107), one display (either LCD or LED), a PCB, passive components, miscellaneous hardware and a detailed 6-page application note.

The comprehensive application note contains all assembly instructions.

Interfacing microprocessor systems

The control of industrial plant and simulator circuits

by P. Jackson and S. O. Newstead

Several microprocessor systems are available, either in kit form or assembled, which can be adapted to control plant. These systems are usually modified desk-top computers with connections to additional memory devices.

Although many training establishments purchase such systems to teach programming, interfacing the microprocessor is not always tackled. This article outlines the design principles required for interface circuits and describes a simple boiler simulator suitable for microprocessor control.

Interfacing circuits for plant control should enable the microprocessor to read an 8-bit digital number, operate an a-to-d converter and read the output, switch external devices on and off independently, and output an 8-bit digital number. The first function is useful when several pieces of equipment are monitored. For example, when raising steam an oil-fired industrial heating boiler must have a flame, an induced draught fan and a forced draught fan in continuous operation. A sensor on each fan and a sensor on the flame, whose outputs are converted to logic levels, can be read as the three least significant bits of an 8-bit number with the remaining bits connected to ground.

A subroutine which deals with this monitoring process can be written as follows,

```
SUBROUTINE NO. 1010
1000 RETURN
1010 READ 27 A
1020 IF A = 7 GOTO 1000
1030 IF A = 0 PRINT "ALL SYSTEMS FAIL"
1040 IF A = 1 PRINT "F.D. & FLAME FAIL"
```

500 IF A = 7 GOTO 670
660 STOP
670

Therefore, a healthy system can be temporarily closed down, and a faulty system closed down permanently. The second function is useful whenever an analogue transducer is used. For example, pressure, temperature, acidity, rate of flow or position measuring devices. The program must be held until the a-to-d converter has completed its task. If the converter uses a counter and a comparator, the time for the converter to operate is proportional to the magnitude of the analogue signal. The status strobe from the converter is therefore

![Fig. 1(a). 16-address demultiplexer. If ports 8 to 15 are required, use 74LS138 in place of 74LS154. Control signals from a microprocessor system may be RD and WR to distinguish between read and write, with IOREQ and MREQ to distinguish between input/output ports and memory. Alternatively, they can be IO and IW with NR and NW. In this case IOREQ can be achieved as shown in (b).](image)

![Fig. 2. 32-address demultiplexer. The address lines may need to be buffered.](image)
The third function, switching external devices on and off, is the control of the plant by the processor. The final function, which gives an 8-bit digital number as an output on eight lines, can be used when variable control signals are needed. A programmable power supply in automatic test equipment could be controlled in this way.

When designing interface circuits, the signals available from the c.p.u. must be considered together with the system it is connected to and the plant to be controlled. Some of the pins on the c.p.u. are buffered and will drive 74LS logic, others are unbuffered and will drive c.m.o.s. As the interface circuits will probably contain a mixture of 74LS and 74 Gates, control signals from the microprocessor must be buffered, and a c.m.o.s. 4050B provides six buffers at a reasonable cost. If the microprocessor contains a large memory, c.m.o.s. buffers may be needed between address, data and control busses and the interface devices which load them, but this is a matter of judgement. Some microprocessor systems already contain ports, and the process to be described assumes that these exist but additional ports are needed. These ports are connected to the microprocessor, and through which the four functions listed previously are carried out, need to be addressed. Microprocessors have 8, 12 or, more usually, 16 address lines which form the address bus. These are normally fully buffered to cope with the complete memory, 64K for 16 address lines. For port use, the eight least significant lines A0 to A7 are available together with the input/output read (IOR) and input/output write (IOW) signals. The control signals are used when read and write instructions are reached in a programme.

Although machine code can be used to fetch data from a port or to output data to another port, because it is generally easier to work in a high-level language, the examples given here are in BASIC.

A system as purchased may contain some ports which use addresses 0 to 8, 7. Additional ports for plant control can therefore be numbered 8 to 255, using A0 to A7. To obtain 16 extra ports use Fig. 1, or Fig. 2 for 32. C.m.o.s. buffers have been included but it may be possible to use 74LS154 devices and omit the buffers. To read an 8-digit number, connect the eight lines which carry the number to the inputs of the tristate buffer in Fig. 3. An instruction such as 30 READ 26, B would cause address lines A1, A3 and A4 to go high, and when the IOREQ pulse reaches the demultiplexer in Fig. 1, line 26 will go low. The other demultiplexer outputs remain high.

While the IOREQ pulse is present, the RD pulse is received by the tristate buffer in Fig. 3. This pulse, together with address 26, opens the buffer and connects the input signal to the data bus. During the RD pulse the buffer in the c.p.u. opens and closes to load the number on the data bus into a register. Several tristate buffers can be connected to the data bus and selected in turn by each address. If the input to one of these buffers is obtained from an a-to-d converter, three instructions may be used. The first instruction produces a pulse which sets the converter counter to zero and starts the count. At the same time, the c.p.u. is set to a Hold mode, which prevents it from advancing in the program until the wait signal is removed. The wait signal is held by the status signal from the a-to-d converter. The second instruction reads data into the c.p.u., and the third instruction resets the latch set by the first instruction. Typical instructions to read an analogue signal from address 20 and to store it in the memory at location Q are:

80 WRITE 19,1
90 READ 20,0
100 WRITE 19,0

where 19 is an address which the latch of the circuit in Fig. 4, the least significant data line is coupled with address line 19 to operate the latch in two ways. If this is not done, two address lines must be used, which makes the data quoted in the write instruction irrelevant. This method is advantageous when surplus address lines are available.

External devices may be switched by latches which have different addresses as shown in Fig. 4, or eight latches with the same address, connected to DO-07, can output an 8-bit number. These can also be viewed as eight separate switchable lines. If read relays are driven by the 74 logic which makes up the interface system, it is possible to control many types of plant.

An oil-fired boiler simulator for microprocessor control

This simple model illustrates sequential switching of equipment, monitoring of the plant by reading a digital number and taking appropriate action, reading of an analogue number via an a-to-d converter and taking action based upon its value, use of a software delay after switching a device on and then verifying that the device is operating, printing pressure and temperature at predetermined intervals and, in the event of major failure within the plant, closing down and locking out the plant followed by a print out of the failures and an audible alarm.

The boiler simulator comprises an integrated draught fan and forced draught fan. When the starters are switched on, these fans gradually run up to speed so the fan-running signal is subject to a delay. When the boiler is started, the fans must run for a while to purge the furnace before fumes are sprayed in. A fuel pump, which must not be switched on unless the furnace has been purged, the fuel has been heated above the minimum temperature and the ignition has been switched on.

A flame detector. The flame must appear a short time after the oil has been switched on and, if it does not, the boiler must be shut down. The microprocessor can be programmed so that if a flame failure stops the fuel pump, purges the furnace and attempts to ignite the boiler again. A fuel heater. This is easily switched on, but a check may be made by measuring the fuel temperature, switching on the heater, introducing a software delay, measuring the fuel temperature again and checking that the temperature has risen.

The logic is 74 series throughout, does not provide latches in the simulator because they are part of the output ports of the microprocessor system. Logic 1 applied to the fan start input of Fig. 5 switches the starter l.e.d.s red to green. After a short delay the red l.e.d., which indicates that the fan has run up to speed, turns on and a logic 1 appears at the fan-running terminal. The delay must be allowed for by the software. This circuit can be used for both fans and for the fuel pump with a smaller capacitor to simulate the faster response. If the fan-failure switch is closed, the starter will operate but the fan will not run up to speed. The a-to-d converter in Fig. 6 gives an output proportional to the fuel temperature. This output is between 00 and FF (0 and 255) and can be displayed as °C without scaling. Once the oil is lighted, the ignition can be switched off. If the fuel pump stops, however, the flame will go out. Flame failure and ignition failure can be manually introduced at any time as shown in Fig. 7 and the program should cater for these eventualities.
Digital noise filter

Simple design suitable for electronic clocks

by P. A. F. Lam

Although l.s.i. techniques and mass production have produced reliable low cost digital clocks, the logic circuits are still susceptible to false triggering pulses from electrical noise and switching transients. A common solution to this problem is the addition of a carefully designed low-pass filter, but, in some applications, this does not always remove the problem. A more effective solution is the addition of a simple digital noise filter which can eliminate over 90% of all false trigger pulses.

A typical digital clock arrangement is shown in Fig. 1 (a) and a modified circuit is illustrated in Fig. 1 (b). The filter is based on a non-retriggerable monostable, shown in Fig. 2, whose time constant must be smaller than the period of the incoming pulses in Fig. 3. In most clocks i.e., the time reference is derived from the mains frequency, therefore, $T = 1500\text{ms}$ and $<1/50$. Because the monostable is non-retriggerable, the clock is immune to noise which occurs during the $T$ period in Fig. 4. If a pulse appears in the $T$ region, the monostable is triggered but the next correct trigger pulse occurs within the new $T$ range and is rejected. Therefore, the reference frequency is not changed and the phase error only lasts for one pulse. Clock accuracy can only be affected if a continuous stream of noise pulses occur during the $T$ region in a time $>T/n$ where $n$ is $(T/T_f-1)$.

A longer period for $T$ gives a higher noise immunity coefficient $n$ but, usually, it cannot be longer than 95% of $T$ due to the stability of the circuit. If this filter is to be used in a very noisy environment, the addition of an ordinary power-line filter will improve the performance. Application of this circuit is not limited to digital clocks because the design can be extended to any digital signal which has a periodic nature e.g., the synchronizing signal from a communication modem.

We have received from Plewsy an application note on the use of the TDA 1065A phase- controlled i.e. in closed-loop systems with both frequency or voltage feedback. It is available from Plewsy Semiconductors, Crosby Hill Estate, Knutsford, Cheshire, WA6 6HA.

Multiplex keying system for organs – 2

A practical solution to the wiring problem of multiple key contacts in pipe or electronic organs

by A. W. Critchley, Dipl.EI., M.I.E.R.E.

TDM system reduces drudgery and cost of building an organ, whether pipe, electronic or hybrid. It permits a wide range of organ features, many hitherto unobtainable on electronic organs, allowing closer simulation of pipe organs at a fraction of the cost. The principles can easily be adapted for microprocessor control at a much lower hardware cost and complexity.

As demultiplexers comprise not only a significant part of the electronics but also a source of complexity it obviously pays to use the extension principle, see part 1. The various manual outputs come out of the pitch shift register at different times so they must be delayed to arrive at a common demultiplexer at the same time. So manual scan period delays are necessary. When collecting the voice outputs for an extension organ, but not for the traditional one.

Mixture stops

These are normally found only on the large pipe organs and almost never on cinema organs. The principal reason is that they require two or more ranks of pipes for each stop. They have a peculiarity in that the notes sounded are always toward the top of the range, no matter which keys are played, to add brilliance. To achieve this the individual ranks break to lower notes as they come in turn to the top of the keyboard. These breaks occur at different places in the scale of the manual. To be strictly musical these stops should key generators which are independent of the rest of the organ (and have no tremulant on them either) as the pitches are supposed to be true harmonics of the keyed pitches. This is really a question for argument amongst purists but the reasoning is that the multiple notes sounded generate beat frequencies which should be the same as the fundamental or other low harmonics of the keyed notes. With common generators this does not happen due to the deliberate mis-timing of the even-tempered scale and the resulting beats are off-tune. For most purposes this does not matter too much as a pipe organ is full of mistuned bits at the best of times (the chorus effect) due to the many independent pipes — especially so when mixture pipes are likely to be used. In an electronic organ of one generator rank it is a different story. Still, any mixture is better than no mixture and is simplicity to provide one with this system. The method is shown in Fig. 9 which shows how to generate a four-rank mixture stop as found on a large organ. This one is based on the one found on the choir manual of St Albans cathedral organ.

The range of notes played is from 45 to 92. The maximum pitch required from the generators is $\frac{3}{4}$th but the maximum pitch reduction of a key is $\frac{1}{4}$th (for notes 1 to 12). The pitch shift register thus has to extend for five octaves beyond unison range in order to accommodate this mixture stop.

Composition of a four-rank mixture

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From pitch system

- Voice stops
- Great string
- Swell stop
- Great Trumpet
- Great flute
- Great flute
- Great trumpet

Voice outputs to demultiplexers

Swell flute

Great trumpet

Pedal flute

Tuba

12\ ftr  but the maximum
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Timing

The union pitch delay due to sub-octave coupling and 3212 pitch generation amounts to three octaves. With the five octaves required to generate up to 8 ft for pitch, eight octaves have to be added so to each keyboard scan to give clearance between keyboards. This results in a total of 14 octave tuning. It would be reasonable to settle for the good octave number of sixteen which then allows for a super-octave coupling (2B pitch) if desired. A further keyboard scan period could be added to cater for other contact data such as stops, pistons, etc.

Sixteen octaves contains 192 pulses (keys). This is convenient as a suitable "cm.m.o.m. shift register contains 64 bits so that three packages would give the correct delay between manuals.

Demultiplexing

Conversion of the serial data back into parallel information to switch on and off the various pitches is performed in a demultiplexer consisting of a D-bistable per pitch and a decoder which sequentially clocks them. Fig. 10. The data inputs of all bistables are paralleled and each clock input receives one clock pulse per complete scan of the organ. The output data are therefore incremented in scan and faithfully follows the original keying.

There is unfortunately a practical problem with this arrangement in that the integrated circuits are packaged with separate data inputs and a common clock input. To overcome this, another shift register with taps at every stage is used to drive the data inputs sequentially whilst the clock input of the bistables receives a single clock pulse per scan. The clock input of the shift register is driven at the data pulse frequency. Fig. 11 shows the practical system.

The outputs of the bistables operate whatever form of keying circuit is to be used; a c.m.m.o.m. transmission gate is one possibility. A transistor interface would be used to drive a pipe organ magnet when the demultiplexer could be mounted on the pipe chest and thus save more wiring.

Automatic pedal

Pianists are sometimes called upon to accompany orators at an organ but are not able to perform adequately with their feet for the bass part of the music. Here is the answer.

The pedal department can be played from the lowest note only of whatever is being played on the manuals, usually the great mandal. Due to the scanning process, the first note obtained from the manual is also the one of lowest frequency. The simple circuit of Fig. 12 obtains this note and ignores the rest. The input data is set an R-D latch which can be set only once by the input data if enabled by the reset gating pulse. The resulting pulse is then shortened to obtain only the leading edge. This signal, together with a pulse occurring just before the great scanning period, reset a counter clocked at note rate. Its period is sufficient to place the output transition in the right place for the one to be played in the pedal scan time - it must be less than one total scan. A D-bistable and nor-gate reduce the long pulse from the counter to a one-note wide pulse at this time.

The output signal could be further gated to prevent further shifts from being operated by high notes on the manuals. It could also "break back" the pedal notes to the lowest octave whichever keys were being played if a variable shift register were also included.

Automatic melody

With a small organ it would be useful to be able to solo and accompany on the same manual without the bother and expense of second-octave keys or splitting the keyboard. This can be done by extracting the last, or highest, note from the keyboard in use and using it to operate some other keyboard or voice. It is the reverse of the automatic pedal system.

A counter with a period at least equal to the delay before the played note and the note to be played is clocked at the note rate. It is continually being reset by the input data from the manual so that the counter produces an output change at the correct time to activate the note to be played as a solo. To prevent continuous action, the reset-pedal is fed with a pulse which disables the counter after the time required to produce the output. If no notes are played, the counter will not then give a false result. A D-bistable and AND-gate converts the counter output back to a single note-wise output.

For soloing on the same manual with a different voice, a complication arises in that a single clock is to be reset just before that manual can operate. So to get the information from the voice demultiplexer requires that the counter have a delay to one total scan less one manual scan and the manual scan made up with a shift register to render it coincident with the original note.

Percussive action

For bells, chimes and similar percussive effects, each note has only a short duration even though the key may be held down. It also has to operate whether or not other keys are held down on the same manual. This is achieved by digitally shortening each note to a single data stream for a particular demultiplexer. One such circuit will work for all the notes on that demultiplexer. Each note has its own decay system as required for the voice effect which is part of the demultiplexer.

A suitable period for each note to operate is perhaps two scans of the organ (96 seconds) and the delay is provided by a shift register.

An AND gate cancels out any pulses after the two scan periods. The shift register must be clocked at note rate but the total delay to be in increments of the total scan time to effect cancellation in the gate. This gives a long shift register, Fig. 14.

One of these circuits can handle all the percussive requirements of the entire organ if the output is routed and gated by appropriate manual gating pulses. With
Further delays in increments of manual scan periods it can also provide pizzicato coupling between manuals. These delays already exist in the coupling system of the British Amateur Television Club and has contributed many articles to their magazine CTV as well as to other magazines and Wireless World (Aug. 71).

His interest in organs is purely private, learning to play the church organ at the age of 14 in St Annas-on-Sea in Lancashire. Famous broadcasters on the cinema organ impressed him in this instrument, and later he became Minor's organist at a cinema in Uxbridge, playing for his own amusement. A life-long interest in organs led to several unfurnished electronic organs -- whoever finishes one of these projects! They must surely have the highest mortality rate of any home construction project. Presently he is building a three-manual entertainer type of organ with all the effects and second touch which embodies the principles outlined in this article.

Arthur W. Crichtley is President of Crosspoint Audio Limited of Scarborough, Ontario. He is a former committee member of the British Amateur Television Club and has contributed many articles to their magazine CTV as well as to other magazines and Wireless World (Aug. 71).

This page contains a list of telephone numbers and addresses for various tube suppliers and manufacturers.

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**BOOKS**

Hi-Fi Choice No. 20 — Cartridges and Headphones, by Martin Collins, is the latest in this very useful series of guides to the choice of audio equipment. It follows the familiar form of a long introduction for both technical and non-technical readers, preceding a large number of test reports and data charts, buying recommendations and comparison charts on cartridges and accessories, the same procedure being followed for headphones. Clearly, the reviewers themselves are an extremely useful guide to what is going on of this type of device, which is not easily understood by the layman, the information otherwise being too remotely culled from a large number of audio magazines, if it exist at all, but perhaps the most helpful parts of these books are the introductions. There have been many attempts to explain the finer points of audio devices to the general public, but these are models of clarity.

Hi-Fi Choice No. 20 costs £2.00 in paper- back, is published by Sportscene and is available from bookstalls.

Communicating with Microcomputers, by Ian H. Witten, is a layman's introduction to methods of relating humans and microcomputers. The book begins with some general talk on the subject of what micros are and what they can do, establishing the level of subsequent treatment and explaining some of the terms to be used later in the book. Communication within the micro itself — buses and bus control — is then examined with a view to providing a sound base for the ensuing descriptions of input and output and machine interface equipment keyboards and v.d.u. for example. Later sections of the book are concerned with the technology of graphics displays and their control, and with the ways in which a microcomputer can be used to build programs. Throughout, the processor is considered as a component in a system, and programs are dealt with at all.

Dr Witten was, until recently, at the Man-
imelane Systems Laboratory of the University of Essex, and has contributed several articles to Wireless World on the subjects covered in this book. The publishers are Academic Press Inc. (London) Ltd, 24-28 Oval Road, London NW1 7DU, and the book costs £8.80 in hardback (£9.50 in paperback).
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**Tellegen’s theorem and some applications**

Encounters with a powerful network tool

by Harry E. Stockman

Although Tellegen’s theorem is a really basic network theorem, implying as it does a re-statement of the law of energy conservation in networks, it is not often given the attention it deserves by electronics engineers. This article first introduces the original formulation of the theorem in terms of energy and power, then discusses an immittance version of it, written for driven networks with storage elements, and finally gives some examples of its application to practical linear networks.

Tellegen’s theorem is one of the most basic network theorems ever formulated, since it implies a re-statement of the law of energy conservation as applied to networks. It offers a highly useful method for analysis of electrical systems. In mathematical shorthand, the fundamental message of the theorem may simply be stated as $\Sigma v \cdot i = 0$, where $v$ is current, $i$, voltage, and $t$, time.

The prerequisites for the use of the theorem are knowledge of the network topology, and Kirchhoff’s laws. In some instances and special cases one need not even know the network topology so long as certain mathematical relations pertaining to the network are known. Typically, Kirchhoff’s voltage-sum law and Tellegen’s theorem together imply Kirchhoff’s current-sum law, and the latter plus Tellegen’s theorem imply Kirchhoff’s voltage-sum law.

The very general nature of Tellegen’s theorem is evident from the fact that it holds for all dependent sources as well as for independent networks, whether time-variant or time-invariant. It is valid for the periodic steady state as well as for transients, and for reciprocal as well as non-reciprocal networks. With reference to transients, we should not be surprised to find that among the many things that can be arbitrarily added or subtracted, the excitation of the system can be almost anything, with one or more driving sources, in any mixture of coherent, incoherent, and random sources.

The system can be driven in the steady state, periodic steady state, or transient state, with exponential and sine-wave drive common cases. In spite of all these remarkable features the theorem is not well known, or rather, it has remained quite unknown to the practical engineer up towards the end of the 1970 decade. The reason for this is the stark simplicity of the theorem, its appearance of being self-evident. In numerous applications it is simply taken for granted.

In this short article we shall stay away from any and all proofs of Tellegen’s theorem. The reader interested in such proofs may consult ref. 2, which proceeds to show how Tellegen’s theorem may be used to derive or prove other theorems. Virtually, if there is no end to the number of theorems derivable from Tellegen’s theorem. The following quotation from ref. 2 is timely: “There is hardly a basic network theorem that cannot be proved by invoking Tellegen’s theorem”. A few typical cases are Heaviside’s transient theorem, Van der Pol’s transient theorem, the reciprocity theorem, and the reactance theorem. The last two are well known. Heaviside’s transient theorem deals with energy supplied during transients in non-linear networks, and Van der Pol’s transient theorem pertains to excess electric energy over magnetic energy in a CLR one-port, excited by direct voltage. Actually, when we are using Tellegen’s theorem, we are inclined to automatically involve other theorems, and indeed we shall find this to be true in the following.

Tellegen’s theorem implies that the energy entering the system equals that leaving it, some of the departing energy often being changed into other forms of energy. We may write a basic power relation for resistive networks in the simple form

$$ P_{in} = P_{out} + P_{lost} $$

Here $P_{in}$ includes the power contributed by existing non-linear, or any non-linear source of energy, the sign of the term being decided by the relative direction of the current and voltage that applies to each dependent source. These sources, so common in today’s transistor devices and circuits, are here of the simple kind $I(V)$ or $I(V)$, in complex notation $k$ and $k$. The proportionality constant $k$ may also be complex. In the following application examples we shall limit ourselves to linear networks.

Reducing to immittance

In his theorem formulation, Tellegen employs current–voltage products, thus dealing with power, readily extended to energy. Accordingly, he achieves an elegant treatment, independent of the precise form of the network, its number of meshes and nodes. In communications and electronics, however, many energized networks are inherently of single-mesh or single node-pair form, or can with a reasonable amount of work be turned into one or the other of these two forms. Some interesting possibilities now evolve. If, in a given power relation such as equation (1), we divide out the common variable (current in a mesh, voltage in a node pair), one of Kirchhoff’s laws results. If we carry out the same divisions a second time, an immittance (admittance or impedance) summation obtains, still governed by Tellegen’s theorem. While our reduction from power to immittance scarcely requires a theorem of its own, such a theorem has nevertheless been published. Written for driven networks with storage elements, the immittance theorem takes the general form

$$ \Sigma I(y) + Z_I(y) \cdot 0 $$

Note that this formula is restricted to single mesh and single node-pair networks. Like its parent theorem, the immittance theorem holds true whether the network is stable or brought to the point of instability. The summation always yields a zero with (2) providing an identity. This matter will be clarified in a following example. With reference to (2) it goes without saying that all sources must be converted to immittance by an application of the compensation theorem. Currents and voltages are automatically eliminated.

One important field of application for the original theorem as well as its immittance version is that of checking already obtained solutions to network problems. Such checking may involve considerable labour, however, particularly for algebraic solutions. On the other hand, since the Tellegen theorem solution may differ considerably from more common solution methods, the practical tool Tellegen has given us is highly useful for checking purposes.

As a first application example, consider the simple operational amplifier in Fig. 1, identified by the following formulas

$$ A_0 = \frac{V_0}{E} \quad R_{0} = \frac{R_{0}}{R_{0} + (1 + J) R_{0}} $$

Here $A_0$ is the system amplification, $R_{0}$ the system output resistance, $R_{0}^{*}$ the inherent amplifier output resistance, $R_0$ the load resistance, and $a$ and $b$ initially constants. The voltage $aV$ marks a dependent source. Let us dwell for a moment on the derivation of (4). Perhaps the most basic
Stability considerations

If our aim is to establish the stability conditions of a network in general, starting from the network, the above discussion shows that the summation of power, or, in other words, the so-called power, is not a sufficient criterion. The specific case of \( R_s = R_{out} \), we don't mind that \( R_s \) is in our derivation. This is the key to the point where Telllegen's least costly condition gives us the mathematical foundation. In general, we will terminate the port in \( R_{out} \) instead of \( R_s \) and employ the compensation theorem to determine the output impedance. Our experience may simply be to determine this impedance, we have already learned how to do this, how can we then get the transfer function of signal, it is known, but now let us instead assume that it is unknown, then we have the following (8) then hnn a very direct method of determining output impedance from a given network. We must find the ratio of \( t \) to (8) above examination of the network, we arrived at a summation that gave zero. The same result obtains if we instead work from \( v_t \), or from \( i_n \), into the network, and then form the quotient \( v_t \div i_n \), which is \( R_{out} \).

As another alternative, we may for a moment go back to the time when Thévenin’s and Norton’s theorems were combined into a single compensation theorem. This theorem formulation shortens the time we would like to use, the output impedance of the Thévenin and the Norton equivalents, existing simultaneously. The proof is specifically described by the Thévenin-Norton dependent-source theorem, being one of the names under which this theorem appears. The stationary solutions in the two network equivalents under the same conditions. That \( E^* \) simply implies the output impedance, and this is true whether or not the network contains dependent sources.

The starting point for the application of this theorem may be either the network, or its transfer function, which in our example is (3). Thus (4) is actually included in (3). This entire procedure for deriving the Thévenin generator and the Norton generator from the transfer function is a specific application of the time-saving theorem called the equivalent generator theorem. This theorem has been discovered in the same way that the problem of the output impedance can be read directly off without the need for any calculations when

With reference to our example, with (3) the proper transfer function, the theorem simply states that the statement is equivalent to the denominator, the term that describes the load as far as the source is concerned. If in fact, a negative-feedback system, for which Telllegen’s theorem is not valid, can be made to work with this theorem.

Practical example

Above we have given particular consideration to a situation in which we wish to make this quantity a key issue in the application of Telllegen’s theorem. The network of Fig. 1. is in fact, a negative-feedback system, for which Telllegen’s theorem does not hold. The network, the above examination of the network, we arrived at a summation that gave zero. The same result obtains if we instead work from \( v_t \), or from \( i_n \), into the network, and then form the quotient \( v_t \div i_n \), which is \( R_{out} \).
Bourgeois ballistics
There has never been a better time for the d.i.y. enthusiast. Employing tradesmen to come and poke about in your house or on your car gets more ruinous by the day, and the results are very often little better than could be achieved by a troop of monkeys with a talent for social advancement. Run-of-the-mill kitchen, bricklaying, plumbing and painting need hold no terrors for the averagely decent and even those of us with a full set of ten thumbs usually win through in the end. You can often obtain a lot of your work from friends, for the de-creased sitting-room or a nicely finished set of bookshelves.
There has always been a feeling of cosiness, for me, in all these d.i.y. magazines. The same old subjects appear every year; loft insulation in November, swimming pools in May. It’s astonishing the things some people will attempt, but I doubt that many folk would consider a project I’ve just seen on a press handout, here on my desk—a do-it-yourself bullet-proof kit for vehicles. No experience necessary, it says here. There’s one thing, though; it could give rise to some stimulating over-the-garden-fence conversation.

“Morning, George.”

“Morning, Harry. No, I’m just bullet-proofing the car. The wife keeps getting shot up on the way back from the supermarket’s, so I thought I’d beef the old bus up a bit. It’s coming along, I’ve filled all these bullet holes in every weekend.”

“Yes, see what you mean. Mind you, it’s all right for your three-car garage and luxury stuff, but you’ll be in trouble with those blasted bazooka rockets.”

“Well, I haven’t got one yet for more than heavy-calibre machine-gun protection. I said I’d put the new line down the road that’s coming out today, and you know what she’s like if I don’t do things straight away. She’s out this morning, down at the hand-grenade class.”

Butter side down
Having just taken our library out of the orange plastic boxes it came from Dorset House, I had a unique opportunity to observe Murphy’s Law in ineradicable action. The library’s former home was more a hole in the wall than a room and everything was stacked up in unusable heaps of eradiation. We’ve got stuff here going back to 1911 and the collection is growing all the time, what with the scores of magazines and books in and out of print, the library also used to be the place where all the office embarrassments were buried, on the basis of a fair review, up until 2011 they wouldn’t matter any more. Packing it all up for the move, we decided to give the old behemoth a great stack of papers and books that we didn’t want and couldn’t find space for. Some of it hadn’t been seen, let alone used, since the BBC was a Company, not a Corporation. So, with a heavy heart and with mewing and wailing, we shang it. After all, you have to be sensible about this sort of thing—it’s not a bit of good hoarding waste paper. We kept the useful stuff and the more important historical material and thought we’d done well.

I expect most of you are well ahead of me by now. Yes, of course, the very first thing that sprang to our new, streamlined office, efficient library was in one of the old maga-

No sale
Now we are heading so surely towards the cashless, chummy society you would think commercial transactions would have become simplicity itself. It only seems to be a mere mechanical process of transferring a few digits out of one computer into another in a matter of microseconds. Not so, unfortunately. The old Adam (which includes his rib, I hasten to add) still holds sway in such ignoble distinc
tions as distrust of the other fellow and his computer.

The other day, for example, we had a despairing phone call from an engineer in a large public utility who was unsuccessfullly trying to buy a bit of electronic parts from one of our mail-order advertisers. Could we help? Apparently the public utility wanted to place an order through its normal system, by which payment would be made through its usual bank payments. The mail-order firm, however, was not paying. They insisted on cash on order, or, no sale. It seems at least three wise accountants in the public utility had had a go at it at different times, so doubt objects catch them off guard with a variety of siren voices; but no, they were adamant. Mind you, I can understand their reluctance. A firm who runs a small business tells you that you can easily face ruin with a few of these large corporations as customers—there can take up to a year to pay their bills. Anyhow, the engineer in question should offer the engineer was: why not pay the required sum himself, out of his own pocket, and then recoup it later from his employer, who surely must be honest enough to cough up? There was a sharp intake of breath at the other end of the telephone, followed by a long silence: “Oh, er... I don’t think our organisation could cope with anything like that...”

It’s extraordinary that there can be such a stalemate between two parties who genuinely want to do business together. One is keen to buy, the other is willing to sell, but because each is a stranger to the other, the method of transaction the result is no busi
tness at all. As long as this generation has not become so fortyfied it’s surely time we got in some of those intelligent machines that can contribute to the savings in time. About half a month. Machina sapiens might be able to teach homo sapiens a thing or two about how he should be functioning.
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