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OF

THE INSTITUTION OF ELECTRICAL ENGINEERS

FOUNDED 1871; INCORPORATED BY ROYAL CHARTER 1921

PART B SUPPLEMENT

INTERNATIONAL CONVENTION ON TRANSISTORS AND ASSOCIATED SEMICONDUCTOR DEVICES

MAY 1959

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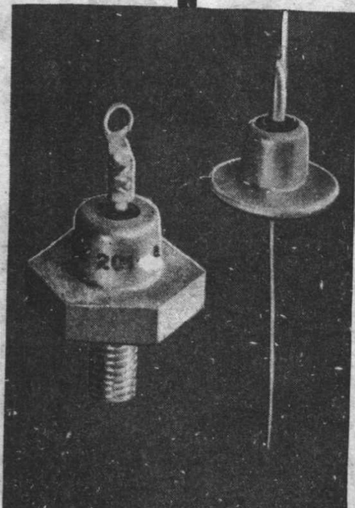
AEI Silicon Junction Rectifiers



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Ratings

TYPE	P.I.V. volts	TYPE	P.I.V. volts	TYPE	P.I.V. volts	TYPE	P.I.V. volts	TYPE	P.I.V. volts
MAXIMUM CURRENT AT 25°C									
0.7 amp.		1.0 amp.		1.5 amp. *		2.3 amp. *		10 amp. *	
SJ051B	50	SJ052B	50	SJ051A	50	SJ052A	50	SL101A	100
SJ101B	100	SJ102B	100	SJ101A	100	SJ102A	100	SL201A	200
SJ201B	200	SJ202B	200	SJ201A	200	SJ202A	200	SL301A	300
SJ301B	300	SJ302B	300	SJ301A	300	SJ302A	300	SL401A	400
SJ401B	400	SJ402B	400	SJ401A	400	SJ402A	400		
SJ501B	500			SJ501A	500				
SJ601B	600			SJ601A	600				
MAXIMUM JUNCTION TEMPERATURE									
120°C		200°C		120°C		200°C		150°C	

* *When mounted on suitable cooling fins.*

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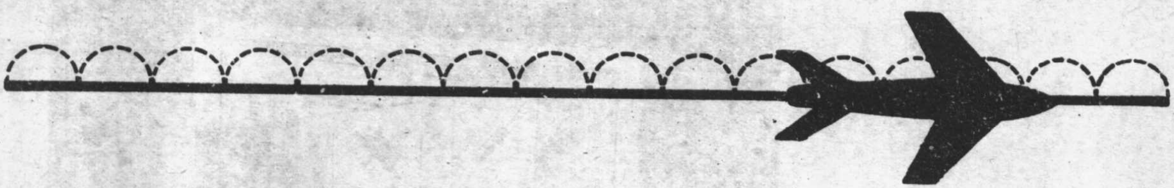

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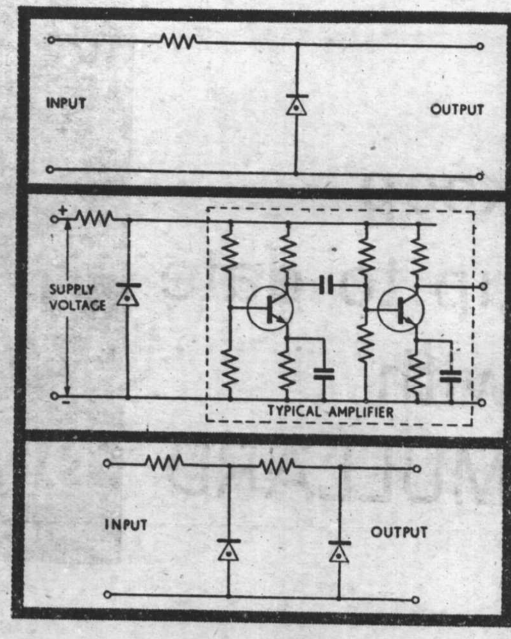

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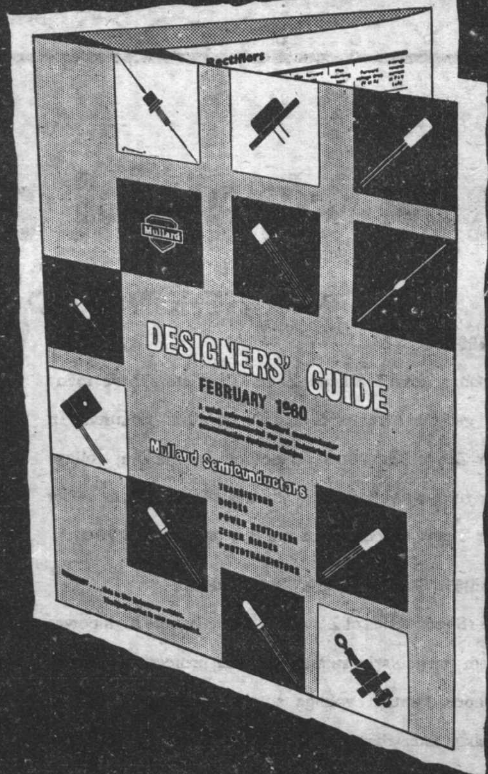

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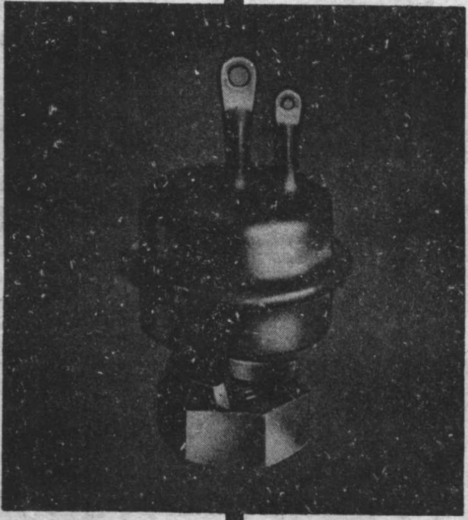

Some of the applications:

- ★ Motor Control
- ★ D.C.-A.C. conversion
- ★ Frequency conversion
- ★ Phase-controlled D.C. power supply
- ★ Static switching
- ★ Ignitron firing and numerous other applications in the aircraft, instrumentation and process control fields

Ratings

Rectifier Type:	Peak inverse voltage volts	Mean D.C. forward current amp.	Average Trigger power watts	Rectifier Type:	Peak inverse voltage volts	Mean D.C. forward current amp.	Average Trigger power watts
CX10/25	25	10	0·1	CX5/25	25	5	0·1
CX10/50	50	10	0·1	CX5/50	50	5	0·1
CX10/75	75	10	0·1	CX5/75	75	5	0·1
CX10/100	100	10	0·1	CX5/100	100	5	0·1
CX10/150	150	10	0·1	CX5/150	150	5	0·1
CX10/200	200	10	0·1	CX5/200	200	5	0·1
CX10/250	250	10	0·1	CX5/250	250	5	0·1
CX10/300	300	10	0·1	CX5/300	300	5	0·1

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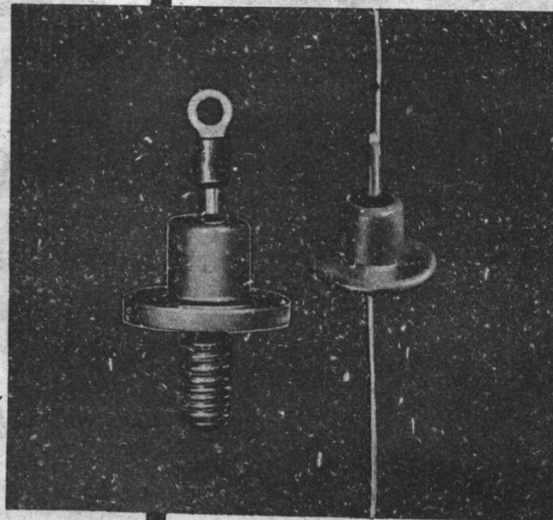
AEI 'ZENER' voltage reference Diodes



For precise control of voltage through specified slope resistance and temperature co-efficient

SOME OF THE APPLICATIONS

Stabilised power supply, Accurate voltage reference source, Voltage surge suppression, Over-voltage protection, and numerous other applications in the fields of instrumentation and control.

Ratings

TYPE	Reference Voltage at 20 mA			Dynamic slope resistance at 20 mA			Max. Reference current at 25°C	
	Min. volts	Typical volts	Max. volts	Min. ohms	Typical ohms	Max. ohms	Stud-mounted amp.	Wire-ended amp.
VR35	2·9	3·5	4·1	15	17·2	20	1·26	0·520
VR425	3·9	4·25	4·6	14	16·0	19	1·15	0·470
VR475	4·4	4·75	5·1	12	14·4	18	1·04	0·430
VR525A	4·9	5·25	5·6	12	12·8	17	0·97	0·400
VR525B	4·9	5·25	5·6	6	10·0	12	0·97	0·400
VR575A	5·4	5·75	6·1	5	5·8	10	0·90	0·370
VR575B	5·4	5·75	6·1	0	3·0	5	0·90	0·370
VR625	5·9	6·25	6·6	0	1·8	4	0·84	0·350
VR7	6·4	7·0	7·6	0	1·5	4	0·69	0·280
VR8	7·4	8·0	8·6	0	1·5	4	0·57	0·240
VR9	8·4	9·0	9·6	0	1·6	4	0·52	0·220
VR10	9·4	10·0	10·6	0	2·5	5	0·42	0·200

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SESSION ON APPLICATIONS—COMMUNICATIONS

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LINE COMMUNICATIONS INCLUDING PULSE CODE TECHNIQUES

By J. R. TILLMAN, D.Sc., Ph.D., Associate Member.

(*Lecture delivered at the* INTERNATIONAL CONVENTION ON TRANSISTORS AND ASSOCIATED SEMICONDUCTOR DEVICES, *26th May*, 1959.)

Despite some pioneering work in the applications of transistors to line transmission systems, we do not yet find the transistor in widespread use in these systems, and before some of the many potential uses are dealt with, reasons must be given for its slow entry into this field.

Modern systems of multichannel telephony have been evolving continuously over the past 25 years, taking advantage of improvements in cables and thermionic valves and in the theory of active and passive networks. The high standards now set and the system planning adopted make it difficult for any new active device to effect a quick entry into these systems unless the new device can match the valve in its gain-bandwidth product, noise factor and power output. So far, transistors in production fall short of thermionic valves on two or more of these scores, and, failing equality, the use of the transistor entails new systems, no matter what other advantages it can offer. New systems always take several years to develop; they can take quick advantage of past improvements in filter design and in cables, but it is not so obvious that current practices in the application of negative feedback to that most important item, the line amplifier, can be quickly applied to transistor amplifiers. Advances are being made here but more are needed, both in circuit configurations and in the engineering required to tolerate reasonable spreads of the more important transistor parameters. It may be that the common-base circuit, without much overall feedback, will be used, as well as configurations permitting much feedback.

The important question is: are the advantages offered by the transistor likely to offset the changes necessary in system planning and design? The problem has yet to be fully resolved. The much reduced power consumption is clearly an advantage at the terminals, where many active devices have to be accommodated, and perhaps it is equally so in making power-feeding to line amplifiers a relatively easy problem. These amplifiers would be buried or pole-mounted, and a transistorized system, though requiring closer spacing of its amplifiers, would require fewer buildings per route. Another advantage sometimes claimed for the transistor is that of greater reliability. But are the claims for these applications justified, on current evidence? Personally, I think not, and I would make a plea for much more information on this point. Because circuit engineers lack sufficient data on life performance, they cannot pay sufficient attention to the influence that their designs have on the overall reliability of their equipments. There may be insufficient feedback from the transistor manufacturer to the circuit designer and vice versa. Until operating organizations are reassured by field results on this very important point, the widespread introduction of transistors in this domain is bound to remain retarded. Perhaps the advent of transistorized multichannel v.f. telegraphy terminals which have preceded their counterparts in telephony (because they make fewer demands on the bandwidth and linearity of the active components) will provide a source of life data which can be translated for other systems.

Having explained the lack of any existing large-scale applications of the transistor, let me turn to some potential uses.

Power feeding to buried amplifiers will restore the repeater section length as one of the variables in the design equations of systems of carrier telephony. Section lengths can now be fixed by repeater cost and by the linearity which can be achieved with adequate gain and phase margins, rather than by the availability of buildings. There are even some indications that 2-stage amplifiers, by simplifying the problem of the application of loop feedback, may show to advantage. Thus, it may be practicable to carry ten supergroups on a $\frac{3}{8}$ in coaxial cable with a repeater spacing of three miles.

The cost of the terminal equipment of carrier systems has always been considerable, but the transistor offers several ways

Dr. Tillman is at the Post Office Research Station.

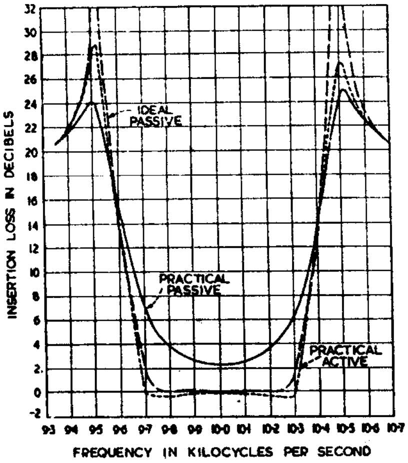

Fig. 1.—Transmission of M-derived band filters.

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ever, has it been considered worth while. Will the smaller size and much reduced power consumption of the transistor remove the reluctance to add an active element to these, hitherto exclusively passive, networks?

One of the greatest weaknesses of conventional carrier systems is the necessity for a high signal/noise ratio at all points along the route. It is possible to reduce, but by no means to eliminate, this stringency by the use of compressors and expanders; an earlier paper* described how the transistor offers considerable advantage in this application. Fig. 3 is a reminder of the overall performance of that compandor. A 2 : 1 logarithmic compression ratio and a 1 : 2 logarithmic expansion ratio have been accurately obtained over a signal range of 60 dB. The superiority of the transistor here over the earlier-used diode lies in the almost complete elimination of any series ohmic component of its input impedance, particularly at the low emitter currents used.

Many countries possess a considerable number of audio routes, usually loaded, between towns separated by 15–30 miles. The circuits must either be amplified by conventional 4-wire or 2-wire repeaters if they are to be of low loss, or, if not repeatered, must be so lossy as to be something of an embarrassment in the overall network. The Bell System has shown, on a very wide scale within the past few years, the benefits of fitting negative-

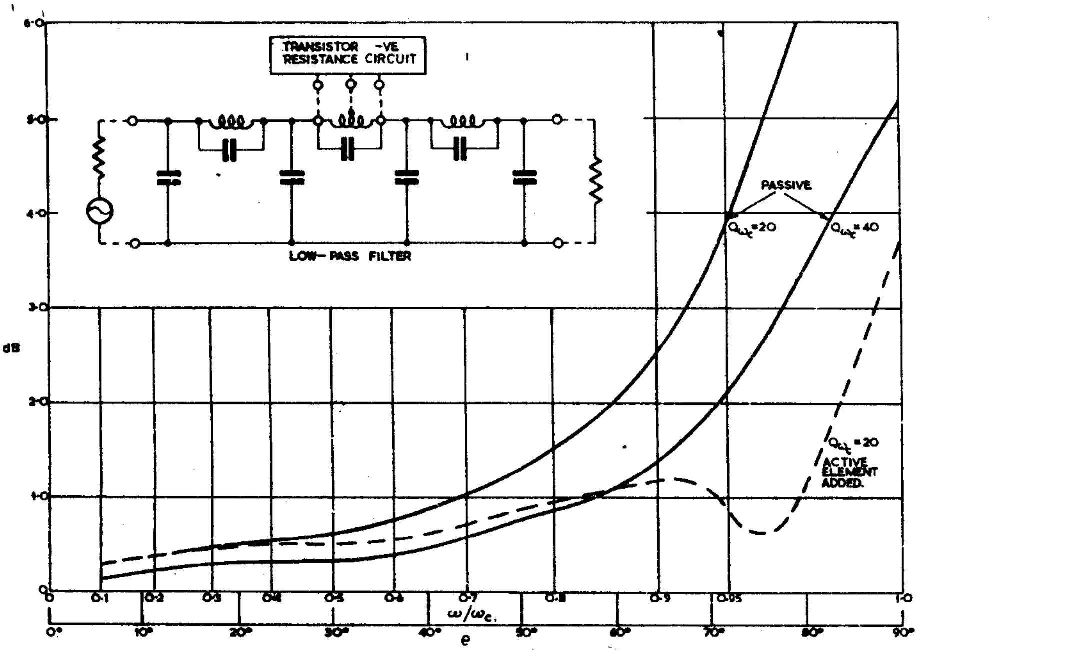

Fig. 2.—The transmission performance of a low-pass filter with and without an active element.
Horizontal scale linear in θ = arc sin ω/ω$_c$.

of reducing it. For instance, used as a modulator the transistor offers improved performance, certainly at frequencies up to 1 Mc/s or so, and demands less carrier power. A detailed study of this use is long overdue.

Transistors can also be used to reduce the pass-band losses of filters. Bangert showed how a band-pass filter can be improved (Fig. 1), and similar improvements can be obtained with low-pass structures. Fig. 2 shows the effect of one transistor compensating for the losses of three inductors, all deliberately degraded to emphasize the point being made. Similar improvements can be obtained using thermionic valves, but rarely, if

impedance amplifiers using thermionic valves. Linvill developed similar circuits using transistors, and I do not doubt that they are now finding uses in this application. Other transistorized negative-impedance convertors are possible, and the British Post Office is currently testing one of its own in the field. It is illustrated in Fig. 4; the upper half shows the essence of the convertor in its two forms, short- and open-circuit stable. Below we see how a pair, one of each type, can be used to form a T-network offering negative attenuation (i.e. positive gain) and a

* THOMSON, D.: 'A Compandor using Junction Transistors', *Proceedings I.E.E.*, Paper No. 2868 E, May, 1959 (106 B, Suppl. 16, p. 619).

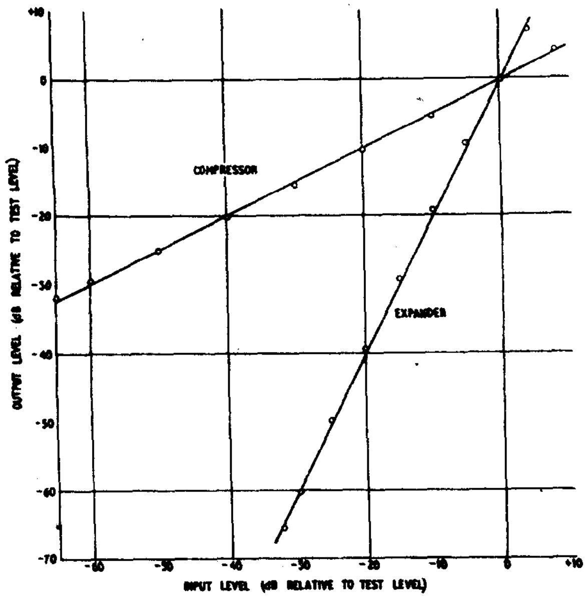

Fig. 3.—Compression/expansion characteristics of a speech compandor using junction transistors.

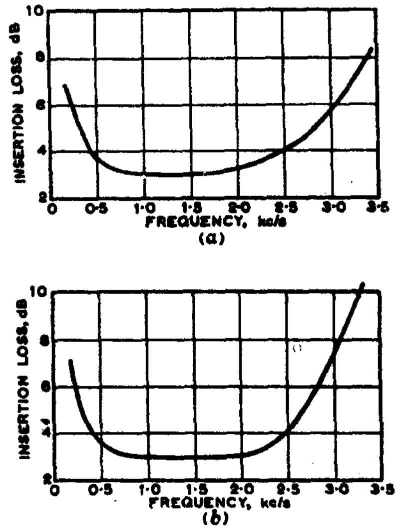

Fig. 5.—Insertion-loss/frequency characteristics of circuits.

(*a*) Repeater at one end.
Circuit consists of 22 miles of 20lb/mile p.c.q.t. cable loaded with 88mH coils at 2000yd intervals.

(*b*) Repeater at mid-point.
Circuit consists of 28·5 miles of 20lb/mile p.c.q.t. cable loaded with 88mH coils at 2000yd intervals.

good match to the cable impedance, as opposed to the poor match afforded by a single series or shunt negative element.

The improvements obtainable with this type of repeater are shown by the attenuation distortion curves of Fig. 5. The upper curve is appropriate to terminal use, the loss before insertion of the repeater being 10dB. The lower curve is appropriate to insertion at the mid-point of a slightly longer route for which the loss before insertion was about 13dB. Both circuits are stable for all terminating conditions, working and faulty.

When we turn from these very short repeatered routes to some of the very longest, the transoceanic routes, we find that

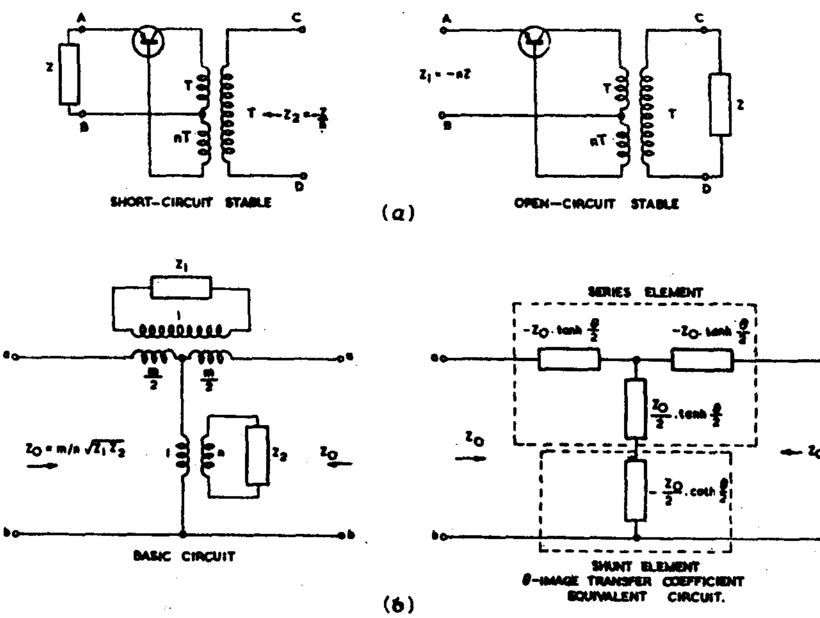

Fig. 4.—Transistorized negative-impedance convertors and their use in a repeater.

(*a*) Negative-impedance convertors.
(*b*) 4-terminal negative-impedance repeater.

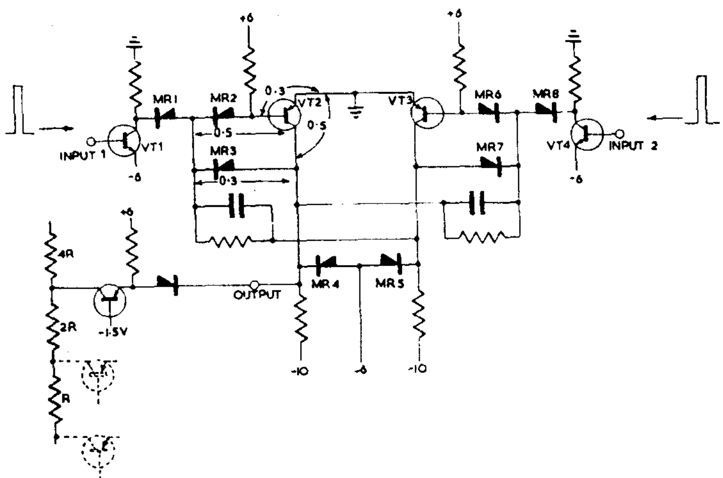

Fig. 6.—Use of transistors in p.c.m. equipment.
Circuit of part of the coder.

the immediate prospects of the transistor are being used negligible, and that widespread use within five to seven years will depend on favourable progress simultaneously on several fronts, transistor design, circuit design and transistor reliability. The ability of the transistor to work from a supply voltage of, say, 20 volts is an advantage which system designers would like to use, but above all, reliability must be established before long routes can be equipped.

Several attempts have been made to reduce the bandwidth necessary to transmit speech; systems have been based on analysing the spectrum of the voice signals and on transmitting a few key parameters which describe the spectrum. The parameters change at rates comparable with those of the movements of the mouth, i.e. very slowly, and can each be contained within a narrow bandwidth. Should any such system prove acceptable commercially, it would undoubtedly be designed around transistors. Its use would, however, be restricted to routes of such a length that the additional terminal equipment required was cheaper than the additional conventional channels it rendered unnecessary.

Even if bandwidth reduction is not thus possible, better utilization of a group of n circuits can be provided by using speech interpolation, in which a one-way communication channel out of the group of n is allotted to a conversation in the appropriate direction only when this is needed. The reverse direction of that circuit would be available for another conversation. There are expectations that m conversations could thus simultaneously take place with the ratio m/n as much as 2 without impairment being noticeable, provided that n is at least 20 or so. The terminal equipment is very extensive, using many thousands of transistors for a group of 36 circuits, and may prove economic only for the very longest (e.g. transoceanic) routes. The transistors are variously used as amplifiers, oscillators, detectors, gates, switches and other computing elements. The first installation, designed by the Bell Telephone laboratories, is scheduled for installation on London–New York circuits in a year or so.

I mentioned earlier the need for high signal/noise ratios in conventional amplitude-modulated carrier systems. Few attempts have been made to design multichannel systems based on alternative forms of modulation demanding less stringent ratios. F.M., p.a.m. and p.p.m. appear to offer no overall advantage. Pulse code modulation was extensively studied more than 10 years ago but also proved uneconomical, although it did replace line amplifiers by regenerators permitting poor signal/noise ratios and eliminating some linearity considerations. The coding equipment in particular was expensive, but coders using transistors are now being studied and are meeting with some success. Fig. 6 shows the type of circuit they involve. Here we have a part whose object is to switch on a constant-current generator on receipt of a pulse of short duration at input 1 and to hold the operation until receipt of a similar pulse at input 2. The speed of operation, using fast alloy transistors, is such that the rise time is about 60 millimicrosec; the output-pulse duration need be only 1 microsec. The use of the *n–p–n* transistors to turn on T1 (and later T2) and the prevention of bottoming by pairs of diodes (one germanium and one silicon), MR3 and MR2, and their counterparts for T2 make this fast operation possible. The circuit is included to show how differently line communication engineers may have to think in the future when wide-band linear amplifiers, ring modulators and filters may no longer completely dominate the field. P.C.M. systems may prove particularly attractive on some old cables installed before carrier working became universal, whose circuit capacity can be much increased by the use of a system which tolerates moderate amounts of crosstalk between pairs and does not require elaborate equilization. The regenerators may have to be fairly closely spaced, but power feeding will present little difficulty.

Several designs of amplifier for conventional audio routes are already in the field and transistorized systems for multichannel telegraphy have been successfully designed. If there is to be a large need for the transmission of data in the form of digital information over long distances, we can well see a big extension of the use of transistors, particularly at the terminals. Here the transistor will be able to start on level terms with the thermionic valve and may well dominate the scene from the beginning.