

VOLUME 106

PART B SUPPLEMENT NUMBER 18  
(IN THE SERIES OF SUPPLEMENTS NOS. 15-18)

1959



*The Proceedings*  
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

SAVOY PLACE • LONDON W.C.2

Price £1 15s.

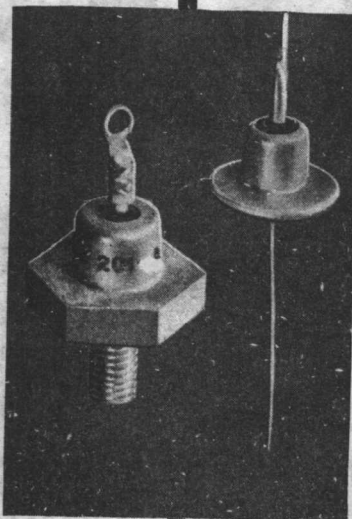


# AEI Silicon Junction Rectifiers

- \* Resistant to shock and vibration
- \* Completely reliable
- \* Fully 'tropicalised'

## SOME OF THE APPLICATIONS:

- Rectification • Control
- Magnetic amplifiers
- Brushless alternators
- Power packs • Blocking duties



## 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.

Write for full details to:

# AEI

**Associated Electrical Industries Limited**  
**Electronic Apparatus Division**  
 VALVE AND SEMICONDUCTOR SALES  
 LINCOLN, ENGLAND

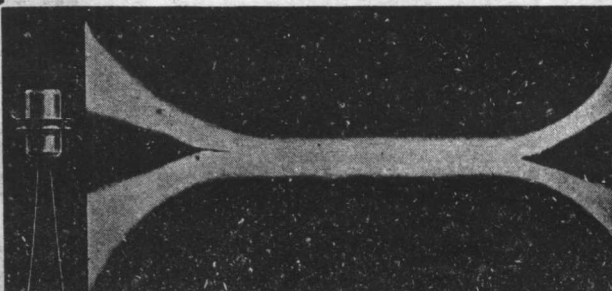
ADC73/04

3Q

## PRODUCTION

G.E.C. original processes  
now achieve  
**QUALITY · QUANTITY · QUICKLY**

3Q production—quality, quantity — quickly! That's the ideal production combination for semiconductors we've now achieved with G.E.C. originated manufacturing processes. And it's because these new processes have so revolutionised our production that you can be sure of getting the G.E.C. devices you want — when you want them! We offer you the widest range in the country — at really competitive prices too!

**G.E.C. was first with Cold-Welding research**

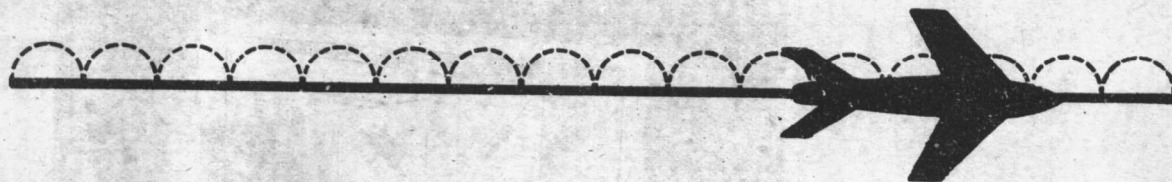
For a long time it was no secret that soft metals could be pressure-welded, but it was G.E.C. research that finally led to the use of cold-welding as a commercial process. The G.E.C. process of surface cleaning by scratch-brushing or etching and pressing between carefully designed dies now produces the type of weld that is perfectly suited to semiconductor manufacture. A G.E.C. cold-welded copper envelope has complete metal-to-metal uniformity, excellent electrical conductivity and thermal properties. The process does not involve the application of heat or fluxes which could damage or contaminate the device. It is a measure of the quality of G.E.C. research that the techniques evolved from it are now in use throughout the world.

QUALITY · QUANTITY · QUICKLY

**G.E.C.****SEMICONDUCTORS**

For information on the range of G.E.C. semiconductor devices please write to: G.E.C. Semiconductor Division, School Street, Hazel Grove, Stockport, Cheshire. Or in London area telephone TEMple Bar 8000, Ext. 10.





# Voltage straight and level...

WITH **TEXAS 1S5000** SILICON ZENER REGULATORS

## SHUNT STABILISERS...

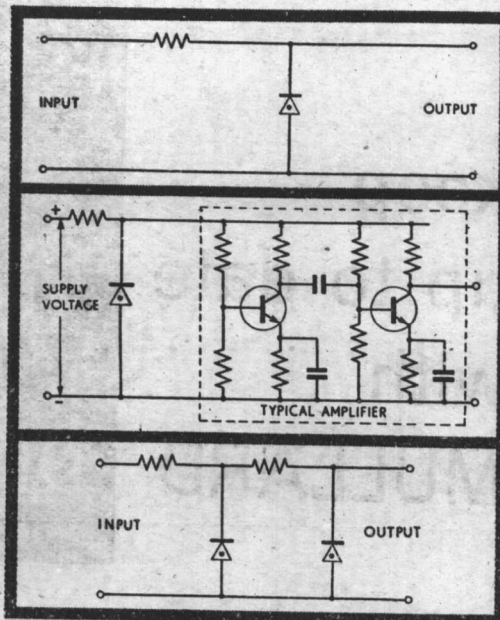
The Texas 1S5000 series of Silicon Zener Regulators have many advantages over gas-filled tubes in shunt stabiliser circuits. In particular Silicon Zener Regulators do not need a striking voltage greater than their running voltage, they are available in a wide range of voltage and the Texas 1S5000 series can dissipate up to 8 watts.

## PROTECTION AGAINST TRANSIENT VOLTAGE SURGES...

The ability of the 1S5000 series of Zener Diodes to handle high power surges makes them particularly suitable for the protection of transistors against short duration voltage surges. Maximum current permitted is much greater than the steady current rating since the duration of the current through the diode is short.

## SMOOTHING ELEMENTS...

The Texas 1S5000 series Zener Diodes can be used as filter components to give an output with low ripple content. The advantages of dispensing with bulky chokes and capacitors can be significant.



**8 WATTS · 15 to 150 VOLTS**

- 5% or 10% tolerances
- conventional or reverse polarity or double anode clipper
- Designed to meet the most stringent requirements
- $-65^{\circ}\text{C}$  to  $+150^{\circ}\text{C}$  operation

**JOINT SERVICE TYPES.** Many Texas transistors meet CV specifications. If you have a requirement for British Inter-Service types please write for full information.

Write for Data Sheets and Application Information on these and other TEXAS devices

**TEXAS TELL YOU MORE.** You can design more accurately with Texas semiconductor devices, because they are completely evaluated in terms of closely defined and reliable parameters, and are consistent in quality and performance.

## OTHER TEXAS SEMICONDUCTOR DEVICES INCLUDE

PNP GERMANIUM TRANSISTORS  
Switching - U.H.F. - Power  
- SILICON RECTIFIERS & DIODES  
High Voltage - Signal - Computer - Photo - Zener  
- SILICON CONTROLLED RECTIFIERS  
SEMICONDUCTOR-GRADE SILICON

**TEXAS**



**INSTRUMENTS  
LIMITED**

DALLAS ROAD BEDFORD ENGLAND

BEDFORD 68051

CABLES: TEXINLIM · BEDFORD

keep  
up to date  
with  
MULLARD



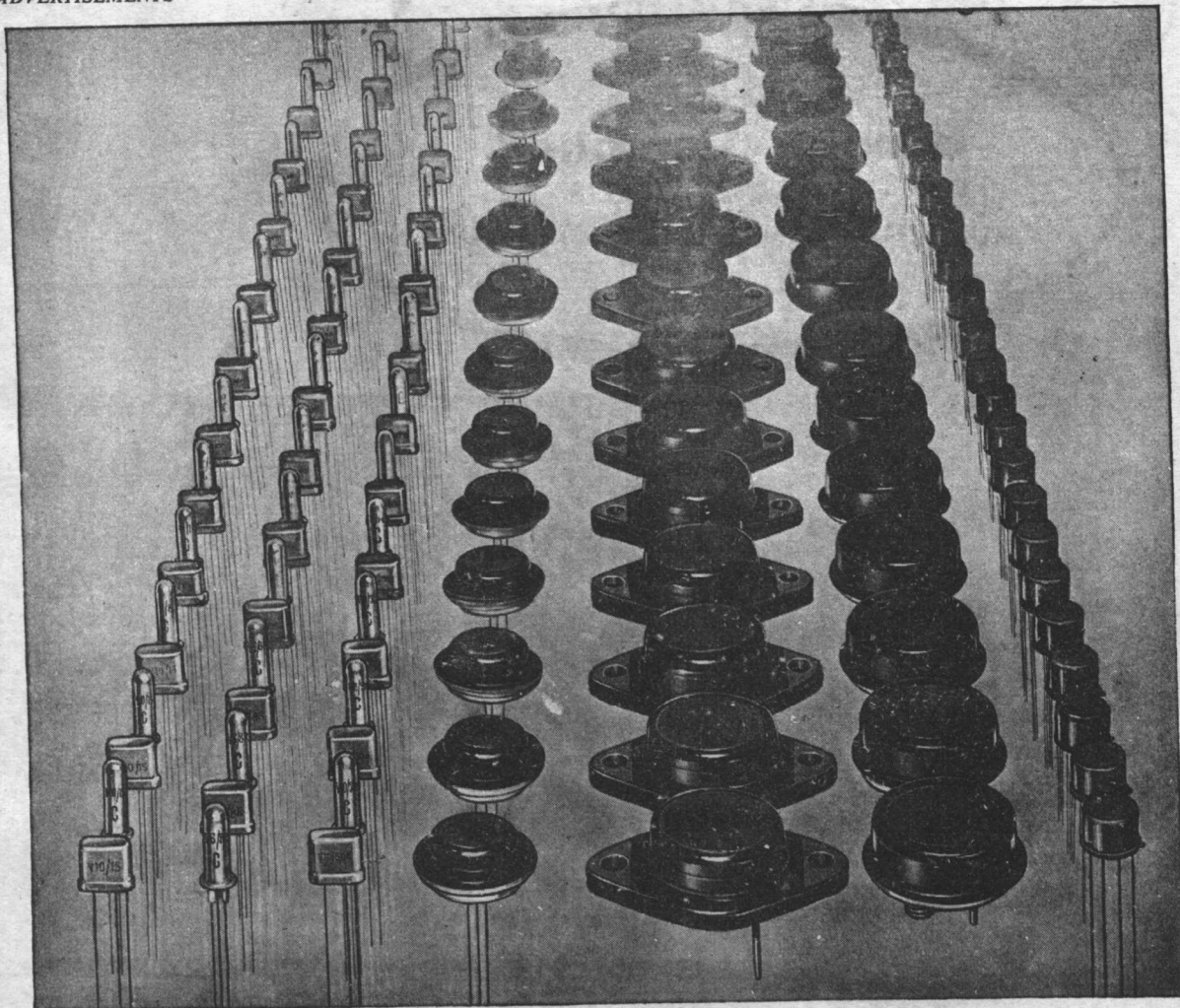
The Mullard policy of constant research and development means that new and improved semiconductor devices are always becoming available. You can make sure that you are up-to-date with this progress by asking to be put on the Mullard mailing list for 'DESIGNERS' GUIDE'. This leaflet, published every four months, gives the latest abridged data for every Mullard transistor, diode and rectifier that is recommended for new equipment designs.



**MULLARD LIMITED • SEMICONDUCTOR DIVISION**  
Mullard House • Torrington Place • London WC1 • Langham 6633

MIS 16





# The Newmarket range includes them all

Visit us at Stand No. G. 307 at The I.E.A. Exhibition

**NEWMARKET  
TRANSISTORS**

Switching	V10/1S, V10/2S, V10/18C, V10/28C	Voltage ratings 10, 15, 20V. Switching Rise times down to .1 $\mu$ s (V10/1S), .2 $\mu$ s (V10/2S) Max. dissipation 125mW; Peak current 500mA. Rectangular or K1007/A1/D2 standard cylindrical style can
R.F.	V6/2R, V6/4R, V6/8R, V6/2RC, V6/4RC, V6/8RC	Voltage ratings 6, 10, 15, 20, 25V. Typ. frequency cut-offs 3, 5.5, 10 Mc/s Max. dissipation 125mW; Rectangular or K1007/A1/D2 standard cylindrical style can
A.F.	V10/15A, V10/30A, V10/50A, V10/15AC, V10/30AC, V10/50AC	Voltage ratings 10, 15, 30V. Typ. betas 20, 40, 75 Max. dissipation 200mW; Rectangular or K1007/A1/D2 standard cylindrical style can
I.P. (Intermediate Power)	V15/20IP, V30/20IP, V60/20IP	Voltage ratings 15, 30, 60V. Typ. beta 40 Max. dissipation 2W; Max. current 2Amp.
N.P. (Noodle Power)	V15/15NP, V15/30NP, V30/15NP, V30/30NP	Voltage ratings 15, 30V. Typ. betas 25, 40 Max. dissipation 15W; Max. current 6Amp. Standard Diamond (JEDEC E2-42) Base Cold welded case
P. (Power)	V15/10P, V15/20P, V15/30P, V30/10P, V30/20P, V30/30P, V60/10P, V60/20P, V60/30P	Voltage ratings 15, 30, 60V. Typ. betas 15, 24, 40 Max. dissipation 10W; Max. current 3Amp.
VHF Drift	V15/20R	Voltage rating 15V. Typ. frequency cut-off 30 Mc/s. Max. dissipation 75mW; Max. current 12mA. JEDEC T O-5—welded case.

If you have not received a copy of our booklet "Semi-conductor Device Data", ask us to send you one.

**Newmarket Transistors Ltd**

Exning Road, Newmarket, Suffolk Telephone: Newmarket 3381/4 Cables: Semicon Newmarket

TA 2722

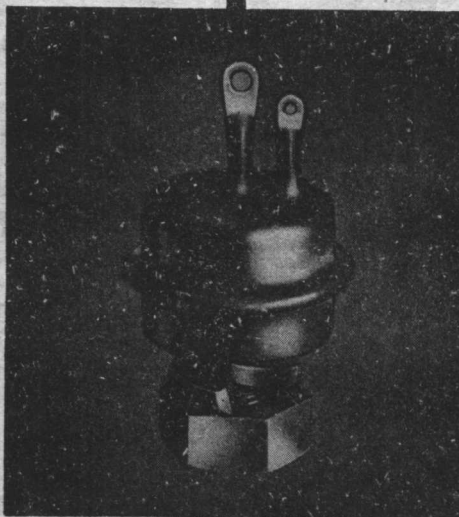
# AEI

## Silicon Controlled Rectifiers

**NOW IN QUANTITY PRODUCTION**

*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	Mean D.C. forward current	Average Trigger power	Rectifier Type:	Peak inverse voltage	Mean D.C. forward current	Average Trigger power
	volts	amp.	watts		volts	amp.	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

*Write for full details to:*



**Associated Electrical Industries Limited**

**Electronic Apparatus Division**

VALVE AND SEMICONDUCTOR SALES  
LINCOLN, ENGLAND





# HIGH EFFICIENCY SILICON RECTIFIERS

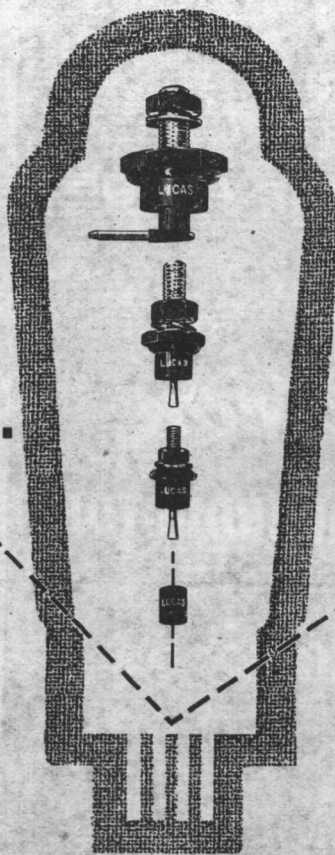


**250** m.A.

**35** AMPS

## MEAN FORWARD CURRENT

- Forward Current Ratings from 250 mA to 35A.
- Low reverse currents.
- Low forward voltage.
- Suitable for high temperature operation.
- P.I.V. up to 400 v.
- Available from production.



**Joseph Lucas Ltd**

BIRMINGHAM

Telephone  
Northern 5252

**G & E Bradley Ltd**

SILICON DIVISION

Telephone  
Gladstone 0012

ELECTRAL HOUSE, NEASDEN LANE, LONDON N.W.10

A Subsidiary Company of Joseph Lucas (Industries) Ltd.



# FERRANTI

offer

a wide range

of

*Silicon*

**SEMICONDUCTOR**

**DEVICES**

#### IN PRODUCTION

Small Signal Alloy and Diffused Junction Diodes  
Low, Medium and High Power Diffused  
Junction Rectifiers  
Zener Reference Diodes  
Voltage Variable Capacitors  
High Speed Alloy Junction Diodes  
2 Terminal Tetra Layer Switching Diodes  
High Voltage Rectifier Units  
Photovoltaic Cells  
Zener Power Regulators

#### TO BE INTRODUCED SOON

High Frequency Diffused Junction Transistors  
Alloy Junction Transistors  
High Power Diffused Junction Transistors  
3 Terminal Tetra Layer Diodes

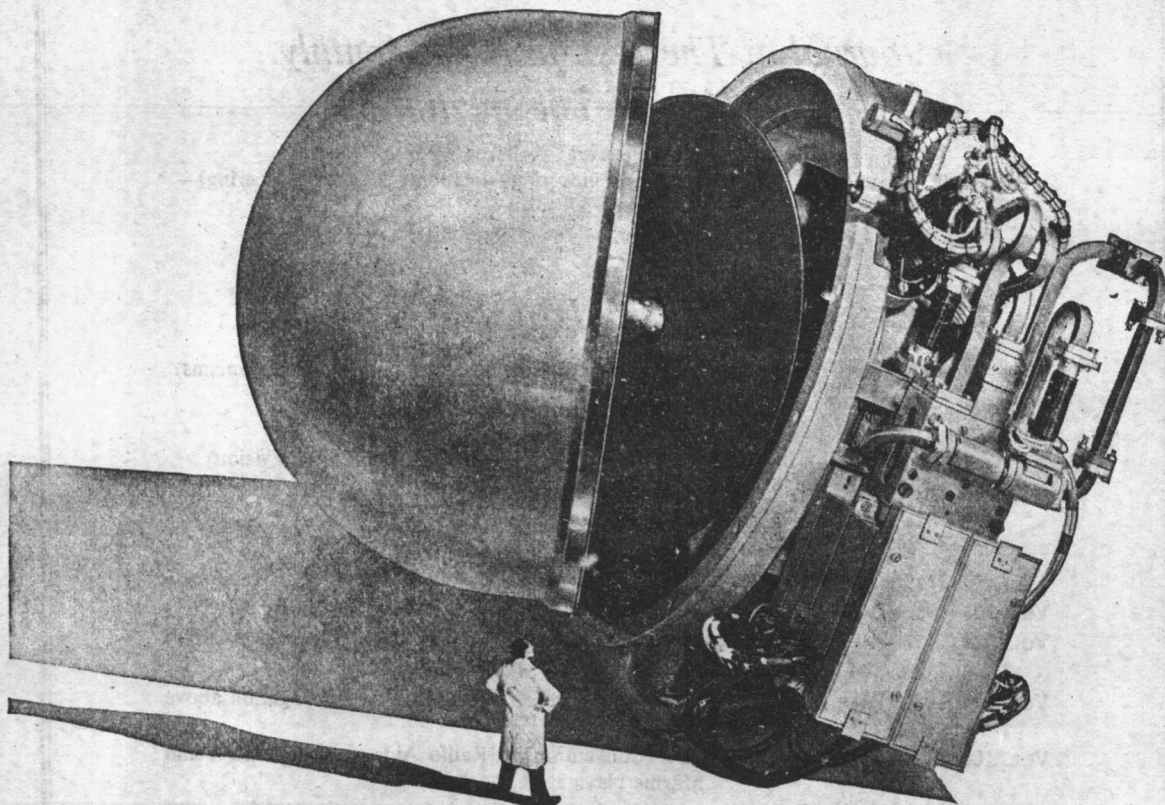


**FERRANTI LTD**

GEM MILL • CHADDERTON • OLDHAM • LANCs • Tel: MAIn 6661

London Office: Telephone TEMple Bar 6666

**Where great things are done  
with Microwaves**



**RADAR:** Fire Control • Navigation of Aircraft and Small Ships • Automatic Landing • Missile Guidance • Transponders • **COMMUNICATIONS:** Multichannel Radio Links for telemetering Data and Speech • **VALVES:** Klystrons and Magnetrons for 35/GCS and 75/GCS bands • Monitor Diodes for 1/GCS to 35/GCS • **INSTRUMENTS:** Comprehensive Waveguide measuring circuits covering 6 to 75/GCS • **RESEARCH:** Outstanding Research and Development of the latest techniques.



COMMUNICATIONS DIVISION • RADAR DIVISION • VALVE D.VISION  
MICROWAVE & ELECTRONIC INSTRUMENTS DIVISION • RADAR RESEARCH LABORATORY

**ELLIOTT BROTHERS (LONDON) LTD**

ELSTREE WAY, BOREHAMWOOD, HERTFORDSHIRE • ELSTREE 2040  
AIRPORT WORKS, ROCHESTER, KENT • CHATHAM 4/4400



A MEMBER OF THE ELLIOTT-AUTOMATION GROUP



Publications of  
THE INSTITUTION OF ELECTRICAL ENGINEERS

*Journal of The Institution—Monthly  
Proceedings of The Institution*

PART A (Power Engineering)—Alternate Months  
PART B (Electronic and Communication Engineering—including Radio Engineering)—  
Alternate Months  
PART C (Institution Monographs)—In collected form twice a year

*Special Issues*

- VOL. 94 (1947) PART IIA (Convention on Automatic Regulators and Servomechanisms)  
VOL. 94 (1947) PART IIIA (Convention on Radiocommunication)  
VOL. 97 (1950) PART IA (Convention on Electric Railway Traction)  
VOL. 99 (1952) PART IIIA (Convention on the British Contribution to Television)  
VOL. 100 (1953) PART IIA (Symposium of Papers on Insulating Materials)  
Heaviside Centenary Volume (1950)  
Thermionic Valves: the First Fifty Years (1955)  
VOL. 103 (1956) PART B Supplements 1–3 (Convention on Digital-Computer Techniques)  
VOL. 103 (1956) PART A Supplement 1 (Convention on Electrical Equipment for Aircraft)  
VOL. 104 (1957) PART B Supplement 4 (Symposium on the Transatlantic Telephone Cable)  
VOL. 104 (1957) PART B Supplements 5–7 (Convention on Ferrites)  
VOL. 105 (1958) PART B Supplement 8 (Symposium on Long-Distance Propagation above  
30 Mc/s)  
VOL. 105 (1958) PART B Supplement 9 (Convention on Radio Aids to Aeronautical and  
Marine Navigation)  
VOL. 105 (1958) PART B Supplements 10–12 (International Convention on Microwave  
Valves)  
VOL. 106 (1959) PART A Supplement 2 (Convention on Thermonuclear Processes)  
VOL. 106 (1959) PART B Supplement 13 (Convention on Long-Distance Transmission by  
Waveguide)  
VOL. 106 (1959) PART B Supplement 14 (Convention on Stereophonic Sound Recording,  
Reproduction and Broadcasting)  
VOL. 106 (1959) PART C Supplement 1 (Position Control of Massive Objects)

*Science Abstracts*

Section A: Physics—Monthly  
Section B: Electrical Engineering—Monthly  
Cumulative Index

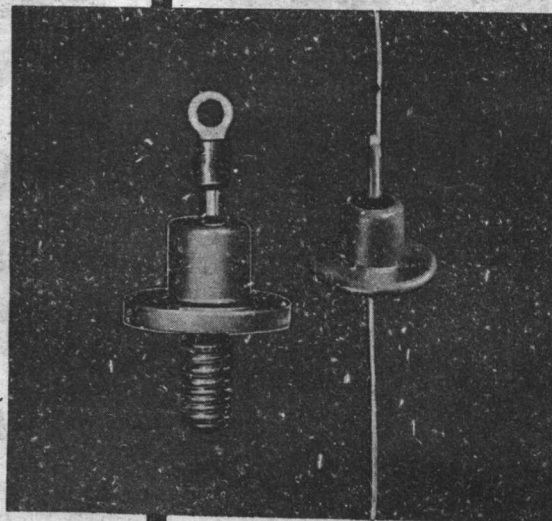
Prices of the above publications on application to the Secretary of The Institution,  
Savoy Place, W.C.2.

# 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

Write for full details to:



**Associated Electrical Industries Limited**  
**Electronic Apparatus Division**  
VALVE AND SEMI-CONDUCTOR SALES  
LINCOLN, ENGLAND





*the name to remember for*  
**INDUSTRIAL TYPE  
 TRANSISTORS**

**BIDIRECTIONAL GERMANIUM TRANSISTORS**

(Effectively symmetrical in significant parameters)

**TYPES TK 20 C, TK 25 C**

For high frequency switching circuits (cut-off frequency greater than 8 Mc/s with the TK 25 C), or small signal amplification.

**ASYMMETRICAL GERMANIUM TRANSISTORS****TYPES TK 30 C, TK 31 C**

For high frequency switching circuits (cut-off frequency greater than 8 Mc/s with the TK 31 C), these are asymmetrical versions of the TK 20 C and TK 25 C respectively.

**TYPE TK 23 C**

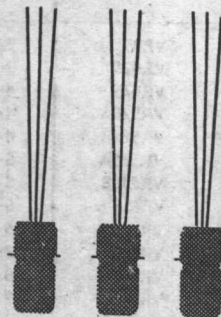
For general purpose low and intermediate frequency applications and telephone and telegraph carrier systems.

**TYPES TK 40 C, TK 41 C, TK 42 C**

For audio and intermediate frequency oscillators and amplifiers requiring high gain and a power output of several hundred milliwatts.

**SILICON TRANSISTORS****TYPES TK 71 C, TK 72 C**

For amplification, switching and control in extremes of ambient temperature; and having excellent saturation characteristics at high collector currents, unusual in silicon transistors.



60/6 MK

**Standard Telephones and Cables Limited**

Registered Office: Connaught House, Aldwych, London, W.C.2

**TRANSISTOR DIVISION: FOOTSCRAY · SIDCUP · KENT**

The Institution is not, as a body, responsible for the opinions expressed by individual authors or speakers.  
An example of the preferred form of bibliographical references will be found beneath the list of contents.

# THE PROCEEDINGS OF THE INSTITUTION OF ELECTRICAL ENGINEERS

EDITED UNDER THE SUPERINTENDENCE OF W. K. BRASHER, C.B.E., M.A., M.I.E.E., SECRETARY

VOL. 106. PART B. SUPPLEMENT NO. 18.

1959

## INTERNATIONAL CONVENTION ON TRANSISTORS AND ASSOCIATED SEMICONDUCTOR DEVICES

### SESSION ON APPLICATIONS—COMMUNICATIONS

621.391 : 621.376.56 : 621.382.3

The Institution of Electrical Engineers  
Paper No. 3058 E  
Apr. 1960

©

## 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  $\frac{1}{4}$  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.

VOL. 106, PART B SUPPL. NO. 18.

© 1960: The Institution of Electrical Engineers

[ 1183 ]

39



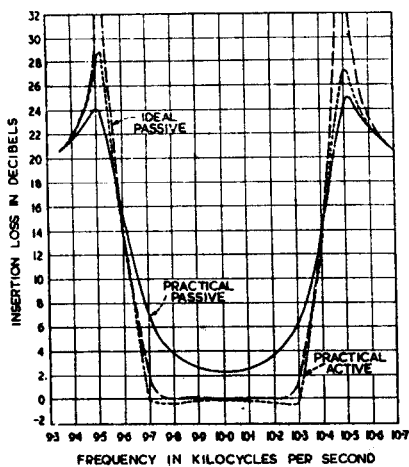


Fig. 1.—Transmission of M-derived band filters.

Reproduced by permission of Mr. J. T. BANGERT, the Bell Telephone Laboratories Inc., and the Bell System Technical Journal.

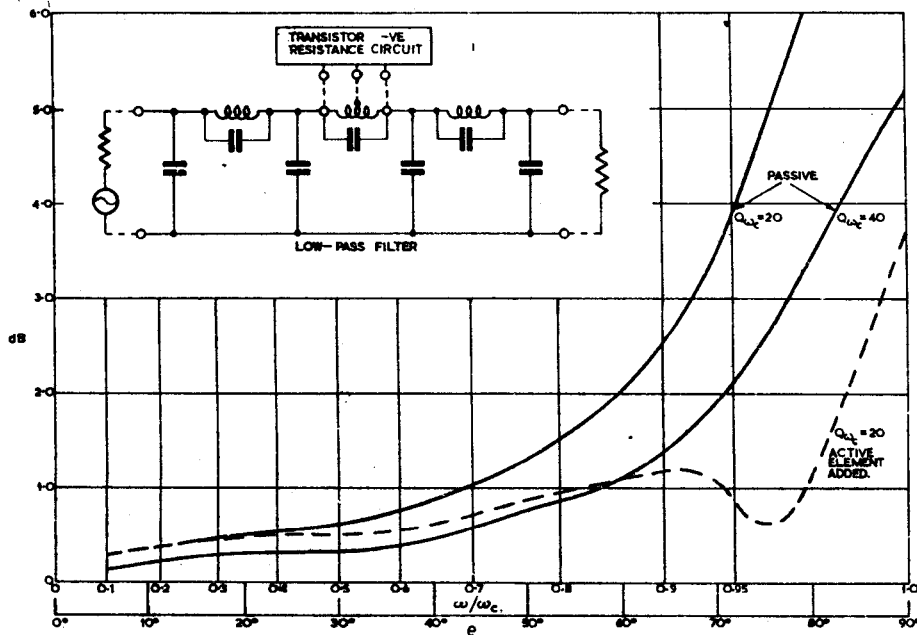


Fig. 2.—The transmission performance of a low-pass filter with and without an active element.  
Horizontal scale linear in  $\phi Q_c = \arcsin \omega/\omega_c$ .

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

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 repeated, 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-

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 converters 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 converter 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).

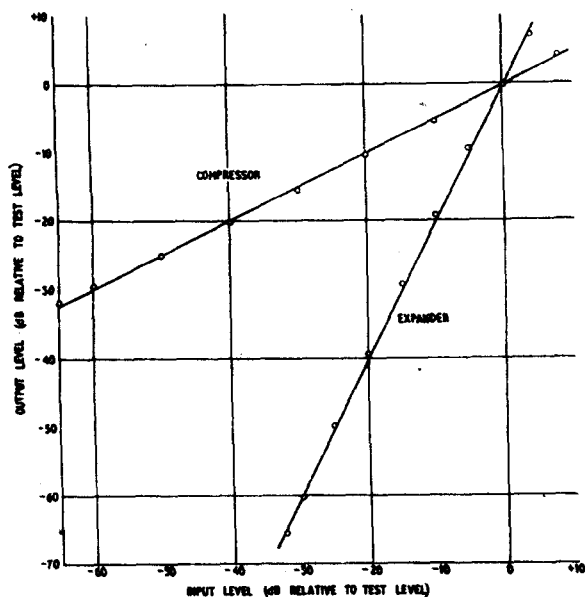


Fig. 3.—Compression/expansion characteristics of a speech compandor using junction transistors.

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 10 dB. The lower curve is appropriate to insertion at the mid-point of a slightly longer

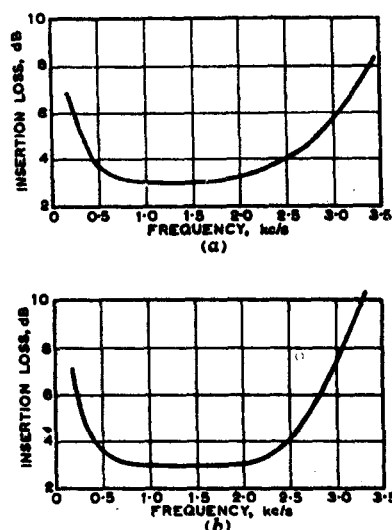


Fig. 5.—Insertion-loss/frequency characteristics of circuits.

- (a) Repeater at one end.  
Circuit consists of 22 miles of 20 lb/mile p.c.t. cable loaded with 88 mH coils at 2000 yd intervals.
- (b) Repeater at mid-point.  
Circuit consists of 28.5 miles of 20 lb/mile p.c.t. cable loaded with 88 mH coils at 2000 yd intervals.

route for which the loss before insertion was about 13 dB. Both circuits are stable for all terminating conditions, working and faulty.

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

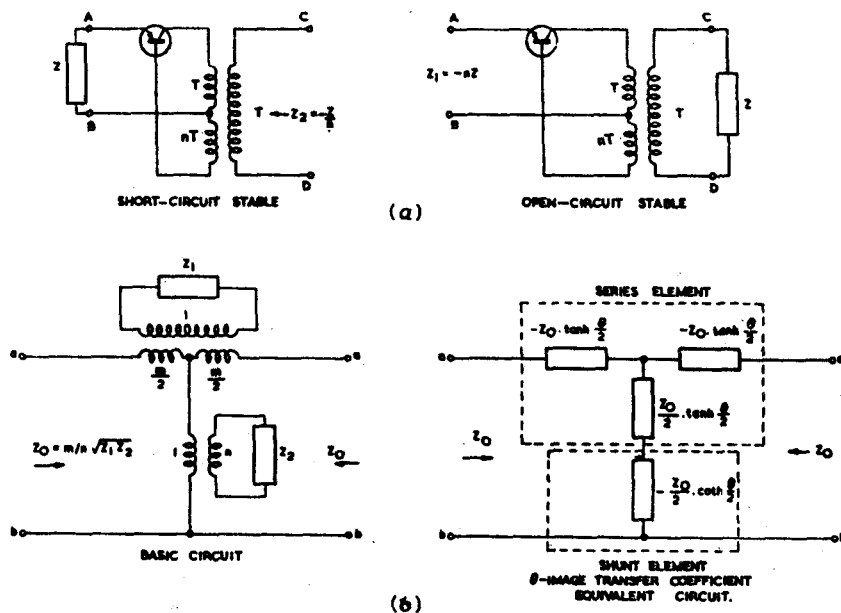


Fig. 4.—Transistorized negative-impedance converters and their use in a repeater.

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



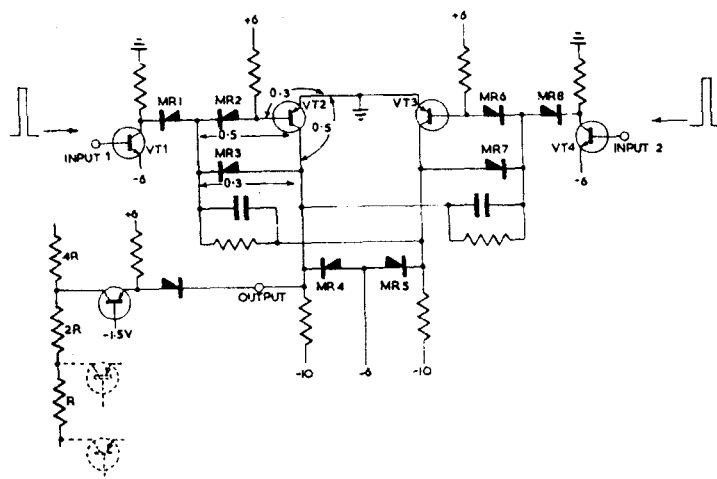


Fig. 6.— Use of transistors in p.c.m. equipment.  
Circuit of part of the coder.

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 equalization. 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.