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MARCONI

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ELECTRONIC INSTRUMENTS FOR TELECOMMUNICATIONS AND INDUSTRY

RESUME D'ARTICLES PUBLIES DANS LE PRESENT NUMERO

MODULOMETRE FM/AM TYPE TF 2300

On nous signale un nouveau modulomètre universel couvrant des excursions de fréquence et des fréquences de modulation plus étendues que les appareils sur le marché. Il offre également la plupart des possibilités dont on ne disposait antérieurement qu' en se servant de trois appareils distincts. Une caractéristique nouvelle est la mesure de la profondeur de la modulation d'amplitude. De plus, une méthode nouvelle et simplifiée permet de piloter par quartz l'oscillateur local. L'appareil peut fonctionner sur secteur alternatif ou sur piles.

Page 34

APPLICATIONS EN FM STEREO DU MODULOMETRE FM/AM TYPE TF 2300

Les mesures effectuées montrent que le nouveau Modulomètre FM/AM type TF 2300, en dehors de ses applications aux systèmes de télécommunication FM classiques, peut servir de démodulateur FM standard en stéréophonie. En liaison avec le Générateur de signaux FM/AM type TF 995A/8M1, il permet les mesures de distorsion et la séparation des canaux sur des récepteurs et émetteurs stéréo.

Page 39

UN APPAREIL DE MESURE COMPLET DE HAUTE PRECISION

Cet appareil de mesure monté sur rack a été conçu par la Division des Transmissions du groupe Plessey Electronics pour l'essai en série des composants d'ensembles multiplex. Pour atteindre les niveaux élevés de précision qui sont demandés, on a recours à des méthodes de mesure dans lesquelles on compare des niveaux relatifs à la perte par insertion d'un atténuateur étalonné. La précision de la mesure devient ainsi indépendante des étalonnages de l'appareil.

Page 42

MILLIVOLTMETRE ELECTRONIQUE HF TYPE TF 2603

Il s'agit d'un nouveau millivoltmètre entièrement transistorisé destiné à la mesure de tensions de 300 µV à 3 V dans la gamme des fréquences allant de 50 kHz à 1 500 MHz. La sonde de 12,7 mm comporte un montage de deux diodes au germanium à reconversion rapide fonctionnant en double alternance dont la réponse est proche de la valeur efficace réelle pour des puissances d'entrée inférieures à 30 mV et pour des valeurs de crête à crête dans la région de 0,5 à 3 V. Les graduations du cadran, longues de 12,7 cm, sont pratiquement linéaires; elles sont étalonnées en valeur efficace d'onde sinusoidale. Six accessoires sont proposés, dont un multiplicateur de 100/1 qui permet des mesures de tensions jusqu'à 300 V. L'appareil peut fonctionner sur les tensions secteur normales ou sur une pile raccordée aux bornes de sa face postérieur.

Page 47

ZUSAMMENFASSUNG DER IN DIESER NUMMER ERSCHEINENDEN BEITRÄGE

FM/AM MODULATIONSMESSER TF 2300

Es wird ein vollständig neuer Modulationsmesser für vielfache Anwendung beschrieben, der sich für größere Frequenzhübe und höhere Modulationsfrequenzen eignet als die bisher erhältlichen Geräte. Er läßt die meisten Verwendungsmöglichkeiten zu, für die nicht weniger als drei verschiedene Geräte erforderlich waren. Ein besonderes Kennzeichen ist es, daß auch die Amplitudenmodulationstiefe gemessen werden kann. Darüberhinaus gestattet eine neue und vereinfachte Methode die Quarzrastung des eingebauten Oszillators. Das Gerät läßt sich vom Wechselstromnetz betreiben und eignet sich für Batteriebetrieb.

Seite 34

FM STEREO-ANWENDUNGEN DES FM/AM MODULATIONSMESSERS TF 2300

Messungen haben ergeben, daß der neue FM/AM Modulationsmesser TF 2300 zusätzlich zu seinen Verwendungen in konventionellen FM Fernmeldesystemen auch als Standard FM Demodulator für Stereoarbeit verwendet werden kann. In Verbindung mit dem FM/AM-Meßsender TF 995A/8M1 können der Klirrfaktor und die Nebensprechdämpfung an Stereoempfängern und Stereosendern gemessen werden.

Seite 39

EIN VEILSEITIG VERWENDBARES PRÜFGERÄT HOHER GENAUIGKEIT

Dieses Prüfgerät, in ein Gestell montiert, wurde von der Abteilung "Übertragungstechnik" der Plessey-Electronics-Gruppe für Reihenprüfungen von Mehrkanalsystemteilen entwickelt. Um der erforderlichen hohen Genauigkeit gerecht zu werden, finden Meßmethoden Verwendung, bei denen relative Pegel mit der Dämpfung einer Eichleitung verglichen werden. Auf diese Weise wird die Meßgenauigkeit von der Eichgenauigkeit des Anzeigegerätes unabhängig.

Seite 42

ELEKTRONISCHES HF-MILLIVOLTMETER TF 2603

Es handelt sich hier um ein völlig neues Volltransistor-Millivoltmeter zur Ausführung von Spannungsmessungen von 30 µV bis 3 V über einen Frequenzbereich von 50 kHz bis 1.500 MHz. Im Meßkopf von 12,7 mm Durchmesser ist ein Paar schneller Germaniumdioden zur Zweiweggleichrichtung untergebracht; bei Eingangswerten unter 30 mV kommt die Anzeige der tatsächlichen Effektivspannung sehr nahe. Im 0,5 bis 3 V-Bereich wird der Spitzenwert angezeigt. Die Skalen des Millivoltmeters sind praktisch linear und etwa 127 mm lang; sie sind in Effektivwerten einer Sinusspannung geeicht. Es sind sechs verschiedene Zubehörteile erhältlich, darunter ein 100:1 Teiler, der Spannungsmessungen bis zu 30 V zuläßt. Anstelle eines normalen Netzanschlusses kann auch eine Außenbatterie zur Speisung benutzt werden. Sie ist an Klemmen anzuschließen, die auf der Rückseite des Gerätes vorgesehen sind.

Seite 47

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ST. ALBANS

ENGLAND

EDITORS

P. M. RATCLIFFE, A.M.I.E.E.

and

J. R. HAYWARD A.M.I.E.R.E.

Having withstood 800 winters, St. Albans Abbey will no doubt pass this year's environmental test. The first snow of winter came early this year and is shown here decorating the west front

In this issue

Measure μV at Gc/s. The new Electronic Millivoltmeter type TF 2603 goes a long way, in both sensitivity and bandwidth, towards meeting all the major r.f. voltage measurement requirements in the communications spectrum. This rectifier/amplifier instrument is all-solid-state—including the probe—and has a useful range of plug-on accessories. In case you are uncertain how TF 2603 fits in with our other voltmeters, here is a comparative table.

Type	*Valve or transistor*	*Volts range, full-scale A.C.*	*D.C.*	*Frequency range*	*Accuracy on centre ranges*
TF 1041C	V	0·3 V—300 V	0·3 V—1000 V	20 c/s —1·5 Gc/s	2%
TF 2600	V	1 mV—300 V	—	10 c/s —5 Mc/s	1%
TF 2603	T	1 mV—300 V	—	50 kc/s—1·5 Gc/s	3%

Back to a.m. Many transmitter engineers will remember our series of a.m. transmission monitors. These imposing rack-mounted assemblies, which measured modulation depth, noise and distortion, went out of production several years ago. Since then we have had no general-purpose a.m. modulation meter until now, when we are back in business with the TF 2300. This is, however, primarily an f.m. deviation meter developed from our current range of pulsed-i.f. discriminator models; by incorporating the various advantages of this range this new model is shown to do the work of three of its predecessors.

By way of a change we have a user rather than a designer writing about our instruments. In this article a Marconi Instruments transmission measuring set, m.f. oscillator and attenuator are shown to adapt readily to a comprehensive production test rig for insertion loss and linearity tests on multi-channel link components.

Accurater and accurater, as Alice might have said. Our latest universal bridge, keeping pace with the general trend in component accuracy, now measures resistance, capacitance and inductance to within 0·1%.

J.R.H.

MARCONI INSTRUMENTS

NEW DESIGN

621.317.799:621.396.61

F.M./A.M. Modulation Meter . Type TF 2300

by
V. F. ARNOLD

An entirely new general purpose modulation meter is described which caters for wider frequency deviations and modulation frequencies than previously available instruments. It also provides most of the facilities which in the past have only been obtained by using three different instruments. A new feature is that amplitude modulation depth can also be measured. In addition a new and simplified method of crystal controlling the local oscillator is provided. The instrument may be operated from a.c. mains supplies or from batteries.

FREQUENCY MODULATED transmission systems fall into three broad classes:—

1. Mobile and fixed point-to-point communications.
2. Broadcasting.
3. Telemetry and radio multi-channel links.

In all these systems it is necessary to make measurements on the carrier deviation of the transmission equipment and on signal generators which are used in the design and testing of the associated receiving equipment.

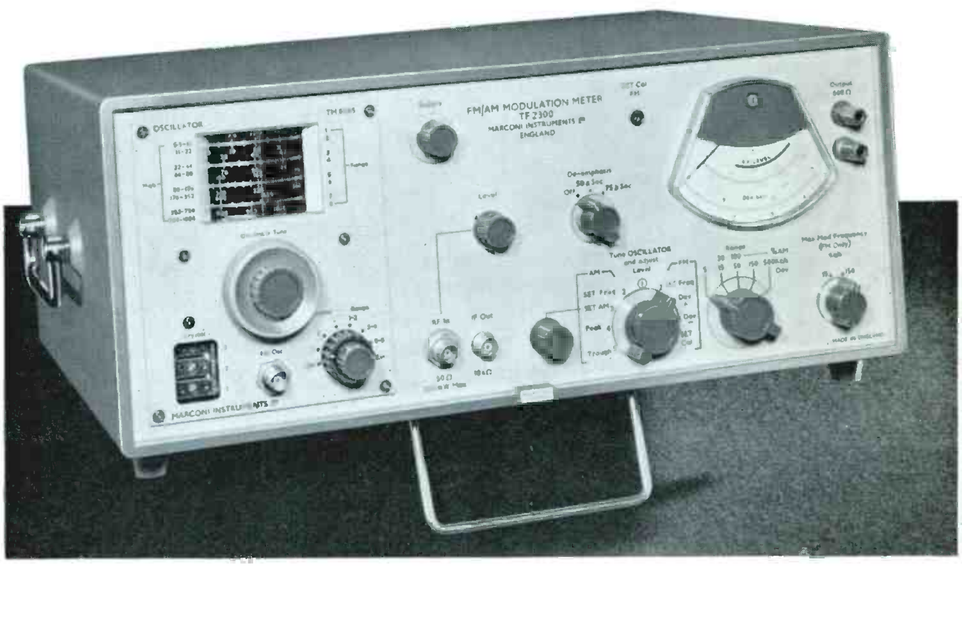
In point-to-point communication systems, narrow band deviation is used in which the maximum deviation is ± 25 kc/s or less and modulation frequencies are usually restricted to the audio speech range.

In broadcast systems the modulation frequencies are again restricted to the audio range excepting stereophonic broadcast systems where a much wider range of modulation frequencies is employed. In the most widely used system, the G.E.-Zenith system[1], frequencies up to 75 kc/s may be used. Frequency deviations of up to ± 75 kc/s are used in both ordinary and stereophonic systems.

Telemetry systems require much wider ranges of both modulation frequency and frequency deviation and the limits currently being introduced are 1·5 Mc/s and 1 Mc/s respectively. Multi-channel radio links may require modulation frequencies up to 20 Mc/s and frequency deviations up to several megacycles. At the other end of the range, deviations on sub-carrier systems may be only a few cycles. Amplitude modulation is also widely used in communication and broadcast systems and in some telemetry systems. Carrier frequencies in all these systems range from a few kilocycles to microwave frequencies.

In addition to measuring frequency deviation or modulation depth, manufacturers or users of transmitting equipment often need to make various incidental measurements; these include distortion and noise levels, spurious amplitude modulation on frequency modulated systems and spurious frequency modulation on amplitude modulated systems.

It is clear that any attempt to cater for all requirements in one measuring instrument would result in a costly and complex instrument providing facilities which the majority of users would not require. On the other hand



F.M./A.M. Modulation Meter type TF 2300 it would be inconvenient to use a different special-purpose instrument for each of the many applications. The obvious compromise is, therefore, to have a general purpose instrument which caters for the widest possible field of use, consistent with reasonable cost and the avoidance of undue complexity.

Modulation Meter type TF 2300 is a general purpose instrument which caters for all requirements in the fixed and mobile point-to-point communication field and for a high proportion of those in the broadcast and telemetry field.

The frequency deviation range is up to 500 kc/s at modulation frequencies up to 150 kc/s. This represents a fourfold increase in both the deviation and modulation frequency range compared with TF 791D Carrier Deviation Meter, the general purpose instrument previously available. This extension of range has been achieved while still retaining a low internally generated spurious f.m. noise figure in the region of –50 dB with respect to 5 kc/s deviation. No other wide range general purpose modulation meter currently available can equal this performance.

The instrument is built up from a number of sub-units. This arrangement is used to give maximum flexibility so that in the future modified versions could be produced by changing certain of the sub-units. Printed circuitry is used on all sub-units and wherever possible the sub-units are plug-in boards. All amplifier stages employ a high degree of feedback to give good gain stability, good frequency response and independence of transistor characteristics.

Being fully transistorized, the instrument can be operated from a.c. mains or from a nominal 24 V battery supply.

Fig. 1 is a block diagram of the instrument. The main sections of the instrument are described below in some detail.

Attenuator-mixer unit

As the input attenuator and mixer have to work at frequencies up to 1,000 Mc/s they are built in a single, compact, well screened unit. This construction helps to keep spurious responses at a low level over a very wide frequency range, by providing short signal paths, and allows for operation near high intensity r.f. fields.

The attenuator has a continuously variable loss and is of nominally constant input impedance, while the mixer is a conventional, untuned, square law type. By utilizing an external local oscillator it is possible to operate the equipment at frequencies much higher than the specification limit.

Local oscillator

With signal input frequencies to the instrument between 4 Mc/s and 1,000 Mc/s, the local oscillator frequency is such that an intermediate frequency of 1·5 Mc/s is obtained.

To achieve this the oscillator, which operates above the input frequency, has two basic ranges covering 5·5 to 11 Mc/s and 22 to 44 Mc/s. Higher frequencies are derived from the second range by using a frequency doubler circuit followed by two harmonic generator circuits. Permeability tuning of the oscillators and doubler circuit by means of ferrite cores is used, which has the advantage over capacitance tuning of reduced microphony.

A major difficulty in the oscillator design was to keep spurious a.m. and f.m. due to hum and noise to a minimum. At the highest frequencies a typical 'worst-case' example is a residual reading caused by noise and hum of –30 dB with respect to full scale deflection on the 5 kc/s deviation range, i.e. 160 c/s, in a 15 kc/s bandwidth. At the lower input frequencies residual readings are less than this, about –46 dB with respect to 5 kc/s, i.e. 25 c/s, for an input frequency of 250 Mc/s.

To obtain a smaller residual reading it is possible to crystal control the local oscillator frequency between 22 Mc/s and 1,000 Mc/s. This is achieved by inserting an appropriate series resonant crystal into one of the three crystal holders on the front panel. The crystal frequency should be between 22 Mc/s and 44 Mc/s, appropriate harmonics being used for the higher

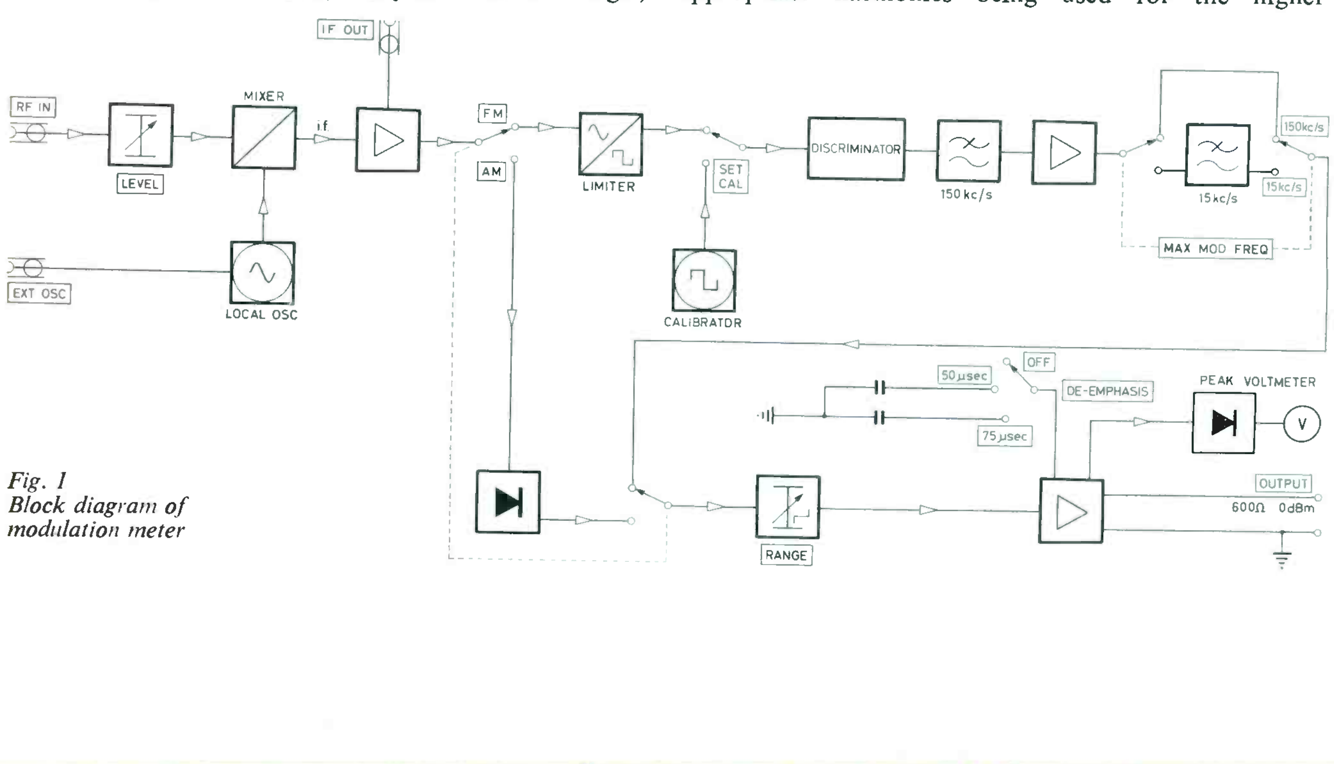


Fig. 1
Block diagram of modulation meter

frequencies. With a crystal controlled oscillator the maximum residual reading is in the region of –50 dB with respect to 5 kc/s full scale range of deviation, i.e. less than 16 c/s deviation due to noise and hum generated in the modulation meter. This figure is much the same over the entire frequency band.

Below 22 Mc/s crystal controlling the oscillator has no great advantage over the free running oscillator; thus on the lowest two ranges crystal control is not included as other sources such as the mixer contribute more to the noise figure than the oscillator.

It is worth mentioning the method of obtaining crystal control of the local oscillator, as it has one big advantage over the present Carrier Deviation Meter type TF 791D. In the TF 791D it is necessary to search for the crystal lock point, observing minimum meter deflection with external inputs removed. In the TF 2300, however, it is only necessary to set the local oscillator to its approximate frequency setting and to switch in the appropriate crystal and the oscillator is then 'locked'. Three crystals are provided so that three predetermined crystal controlled frequencies are available at the turn of a switch.

Because the local oscillator signal is derived by a harmonic method, some spurious readings may occur if the signal under test is also harmonically derived and has large amounts of sub-harmonics present, e.g. less than 20 dB down on the desired signal. An external oscillator input socket is available to which a 'pure' signal of nominally 200 mV e.m.f. and 50 Ω source impedance may be applied if any spurious readings are found. The use of an external oscillator can also be advantageous in certain measurements of f.m. on a.m.

The oscillator section is easily removable from the main instrument for servicing, by unscrewing it from the front panel. H.T. and r.f. connections are then exposed and can be unplugged from the main chassis.

When it is screwed in place in the instrument the whole oscillator is enclosed by a mu-metal screen. This reduces the effects of external fields (at supply frequencies) modulating the oscillator by changing the permeability of the ferrite cores used for tuning the oscillator, when the oscillator is in the free running condition.

The ferrite tuning cores are mounted on a carriage actuated by a lead screw which moves the cores relative to the coil. This arrangement also provides a slow motion tuning system.

I.F. amplifier

The i.f. signal, either a.m. or f.m. modulated, has to be amplified with as little distortion as possible. The primary requirements for a.m. are a flat amplitude/frequency response and a linear transfer characteristic, and for f.m. a linear phase/frequency response.

Because of these needs, the function of i.f. amplification is split into three parts, the first dealing with linear band-pass amplification of a.m. or f.m. signals direct from the mixer. Next, f.m. signals are passed through amplitude limiters while, lastly, a.m. signals pass through a tuned high level amplifier.

All the i.f. amplifier stages are feedback controlled in order to reduce the three basic forms of distortion and to stabilize against gain changes due to temperature and power supply variations. The i.f. band-pass filter has the optimum phase and amplitude characteristics for the modulations concerned.

Limiter stages

From the i.f. amplifier, f.m. signals are passed through three stages of limiting to eliminate amplitude changes. There is a limit to how much a.m. can be suppressed since, as the modulation depth approaches 100%, the limiters find more noise than signal to amplify in the modulation troughs.

The limiters have a secondary function, namely to measure the actual i.f. Provided the a.m. depth is not too great, all i.f. signals are clipped to a constant amplitude. The resultant rectangular waveform is then differentiated and the negative going pulses removed, leaving uni-directional pulses as in Fig. 2. These pulses have a d.c. term, Vm, almost proportional to the repetition frequency. This d.c. is fed to the meter to indicate when the correct i.f. is obtained. Indications of any carrier shift may be observed when modulation is applied to a carrier, since the i.f. monitoring circuit is fairly linear. The meter only gives qualitative information on carrier shift; if a quantitative result is required, a counter may be used in conjunction with the i.f. outlet on the front panel.

The discriminator

The operation of the discriminator is illustrated by the accompanying diagrams, Fig. 3 and Fig. 4.

A pulse of fixed amplitude and duration is generated every time the clipped i.f. signal passes through zero in the positive going sense, Fig. 3b and Fig. 3c. At any given constant repetition frequency these pulses will have a constant mean amplitude, Vm. When the pulse repetition frequency varies due to frequency modulation of the input signal, the mean amplitude will also vary at the

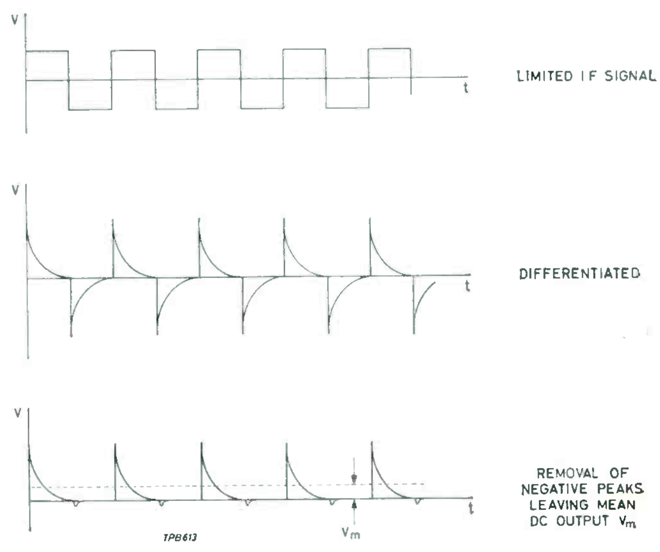


Fig. 2. Operation of limiter

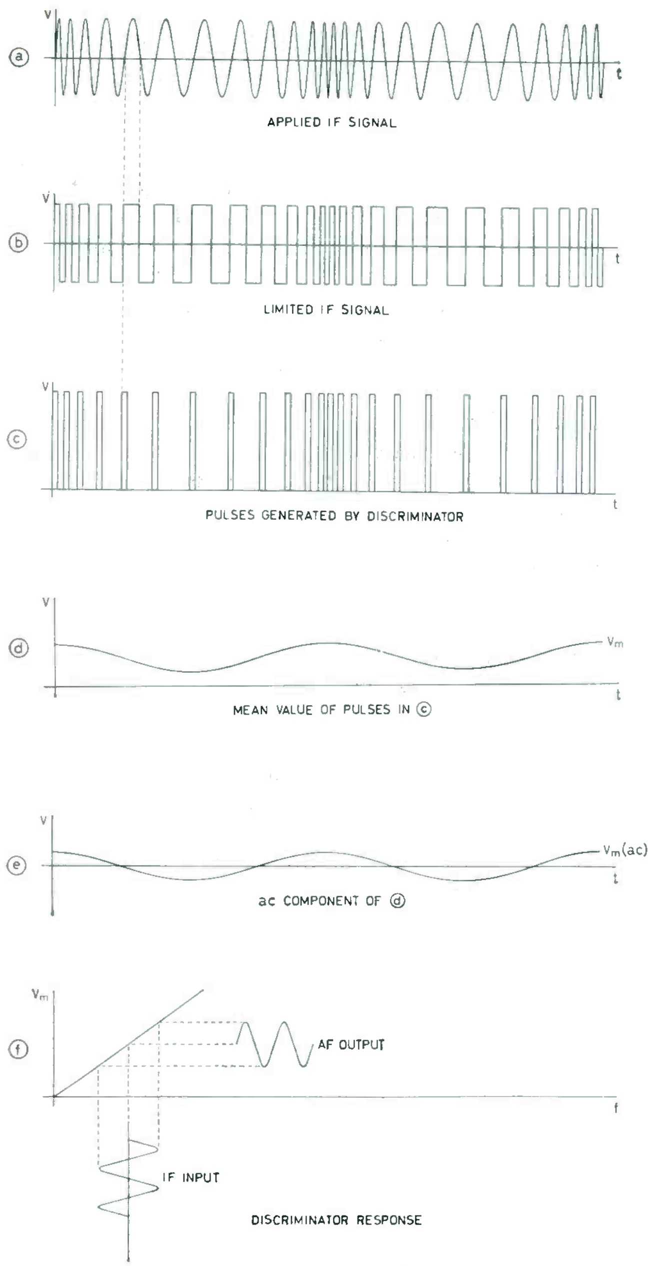


Fig. 3. Operation of discriminator

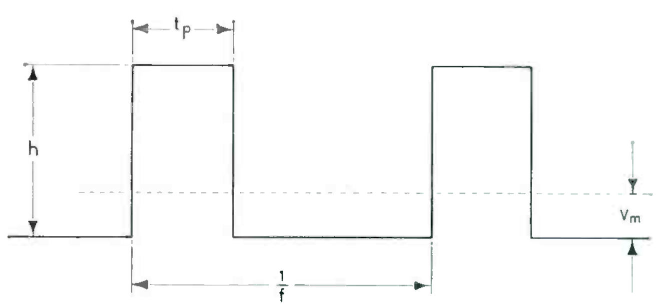


Fig. 4. Idealized discriminator pulses with mean amplitude indicated.

modulation frequency, Fig. 3d. Recovery of this variable component Vm (a.c.) achieves the required demodulation process.

For Fig. 4 the mean value, Vm, is given by:—

$$(h - Vm)\, t_p = \left(\frac{1}{f} - t_p\right) Vm$$

$$\therefore Vm = h t_p f$$

Hence the discriminator is, theoretically, perfectly linear (Fig. 3f). It is, to date, the only system of f.m. demodulation which has this desirable feature. There are practical limitations, one of which is the need to keep the pulse area absolutely constant. Even so, the discriminator has a combination of deviation capability, for a given noise figure, linearity and simplicity, that is difficult to approach with other types.

In practice the limiter output is fed to a Schmitt trigger circuit and the resulting rectangular waveform, which has a constant rise time, is differentiated and used to drive a pulse generator. The pulses from this are then taken to a low-pass filter to remove all but the modulation frequency components, which are then amplified in the l.f. section.

Calibration circuit

Some means of standardizing the discriminator and the i.f. circuitry is desirable in order that absolute f.m. accuracy may be maintained. A standard, crystal controlled, effective deviation is produced and injected into the discriminator input. The l.f. gain may then be adjusted by a front panel control, so that the correct deviation is recorded on the meter. This provides an absolute check for all possible sources of drift, apart from the range switching attenuator, which comprises resistors of sufficiently high basic stability as to render any check on them unnecessary.

Standard deviation is produced by gating a 400 kc/s crystal oscillator on and off at about 2 kc/s. The resulting bursts of 400 kc/s signal are fed to the discriminator as shown in Fig. 5. Thus a square wave output is obtained, at 2 kc/s, whose peak-to-peak amplitude corresponds to a ± 200 kc/s deviation.

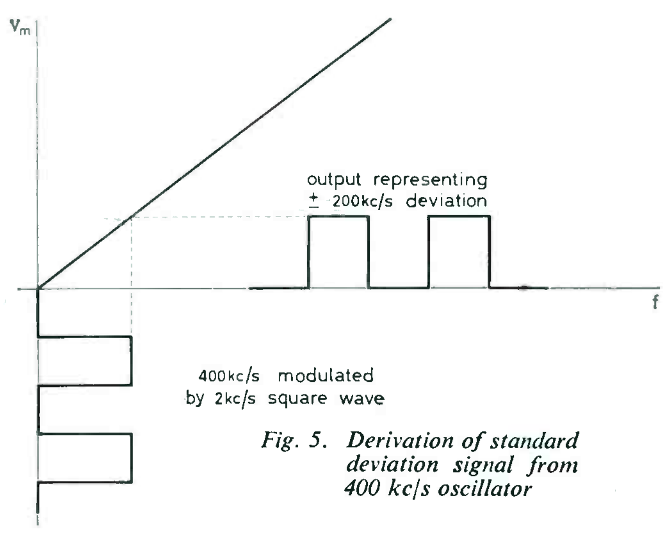


Fig. 5. Derivation of standard deviation signal from 400 kc/s oscillator

A.M. detector

The a.m. section of the instrument is designed to measure modulation of 0 to 95% depth and 30 c/s to 15 kc/s frequency at carrier frequencies from 4·0 to 500 Mc/s. There are two modulation depth meter ranges of 0 to 30% and 0 to 100%. To enable harmonics of the audio frequency range to be measured the modulation frequency range actually extends to 50 kc/s.

In operation the input signal is mixed with the local oscillator output in the same way as the f.m. signal, to produce a 1·5 Mc/s i.f. which is amplitude modulated. The mixer is linear over the required range of amplitude up to 500 Mc/s input frequency.

After the i.f. amplifier, the signal is fed into a further stage of i.f. amplification in the a.m. detector unit via a potentiometer which is used to bring the meter reading to the SET mark on the scale. This sets the correct carrier level at the detector diode and the reading is independent of a.m. depth since the d.c. component from the diode is used. This d.c. component is proportional to the average carrier level which does not vary with modulation.

After the signal is detected, it is fed via a 50 kc/s low-pass filter to the l.f. amplifier. The a.m. section uses the same range switching attenuator and l.f. amplifier as the f.m. section except for one stage of amplification.

For both f.m. and a.m. measurements, the a.m. detector is also used to set the signal level fed from the mixer to the i.f. amplifier. The output from the i.f. amplifier is fed into the detector and the d.c. component from the detected i.f. signal is then fed to the meter. This enables the user to set the level of the i.f. output of the mixer by adjustment of the signal input attenuator.

Low frequency stages

The l.f. section comprises two variable gain stages, an output amplifier and a peak reading voltmeter. Also there are two low-pass filters of 15 and 150 kc/s cut-off frequency respectively, which may be selected by a switch on the front panel. From the discriminator the pulses are fed into the 150 kc/s l.p. filter which produces an l.f. signal proportional in amplitude to the deviation. This signal is fed into the first l.f. amplifier, the gain of which is variable to enable the operator to standardize the instrument against the internal calibration standard. Output from the amplifier is fed to the range switching attenuator and then into the second l.f. amplifier. If required, a 15 kc/s low-pass filter may be switched into the signal path to the range switching attenuator in order to restrict the bandwidth to the audio range. The attenuator has a total attenuation of 40 dB switched in 10 dB steps. This selects the range required on f.m. and a.m. The second l.f. amplifier is provided with a preset gain control for a.m. depth indication standardization. After this amplifier the chain is split into two paths, one going to the output amplifier which feeds the front panel terminals and the other going to the peak reading voltmeter. The output amplifier, which has a 600 Ω unbalanced output, supplies approximately 0 dBm into 600 Ω, i.e. 0·775 V r.m.s., for full-scale meter deflection. Standard de-emphasis filters of 50 μsec or 75 μsec may be switched into the output amplifier. All the l.f. amplifiers have large amounts of feedback applied and hence are very stable and of low distortion.

The peak reading voltmeter is fed from the second l.f. amplifier before the de-emphasis network and is not affected by the network. This circuit comprises an amplifier and a push-pull circuit which enables a large voltage to be fed to the meter diode and an almost linear scale to be obtained; it also keeps the power supply voltage low so that battery operation of the instrument is possible. As in the l.f. amplifier, feedback is employed in this section in order to obtain very stable gain.

REFERENCE

1. Oliver, W.: 'An f.m. stereo version of F.M./A.M. Signal Generator type TF 995A/2, *Marconi Instrumentation*, December 1963, 9, p. 95.

ABRIDGED SPECIFICATION

R.F. input

FREQUENCY RANGE: 4 Mc/s to 1,000 Mc/s.

MAXIMUM INPUT: 3 V r.m.s.

INPUT IMPEDANCE: Nominally 50 Ω.

Local oscillator

VARIABLE FREQUENCY: 5·5 Mc/s to 1001·5 Mc/s in 8 ranges.
Scale accuracy: ±3%.

CRYSTAL OPERATION: Up to three crystals within the frequency band 22 Mc/s to 44 Mc/s may be fitted, for use with inputs between 20·5 Mc/s and 1,000 Mc/s.

External oscillator

Provision is made for an external local oscillator input. Required level: 200 mV into 50 Ω.

I.F. output

FREQUENCY: 1·5 Mc/s.

AMPLITUDE: Between 250 mV and 750 mV e.m.f.

IMPEDANCE: Nominally 10 kΩ.

F.M. measurement

DEVIATION: Five ranges: 5, 15, 50, 150 and 500 kc/s full scale.

Positive or negative deviation selected by a switch.

A.M. REJECTION: Additional deviation error less than ±1 kc/s, when the a.m. depth is 80% and the modulation frequency 1 kc/s.

INHERENT NOISE: −48 dB with reference to ±5 kc/s deviation, measured in a bandwidth 30 c/s to 15 kc/s.

A.M. measurement

MODULATION DEPTH: Two ranges: 30% and 100% full scale.
(Maximum usable reading 95%).

Positive and negative peaks selected by a switch.

L.F. output

FREQUENCY RANGE: 30 c/s to 150 kc/s, with switchable low-pass filter at 15 kc/s on F.M.

30 c/s to 50 kc/s on A.M.

De-emphasis selected by a switch at 0, 50 μsec or 75 μsec.

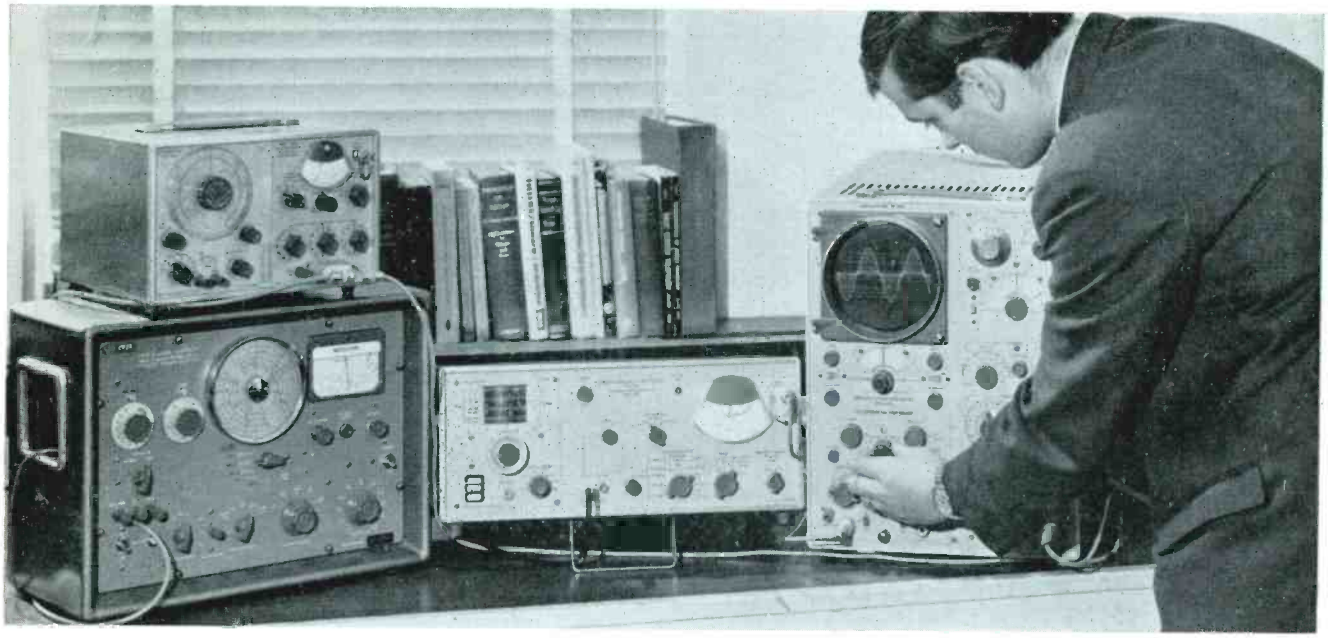
LEVEL: At least 0 dBm into 600 Ω when meter reads full scale.

DISTORTION: Less than 0·2% for deviations up to ±75 kc/s on F.M.

Less than 2% for deviations up to ±500 kc/s on F.M.

Less than 1% up to 60% modulation depth on A.M.

Less than 3% up to 90% modulation depth on A.M.



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F.M. Stereo Applications of F.M./A.M. Modulation Meter type TF 2300

by
W. OLIVER
M.I.E.E.E.

Measurements have been made which show that the new F.M./A.M. Modulation Meter type TF 2300 can be used as a standard f.m. demodulator for f.m. stereo work in addition to its applications on conventional f.m. communications systems. In conjunction with F.M./A.M. Signal Generator type TF 995A/8M1, measurements of distortion and channel separation can be made on f.m. stereo receivers and transmitters.

MEASUREMENTS have been made to evaluate this modulation meter as a standard f.m. demodulator bearing in mind the requirements of f.m. stereo[1].

The frequency spectrum of a typical G.E.-Zenith type f.m. stereo signal with a 1 kc/s modulating tone applied to one channel only (left or right) is shown in Fig. 1 and the test method used to evaluate the modulation meter is shown in Fig. 2.

The stereo modulation source provides the composite modulating signal used to externally modulate the F.M./A.M. Signal Generator TF 995A/8M1. Ideally the demodulated output of the modulation meter should be a replica of the modulating signal applied to the signal generator.

In practice, the distortion components will be modified in amplitude and the channel separation will be affected, particularly at low (50 c/s) and high 15 kc/s) modulating frequencies.

Distortion

If a 1 kc/s tone is applied to the LEFT channel input with no signal on the RIGHT channel, the resulting frequency spectrum including distortion components is shown in Fig. 1. Individual components can be measured by connecting Wave Analyser type TF 2330 to the output of the stereo modulator. If the wave analyser is now connected to the demodulated output of the modulation

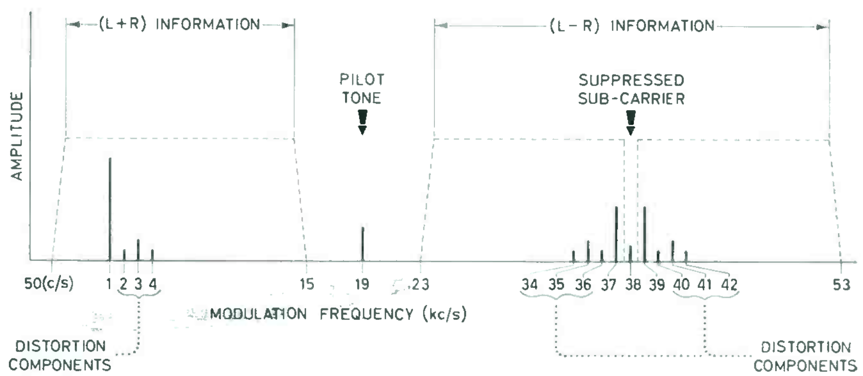


Fig. 1. Frequency spectrum of f.m. stereo signal with 1 kc/s modulating tone

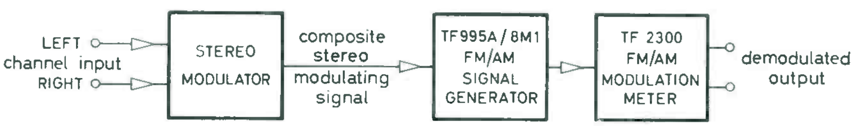


Fig. 2. Test arrangement for evaluating modulation meter distortion

TABLE 1

	(L+R) Channel			(L—R) Channel					
Harmonic order	2	3	4	4	3	2	2	3	4
Harmonic freq.	400 c/s	600 c/s	800 c/s	37·2 kc/s	37·4 kc/s	37·6 kc/s	38·4 kc/s	38·6 kc/s	38·8 kc/s
Stereo modulator only (D_1) dB	–46	–46	–52	–58	–51	–49	–49	–51	–58
Overall distortion (D_2) dB	–44	–46	–52	–58	–50	–47	–47	–50	–58
$\sqrt{D_2^2 - D_1^2}$ dB = mod. meter + sig. gen. distortion	–48	$<$–60	$<$–60	$<$–60	–60	–54	–54	–60	$<$–60

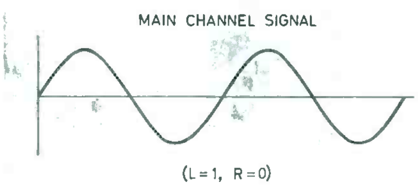


Fig. 3a.

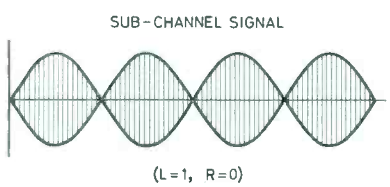


Fig. 3b.

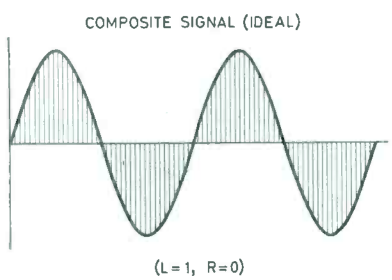


Fig. 4.

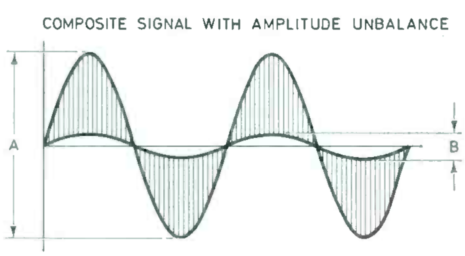


Fig. 5.

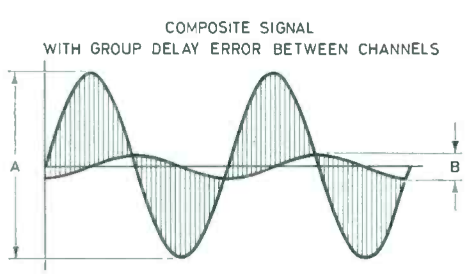


Fig. 6.

Derivation of composite stereo signal showing unbalance and phase shift errors

meter the algebraic difference between the two measurements indicates the amount of distortion added by the signal generator and the modulation meter. Table 1 shows values measured at a test frequency of 200 c/s applied to the left channel input. Measurements were made at a carrier frequency of 100 Mc/s with a deviation of ±67·5 kc/s.

To interpret Table 1 it should be noted that the wanted fundamental signals are those at 200 c/s, 37·8 kc/s and 38·2 kc/s. The distortion components occur at:

400, 600 and 800 c/s,
37·2, 37·4 and 37·6 kc/s,
38·4, 38·6 and 38·8 kc/s.

Other distortion components are small by comparison.

Channel separation

If it were possible to view the 50 c/s to 15 kc/s region separately from the 23 to 53 kc/s area of Fig. 1, on an oscilloscope, the waveforms shown in Fig. 3 would be seen.

The ideal composite modulating signal with the 19 kc/s pilot tone removed is the sum of these waveforms (Fig. 4). In practice there will be amplitude unbalance

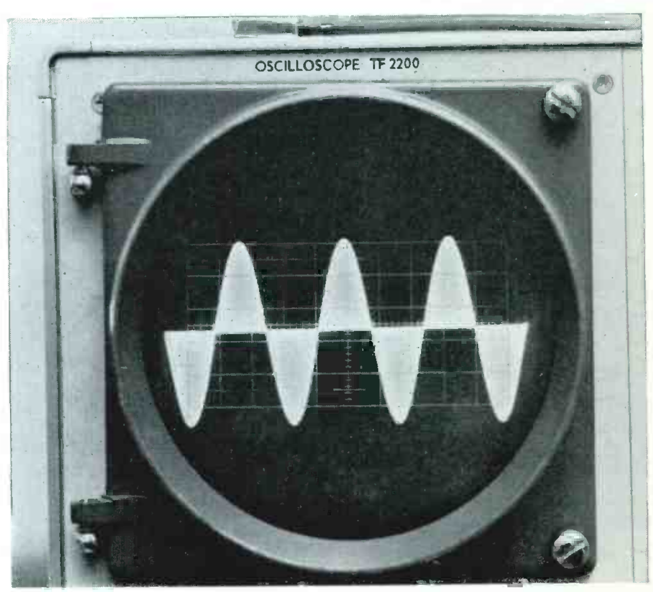


Fig. 7. Oscillograms of composite signal: (a) Ideal

and relative phase shift (group delay error) between the two added signals. These two effects, which can be viewed on a d.c. coupled oscilloscope, are illustrated in Figs. 5 and 6.

The effect of these errors is greatest at the extremes of modulating frequency, 50 c/s and 15 kc/s. At low frequencies, problems are caused by the phase shift introduced by inter-stage coupling components, while group delay and frequency response are the offenders at high frequencies.

In Figs. 5 and 6, amplitude 'B' represents a signal on the RIGHT channel due to an input on the LEFT channel. This means that we can measure the channel separation directly without decoding the composite stereo signal. The separation is given by:—

$$\text{Separation} = 20 \log_{10} \frac{A}{B}$$

Table 2 shows the separation figures obtained with the signal generator and modulation meter with the separation of the stereo modulator adjusted to be >50dB at each measuring frequency.

In order to isolate, to some extent, the separation of the modulation meter alone, measurements were made of the circuits following the pulse count f.m. demodulator. The composite signal was applied to the integrating filter and l.f. amplifier, then the resulting channel separation figures noted at the l.f. output terminals.

To meet F.C.C. requirements an f.m. transmitter must have a separation of >29·7 dB over the range 50 c/s to 15 kc/s. From Table 2 it can be seen that the TF 2300 Modulation Meter has a comfortable margin over this figure.

Conclusions

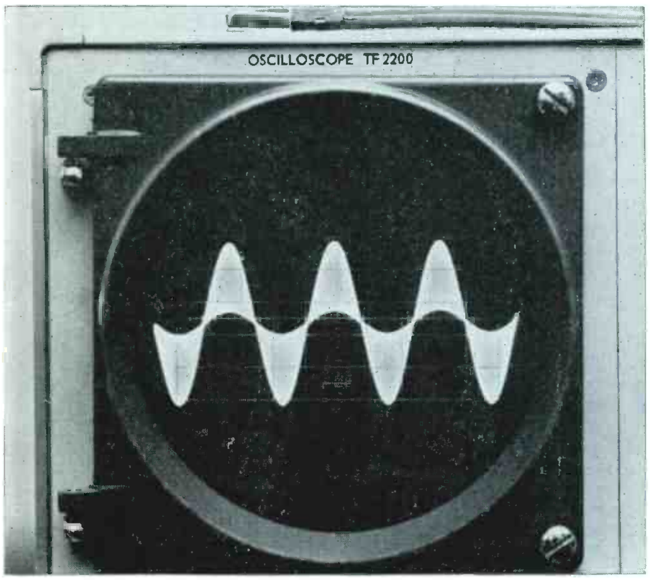
The distortion introduced by the F.M./A.M. Signal Generator type TF 995A/8M1 and the F.M./A.M. Modulation Meter type TF 2300 *combined* is small compared to the amount of distortion present in all stereo modulators tested. The channel separation of the modulation meter is very good at modulating frequencies of 200 c/s and above; even at 50 c/s the separation exceeds the F.C.C. transmitter specification by 3 dB. Since it meets the stringent requirements of f.m. stereo, it is obviously very suitable for testing and monitoring standard f.m. transmissions.

TABLE 2

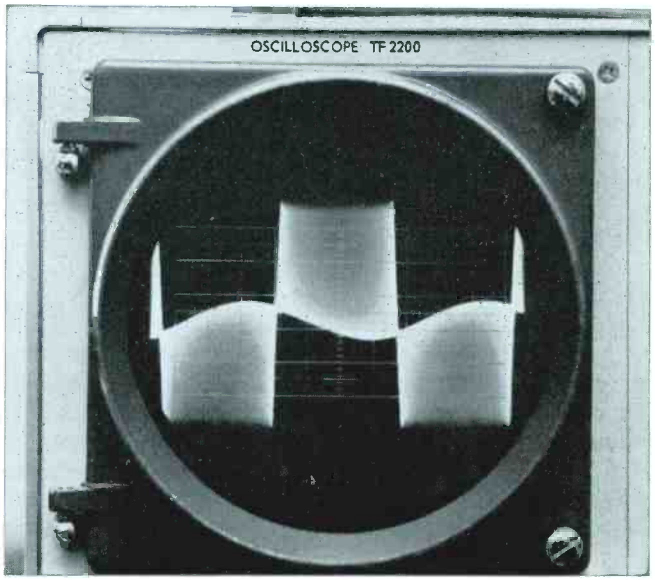
Modulating frequency	Separation dB	
	Sig. gen. + mod. meter	Integrating filter and l.f. circuits of mod. meter only
50	33·5	34·5
100	38·7	40
200	43	43
1 kc/s	46	48
2 kc/s	46	46
5 kc/s	46	46
10 kc/s	46	46
12 kc/s	43	46
15 kc/s	43	45

REFERENCES

1. Oliver, W., 'An F.M. Stereo Version of F.M./A.M. Signal Generator Type TF 995A/2,' *Marconi Instrumentation*, December 1963, 9, p. 95.



(*b*) *With amplitude unbalance*



(*c*) *With phase shift error*

MARCONI INSTRUMENTS

A HIGH-ACCURACY

Comprehensive Test Assembly

by
H. HIPPLE*
A.M.I.E.R.E.

This rack mounted test assembly has been devised by the Transmission Division of the Plessey Electronics Group for production testing of multi-channel system components. To meet the high standard of accuracy required, methods of measurement are used in which relative levels are compared with the insertion loss of a calibrated attenuator. In this way, measurement accuracy is rendered independent of meter calibrations.

Response measurement

The basic method of measuring gain or loss with a transmission measuring set (t.m.s.) is that of applying a standard known voltage to the input terminals of a network, measuring the output level, and calculating the result. In practice, however, the measurement is hardly every really made in this way. Owing to the obvious necessity for standardizing the calibration of the level meter of the t.m.s. against the calibration of the signal source, the method of measurement is nearly always one of direct or partial comparison with the attenuators in the t.m.s.

Standardization is normally done at 0 dBm with the signal source connected directly to the level meter; Fig. 1 shows a conventional arrangement for response measurement, with a change-over switch included for convenience when standardizing the calibration. With a set-up like this, it is very easy to measure the gain or loss of a network by comparison with the attenuator of the t.m.s. The switch is first set to position 1, where the network is included in the circuit; and the signal source output and the level meter range are adjusted for a convenient level reading. Then the switch is set to position 2, where the network is excluded, and the attenuator of the signal source is adjusted to bring the level meter back to its original reading. This change in the attenuation is then equal to the gain or loss of the network, depending upon the direction of the change.

This type of comparison is usually called a slide-back measurement. It has the advantage that virtually no calculation is necessary; the accuracy of the result is largely independent of the calibration of the level meter; and the method can be used with the t.m.s. connected in the conventional way without any ancillary equipment, for even the change-over switch is really a non-essential refinement. The slide-back method has the operational disadvantage, however, that the time interval between the original setting up of a conventional level meter reading and the returning to it, after operating the change-over switch, is likely to be rather long. For precise measurements, this could lead to human error in recalling the exact meter reading, even if the possibility of actual amplitude drift is disregarded.

*Mr. Hipple is with the Transmission Division of the Plessey Co. Ltd.

Direct comparison

Fig. 2 shows an arrangement for comparing the insertion loss of a passive network directly with that of an accurately calibrated attenuator. The output of the signal source section of the t.m.s. is applied equally to the network under test and the calibrated attenuator. The

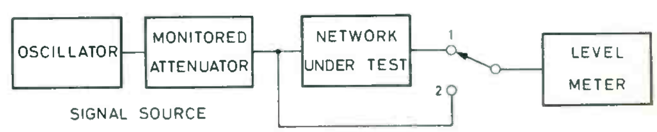


Fig. 1. Conventional arrangement for response measurement with a transmission measuring set

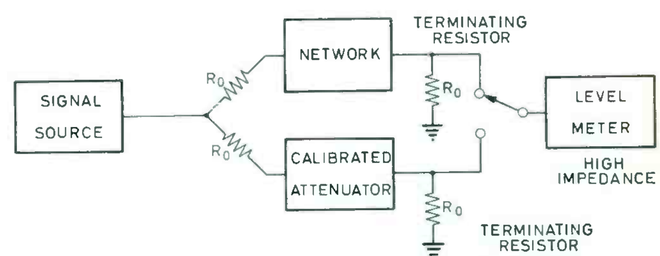


Fig. 2. Arrangement for comparing network with attenuator for loss measurement

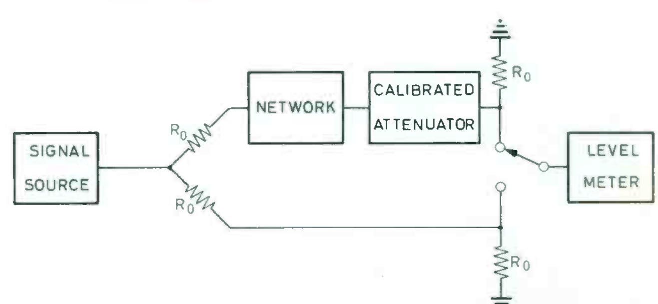
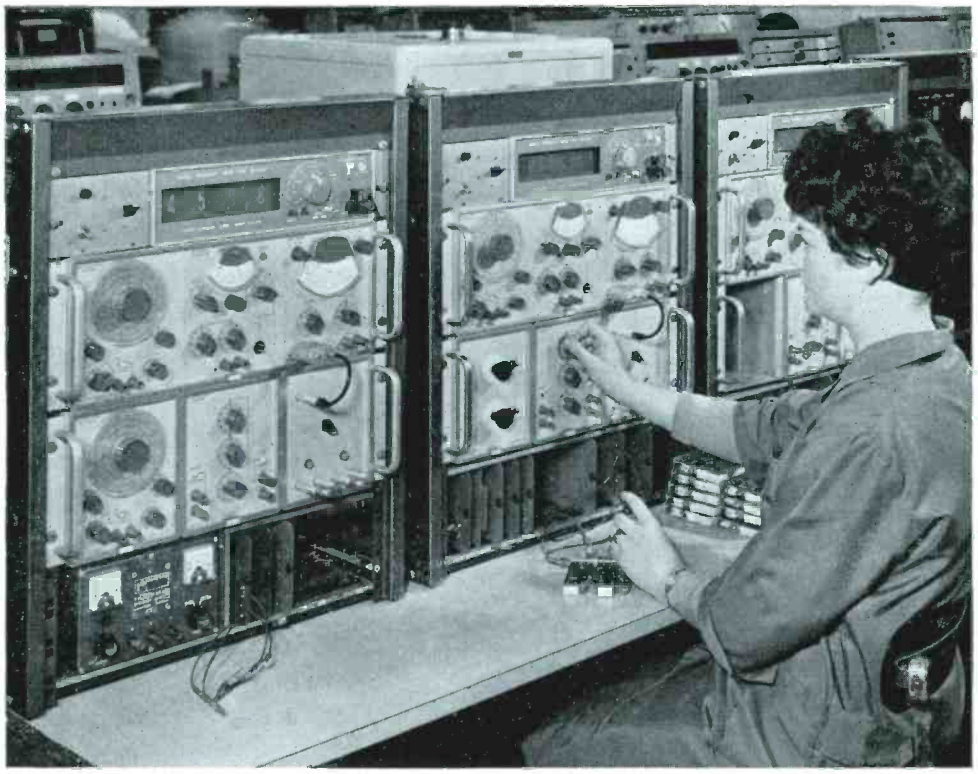


Fig. 3. Arrangement for comparing network with attenuator for measurement of gain



The test assembly as described in the article is shown mounted in the rack in the foreground. Variations of the arrangement, facilitated by the standardized panel size of the units, are shown in the other two racks. In the one being operated, the second oscillator has been replaced by a filter unit.

Photograph by courtesy of Plessey Company Ltd.

level meter of the t.m.s. is switched alternately to the output of the attenuator and to that of the network; and the attenuator controls are adjusted to the setting where the level meter gives the same reading in both positions of the switch. The insertion loss of the network is then equal to that of the attenuator.

For active networks, with gain greater than unity, the system is re-arranged to the form shown in Fig. 3. Here the standard attenuator is adjusted for its insertion loss to be exactly equal to the amplifier gain, so that the level meter has the same reading in both positions of the change-over switch.

Linearity measurement

A similar philosophy can be applied for measurement of intermodulation distortion using the S.M.P.T.E. method. This system of measurement is described in detail elsewhere[1], but a brief description of the method may be useful.

A two-tone signal is applied to the network under test, the frequencies of the tones being widely separated (but within the network's pass band). The amplitude of the low frequency tone, Q, is four times that of the high frequency tone, P.

If the network is non-linear, intermodulation products appear in the output in the form of sidebands spaced symmetrically about frequency P at frequencies $(P \pm Q)$, $(P \pm 2Q)$, $(P \pm 3Q)$ etc.

First, the output signal is passed through a high-pass filter which eliminates frequency Q, and the amplitude of the modulated output is monitored. Then the intermodulation sidebands are separated from their carrier, P, by means of a demodulator and low-pass filter and their level is monitored separately. A measure of intermodulation distortion is given by the ratio of the amplitude of the modulated carrier, P, to that of the demodulated signal. This may be stated either in percentage voltage ratio or in decibels.

Fig. 4 shows a method of comparing this ratio with the insertion loss of an attenuator. When the switch is in position 1, the level meter reads the power in the sidebands; and when it is position 2 the meter reads the attenuated power in the carrier, P, plus sidebands. By adjusting the attenuator to give the same meter reading

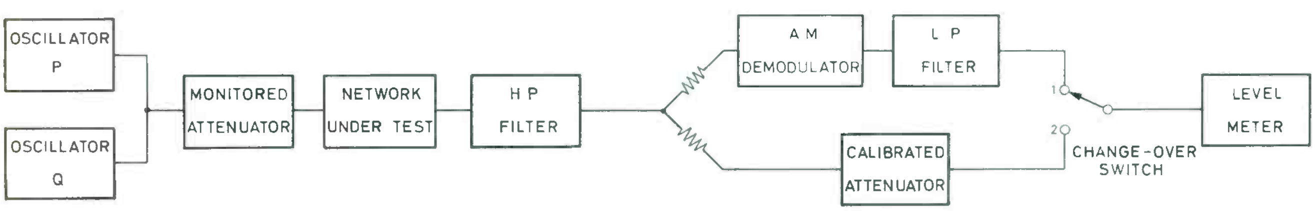


Fig. 4. Arrangement for intermodulation distortion measurement using calibrated attenuator as ratio standard

in both positions, its insertion loss is made equal to the intermodulation distortion ratio.

The test rack assembly

These principles are utilized in a test rack assembly which is being brought into use by the Transmission Division of the Plessey Electronics Group, Liverpool, for response and linearity measurements on components of multi-channel telephone systems.

The rack is intended as a piece of production test equipment; and, as such, it has to meet certain special requirements apart from the electrical functions. It is important that all the controls of the assembly are within easy reach of an operator sitting in front of it; and it is essential that the instrument should be easy to use, so that, once it has been set up by a technician, the tests can be made by an unskilled operator. Previous designs based on valve equipments have usually turned out to be too large for the accessibility requirement; but now the overall concept has been made practical by the small size and electrical stability of solid-state instruments at present available.

The design of the test rack assembly is centred about the M.F. Transmission Measuring Set type TF 2333, M.F. Oscillator type TF 2001 and M.F. Attenuator type TF 2162, the basic electrical arrangements being those shown in Figs. 2, 3 and 4. The general physical layout is shown in Fig. 5.

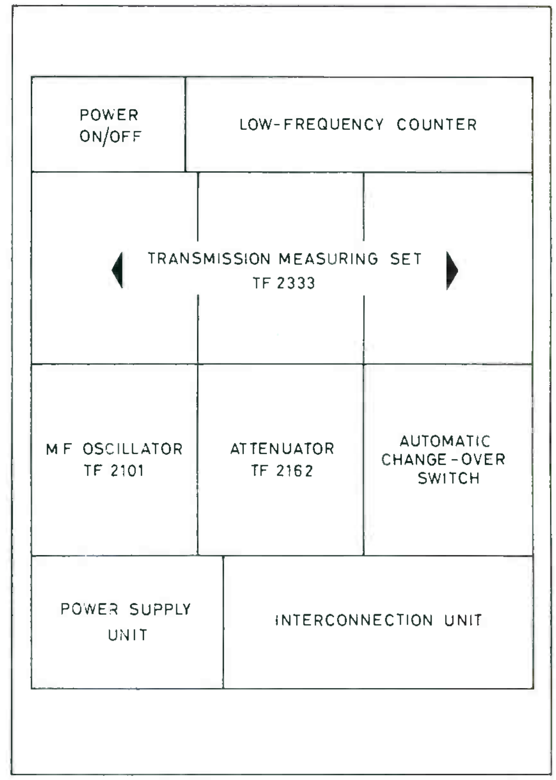


Fig. 5. General layout of rack assembly

Automatic switching

In order to make the equipment as easy to read as possible, the change-over switch is driven automatically, two switching speeds being available—10 c/s and 2 c/s. This enables the operator to find the correct setting for the attenuator by simply adjusting the controls to the position where the meter pointer stops moving. When the 2 c/s switching speed is used the meter pointer wags like an inverted metronome; this speed is used for coarse adjustment. At this fairly slow speed, it is easy to tell whether to increase or decrease the loss of the attenuator, because the indication corresponding to the network is at a constant position on the meter scale, and the pointer swings away from this reading—above or below it according to the attenuator setting.

For the fine adjustment of the attenuator, the switch is set to the fast speed—10 c/s—at which the meter pointer is merely vibrating to present a blurred image. The attenuator controls are then used to bring the blurred image into a single line.

In practice, this change-over switch takes the form of a pair of reed relays driven from a multivibrator in such a way that when one relay is closed the other is open. The speed of the multivibrator is controlled by means of a three-position switch mounted on the front panel. Two positions of this switch select the 10 c/s and 2 c/s frequencies respectively, and the third position enables the operator to stop the multivibrator with either the network or the attenuator connected to the level meter. This position is mainly used when setting up the equipment initially.

Accuracy and discrimination

The accuracy of amplitude measurements made in this way is, of course, the accuracy of the M.F. Attenuator type TF 2162; i.e. from 1% to 2% of the dB setting depending on frequency. For the requirements of Plessey Electronics, this accuracy is improved further by calibrating the attenuator against a highly accurate standard.

As the test rack is used on frequency selective devices, precision of frequency setting is also very important. It was found that the frequency stability of the m.f. oscillator in the t.m.s. is quite adequate, but the frequency dial calibration does not offer enough discrimination. A low-frequency electronic counter is, therefore, built into the rack assembly to monitor the oscillator frequency.

Continuous monitoring is not regarded as being necessary, and connection to the counter is made from the front panel terminals of the oscillator. In normal use the oscillator is connected to the monitored attenuator of the t.m.s. via the socket at the rear, the output being brought to the front panel only when the FRONT/REAR selector switch is in the appropriate position. This facility for switching to the counter is, therefore, built in without any modification. The use of a counter has the secondary advantage that it enables the t.m.s. to be used at frequencies slightly beyond its calibrated range.

Two-frequency measurements

M.F. Oscillator type TF 2101 is mounted adjacent to the oscillator section of the TF 2333 Transmission Measuring

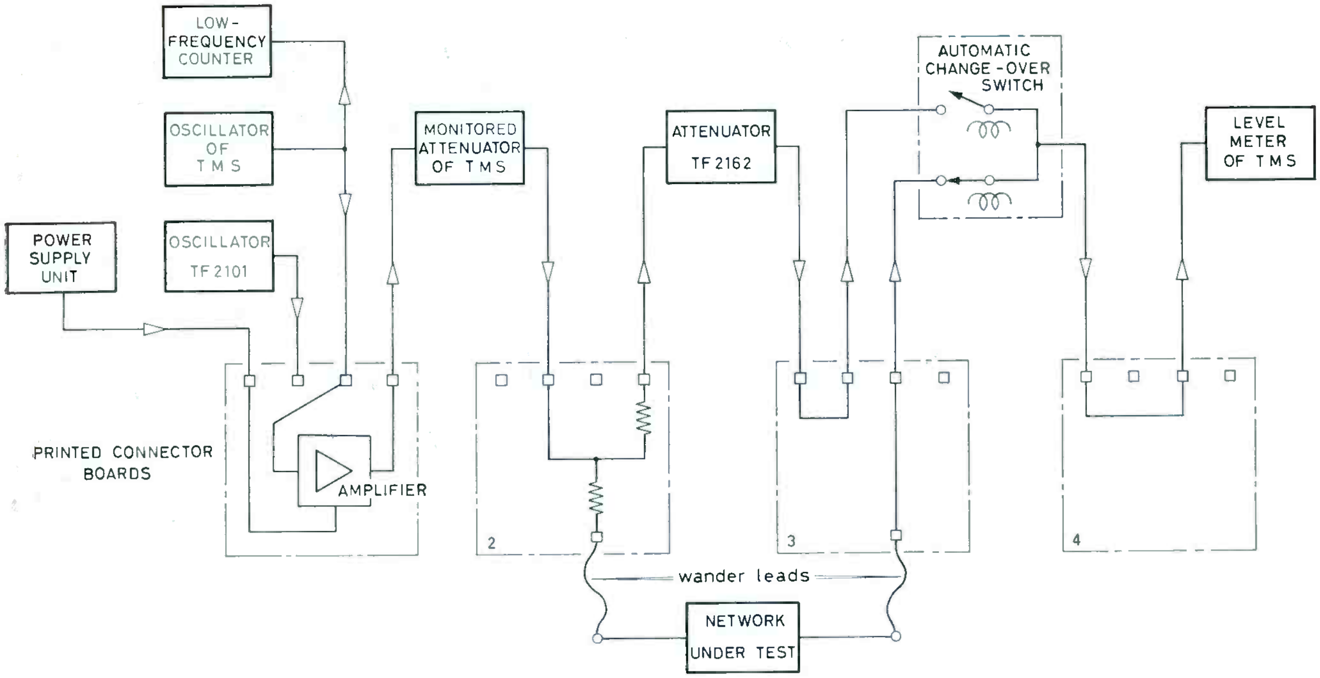


Fig. 6. A much simplified diagram showing typical interconnection

Set. The two oscillators are, of course, identical. Internal isolation of the oscillatory circuits from the terminals is such that two oscillators of this type can be connected in parallel to the attenuator without the need for a matching network and without fear of inter-modulation.

Ancillary units

Test specifications of the networks checked on the rack assembly normally include specified input levels. These levels are monitored by the voltmeter of the m.f. attenuator of the t.m.s., which is sufficiently accurate for the purpose. For some networks, however, the output from the signal source is not sufficient. The maximum normal output level of +3 dBm suffers a 6 dB reduction by the resistive splitter network, giving a maximum test level of −3 dBm. Many networks have specified test input levels of 0 dBm and some others require higher levels still. In order to make the response measurements on these, it is necessary to insert a wide band amplifier between the oscillator and the attenuator of the t.m.s. Provision for the introduction of such an amplifier is included in the flexible system of inter-connection that is used.

This interconnection unit utilizes plug-in printed-wiring boards. The input and output terminals of the individual units which comprise the test rack are wired to a system of bus bars at the back of the interconnection unit—one bus bar to each terminal. These bus bars connect in parallel a number of multi-way printed board connector sockets. Thus, by insertion of appropriately wired boards, any desired combination of connections can be obtained. This, of course, includes connection to the network under test and to any other external unit that may be required; e.g., the wide band amplifier for increasing the source power, or the filters and detector for two-frequency linearity tests. These boards are also used to mount special networks required for certain tests. A much simplified diagram showing typical inter-connection is given in Fig. 6.

REFERENCE

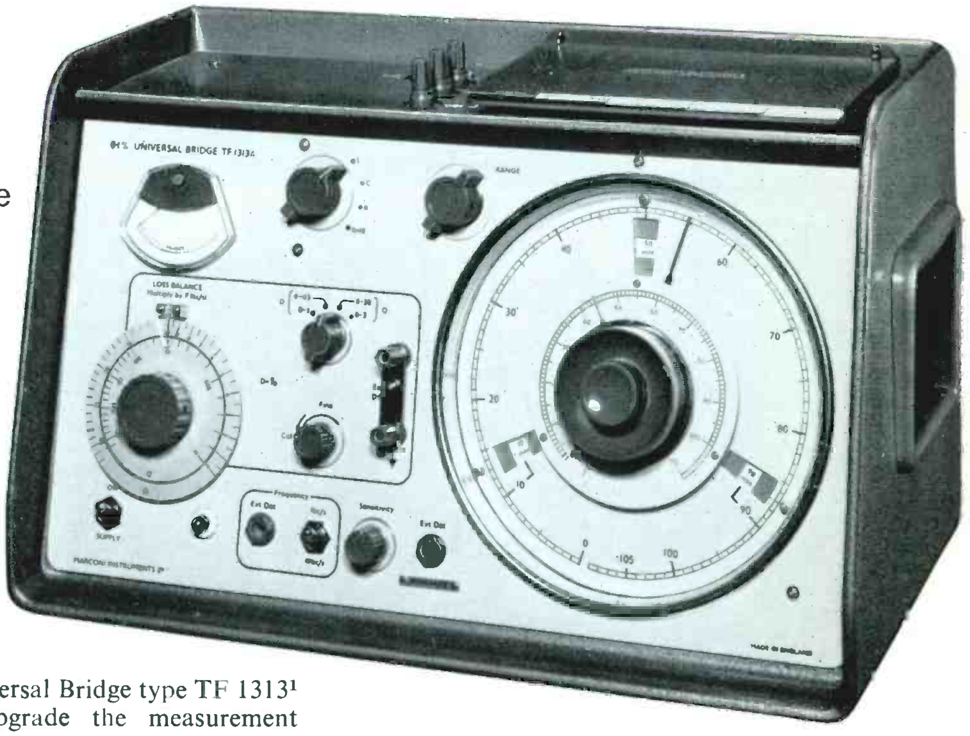
1. Waddington, D. E. O'N., 'Distortion Measurement in Audio Amplifiers,' *Marconi Instrumentation* Dec. 1963, 9, p. 79.

Happy event. We take this opportunity of welcoming the arrival of our new sister journal, *Measuretest*, which will concentrate on the more practical side of instrument technology. In *Measuretest* you will find useful tips about interesting applications, solutions to measurement problems and details of modifications which either improve the performance of a Marconi instrument or adapt it for a special purpose.

MARCONI INSTRUMENTS

0·1% Universal Bridge
Type TF 1313A

621.317.733



THIS NEW VERSION of Universal Bridge type TF 1313[1] has been introduced to upgrade the measurement accuracy for L, C and R from 0·25 to 0·1% over most of the ranges. The need for this has largely arisen from the continued progress of industrial electronics requiring closer tolerance components. Several years ago when the 0·25% version was brought out to augment our long-standing 1% universal impedance bridges there was an increasing interest in components of at least 1% accuracy. Nowadays for many applications the trend is towards components of much better accuracy than 1%.

The 0·1% version uses the same type of bridge configurations as the original although a number of changes were necessary to realize the improved performance. For example, the bridge standard resistors are of twice the previous accuracy and have also better controlled temperature coefficients to ensure the accuracy is maintained over a wide temperature range. The fine balance previously had an accuracy of 0·01% of range full scale and this has been improved to 0·005% by a new specially made control which has greater resolution.

Improved precision of capacitor measurement at 10 kc/s has been achieved by extending the FINE LOSS BALANCE control to the D range as well as the Q. The FINE control was originally intended to assist in balancing low Q inductors, but when used for D balance it allows a convincing true null to be obtained in measurements of really high Q capacitors. Terminals for the connection of external D-Q controls have been retained but these are no longer so necessary as a D range of 0-3 has been added to give a truer series measurement of rather lossy capacitors such as electrolytics. At 1 kc/s these nearly always measure lower than expected if the parallel Q mode is used. Bias, in our experience, rarely makes significant changes to the capacitance of modern electrolytics but, because there are other voltage-conscious devices, a BIAS socket for capacitors in the series mode only has been added adjacent to the test terminals. The maximum permitted voltage is 350 V, being limited by the rating of the internal standard.

To take full advantage of the higher accuracy, the detector sensitivity has been increased so that, on every range, 0·1% error corresponds to an unambiguous meter deflection. Power required for d.c. resistance measurement is reduced and the l.f. response for external oscillator drive is extended. These factors combined have led to the abandonment of the long time constant a.g.c. system of sensitivity control and the substitution of a manual control. The meter circuit is arranged to have non-linear deflection to give as large a dynamic range as practicable.

For resistance measurement the d.c. detector now uses a photo-chopper. The d.c. error signal, which may be as little as 100 μV for 0·1% from a high resistance source, is converted to a square wave by resistors which are switched in value by varying the light from a neon oscillator.

Checking the accuracy of such a bridge puts a strain on the resources of almost any laboratory in the world when all the ranges are considered. It is often necessary to deduce that the bridge is correct on a particular range rather than to prove it directly. A virtue of a universal bridge is that the same internal standards are used for various functions. A careful cross check of all possible sources of error enables the accuracy claims to be justified in areas where adequate national certified standards are not available.

E.C.C.

REFERENCE

1. Crawford, E. C.: '¼% Universal Bridge type TF 1313', *Marconi Instrumentation*, June 1960, 7, p. 183.

621.317.725

MARCONI INSTRUMENTS

NEW DESIGN

R.F. Electronic Millivoltmeter . Type TF 2603

by
P. E. BROWN

This is an entirely new fully transistorized millivoltmeter, designed for voltage measurement from 300 μV to 3 V through the frequency range 50 kc/s to 1,500 Mc/s. The ½ inch diameter probe utilizes a pair of fast germanium diodes in a full wave circuit whose response is close to true r.m.s. with inputs of less than 30 mV and peak-to-peak in the 0·5 to 3 V region. Meter scales are virtually linear and approximately 5 inches long, being calibrated in the r.m.s. value of a sine wave. Six accessories are available including a 100 : 1 multiplier which allows voltage measurements up to 300 V. As an alternative to the normal mains supply, the instrument may be operated from an external battery connected to the rear terminals.

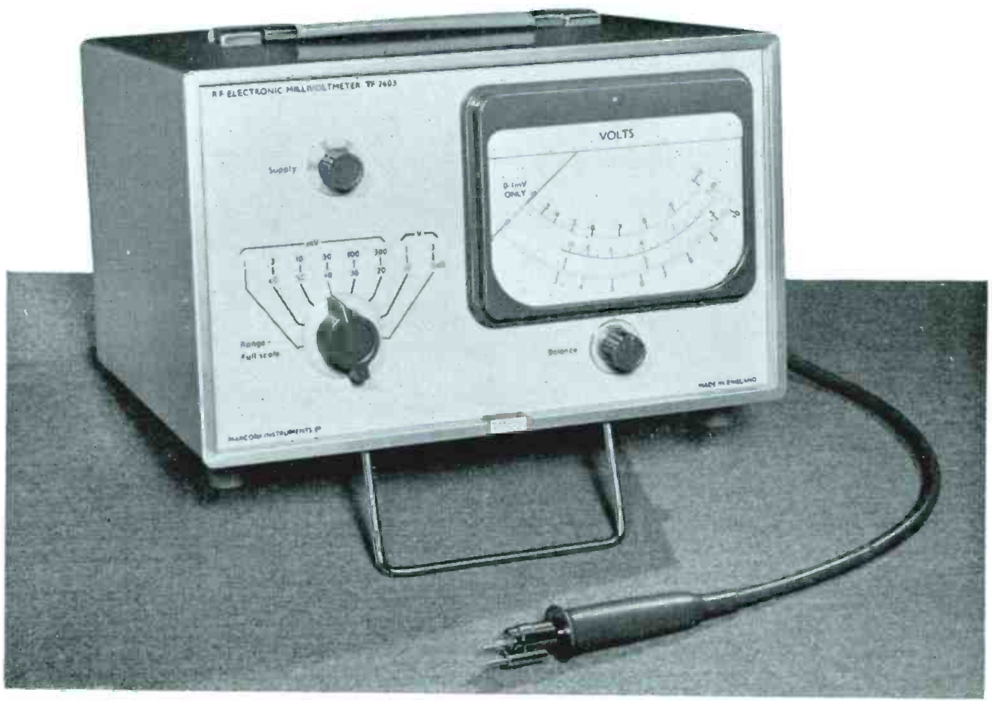
IN THE MAIN, electronic voltmeters follow one of two configurations,

(i) a.c. amplifier—rectifier—indicator,

(ii) rectifier—d.c. amplifier—indicator.

Voltmeters in category (i) first amplify the signal to be measured; the voltage thus obtained is then rectified, the resultant d.c. being used to operate a moving coil meter. This system has many advantages, notably the ability to measure audio/video frequency voltages as small as 300 μV. A high standard of precision and stability is achieved by enclosing the entire amplifier and rectifier system within one main negative feedback loop. Higher voltages (typically up to 300 V) are measured by incorporating a suitable attenuator between the input terminals and the amplifier. Sensitive Valve Voltmeter type TF 2600[1] is a good example of an instrument in this category. The main defect of the arrangement lies in its restricted bandwidth; this is generally in the region of 5 Mc/s, although up to about 100 Mc/s is possible with reduced accuracy and sensitivity.

Arrangement (ii) usually consists of a thermionic diode followed by a d.c. amplifier of two or more cathode followers feeding a meter. Such an instrument (e.g. Vacuum Tube Voltmeter type TF 1041C[2]) can measure voltages ranging from 100 mV to 300 V, its frequency band extending from 20 c/s to 1,500 Mc/s; this performance is obtained with comparatively simple and, therefore, less costly circuitry. Lack of sensitivity is imposed by the



R.F. Electronic Millivoltmeter type TF 2603.

The probe can be stowed in a recess at the back.

inherent difficulty in obtaining a sufficiently stable electrical zero and repeatable diode law. Despite such measures as stabilizing the diode heater supply voltage and/or balancing the diode 'splash' voltage by that of another diode, it is rarely possible to provide less than 300 mV f.s.d. as the most sensitive range.

R.F. Electronic Millivoltmeter type TF 2603 falls into category (ii), but has major differences with respect to the thermionic diode version already described. The probe utilizes a pair of germanium diodes (see Fig. 1) in a full wave detector circuit whose d.c. output passes through a balanced attenuator to an electro-mechanical chopper. The resultant square wave is amplified and rectified, and the d.c. so produced operates the meter. Use of semiconductor devices throughout ensures reliability and freedom from microphony.

Probe

The metal body of the probe has a diameter of only $\frac{1}{2}$ inch and is $3\frac{3}{4}$ inches long, excluding the spike. It contains two germanium gold bonded diodes in a full wave circuit which has smaller inherent error, when measuring complex voltages compared with the half wave alternative; this is especially true when dealing with signals containing asymmetrical waveforms and/or noise. A heater is incorporated in order to minimize changes of sensitivity with ambient temperature variations. Without a heater the probe output would fall as ambient temperature decreases, the slope becoming steeper just below 20°C. The prime object of the heater is to maintain the diodes at a temperature well above 20°C throughout the ambient temperature range likely to be encountered. A thermostat mounted in the main body of the instrument ensures that the heater current is switched on only at ambient temperatures below 33°C thus preventing the probe temperature becoming so high that it is uncomfortable to handle.

The frequency response of the probe is flat between 200 kc/s and 50 Mc/s, and the specification at other frequencies is as follows:—

+0 –0·5 dB from 50 kc/s to 200 kc/s,
±0·4 dB from 50 Mc/s to 200 Mc/s,
±1 dB from 200 Mc/s to 900 Mc/s,
±2·0 dB from 900 Mc/s to 1,500 Mc/s.

In fact most probes (see Fig. 2) are within the 2 dB limits up to 3,000 Mc/s. The fall-off at 50 kc/s (typically 0·1 dB) is caused by the deliberate restriction of the value of the input and reservoir capacitors; this allows connection of the probe to d.c. voltages of up to 300 V without damage to the diodes by excess pulse energy.

The frequency response figures given above assume that the probe spike is directly contacting the live point under test and that the earth connection between the probe case and circuit earth has negligible inductance and resistance. Provided that the probe spike is directly contacting the live point then a six inch length of 14/·0076 wire or its equivalent can be used up to 20 Mc/s. A clip is provided for the attachment of such an earth wire. A telescopic earth spike designed to accommodate differences between live and earth planes is also supplied. It is suitable for use up to 100 Mc/s, or up to 300 Mc/s provided an additional error of up to 2·5% can be tolerated. Above 100 Mc/s the probe case must directly contact a substantial earth point of the system under test; alternatively, various optional accessories can be

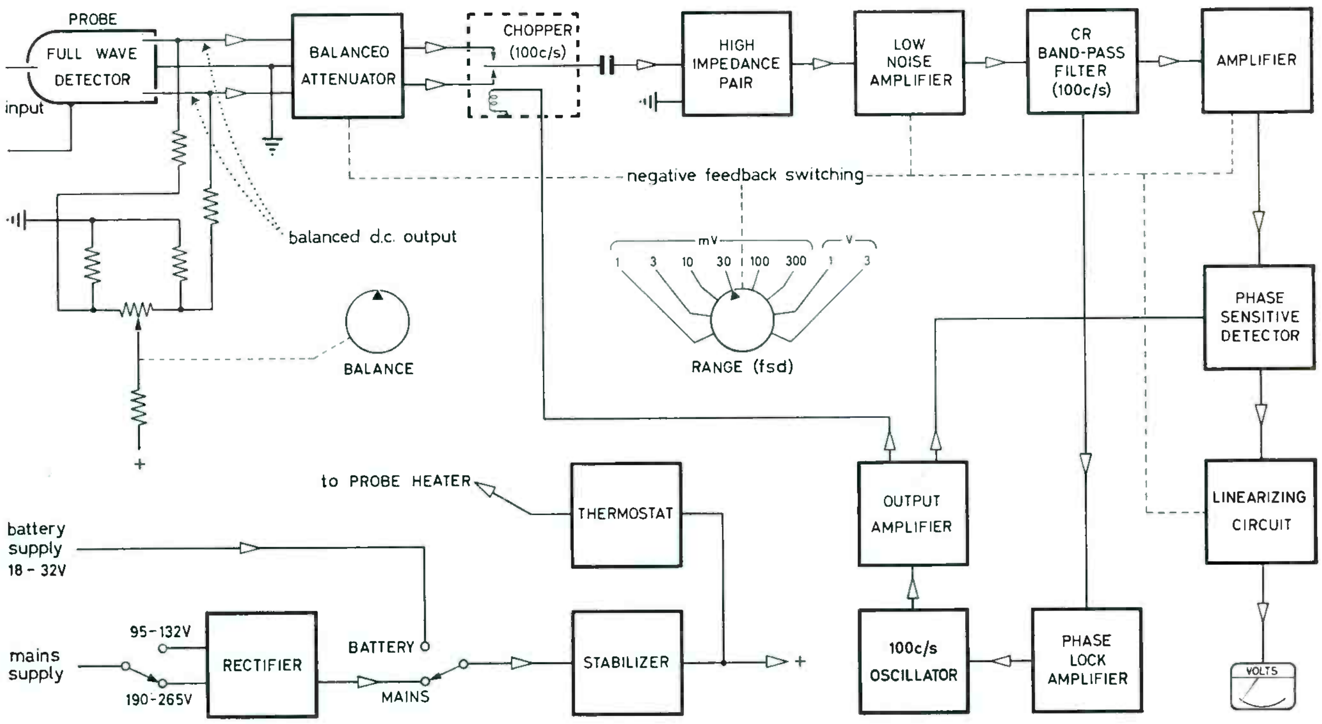


Fig. 1. Block diagram of R.F. Electronic Millivoltmeter type TF 2603

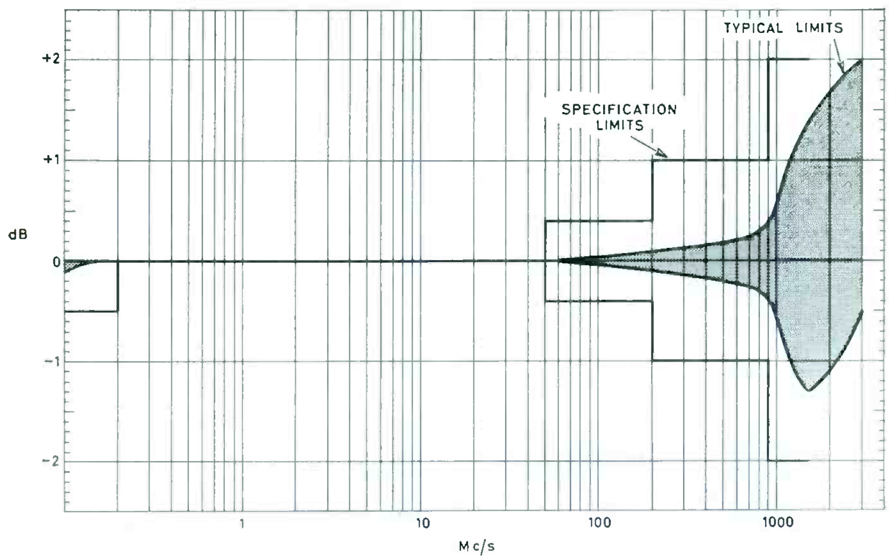


Fig. 2.
Typical frequency response limits of TF 2603 probe

used including Coaxial 'T' Connector type TM 7948 which is usually essential above 900 Mc/s.

The probe circuit responds closely to true r.m.s. when the input is less than 30 mV. In the 0·5 V to 3 V region it behaves as a peak-to-peak device while the remaining ranges fall in between these two conditions.

The d.c. output from the probe varies from approximately 2·5 μV (300 μV input) to 8·2 V (3·16 V input), and the main instrument must provide high d.c. amplification with low noise. Its input/output characteristic must be the inverse of that of the probe, e.g. on the 10 mV range where the probe has a square law characteristic, the amplifier must conform to an inverse square law to achieve a linear meter scale.

Typical input impedance with input of 1 V at 1 Mc/s is 210 k Ω in parallel with 2 pF—see Fig. 3.

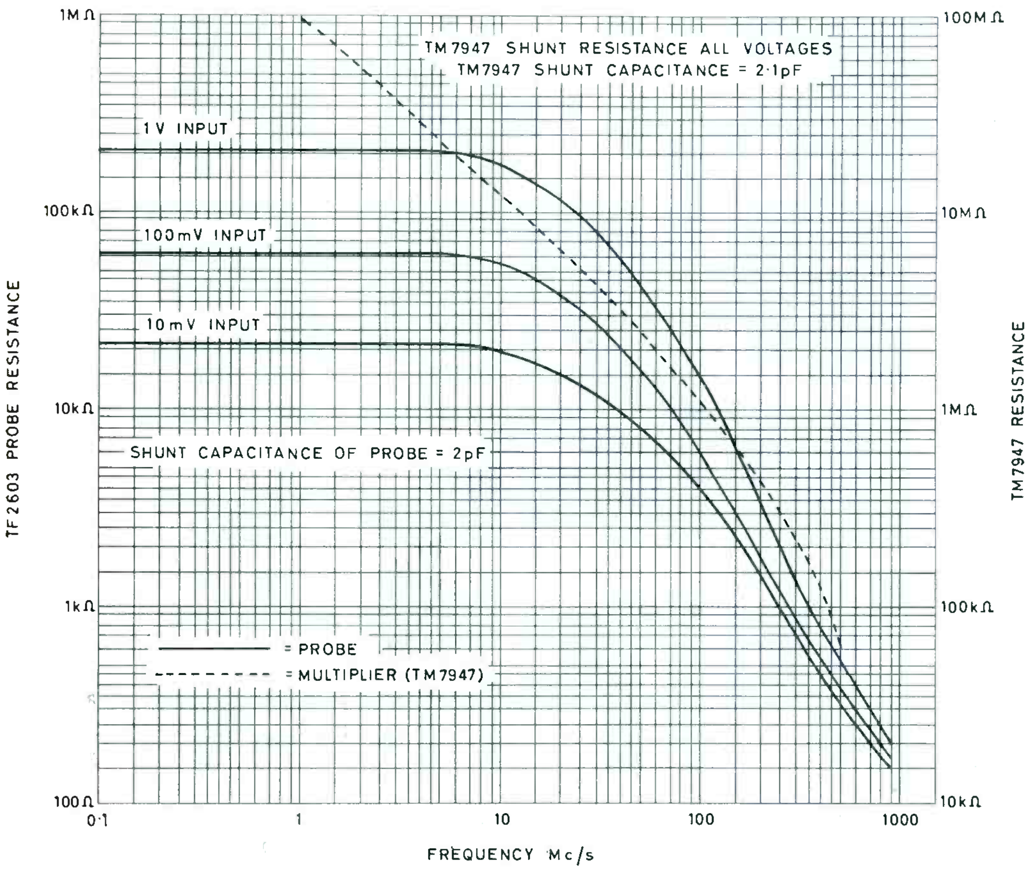


Fig. 3.
Typical input resistance of probe and multiplier

Amplifier

Many precautions are taken to minimize noise; the seven most important are as follows:—

(*a*) The probe output circuit, d.c. attenuator and chopper input connections are all balanced about earth. This arrangement affords many advantages, the chief one being that low frequency (1/f) noise voltages existing at the base of the first transistor are less likely to be chopped at a 100 c/s rate and passed through the narrow band amplifier than would be the case in an unbalanced system.

The slim probe with its spring loaded earth spike greatly simplifies measurements in closely packed circuits

(*b*) The 100 c/s chopper is of the electro-mechanical variety which is vastly superior to the transistor type whose breakthrough spikes and offset voltages are prohibitively large in low voltage high impedance circuits; the balanced attenuator, together with succeeding circuits, has to present a high value load (several megohms) to the probe in order to achieve the maximum possible efficiency. A photo-chopper using cadmium sulphide or cadmium selenide photo-resistors is also noisier than the electro-mechanical version though here the margin is smaller.

(*c*) A high value of resistance is required at the input of the high impedance pair but without the concomitant noise penalty. This is achieved by using a resistor of comparatively low value which determines noise voltage and then by means of positive feedback, bootstrapping it to a much higher effective value.

(*d*) The first four transistors are low noise types run at low collector current and with small voltages between collector and base.

(*e*) A 100 c/s band-pass filter of the multi-stage CR type restricts bandwidth so that noise handled by the output stages is of a low order.

(*f*) The phase sensitive detector not only discriminates against noise but retains polarity sense. This is convenient when setting the meter electrical zero which therefore coincides with the scale zero[3], i.e., on the most sensitive range, noise produces no standing reading but merely shows as a small pointer 'dither' about the mechanical zero mark.

(*g*) The meter damping is chosen to give a small effective bandwidth while still achieving a reasonable pointer speed. Further damping is switched in on the most sensitive range (1 mV f.s.d.) where pointer fluctuations due to noise are typically $\pm 2\%$ (of f.s.d.) about readings below half scale.

There are only two front panel controls, the range switch and balance control. The latter has no effect on the 30 mV range and above, and very little on the 10 mV range. Its purpose is to balance out the few microvolts d.c. which may exist at the chopper input due to the thermal e.m.f's. developed within the probe, attenuator or chopper; these are most significant on the 1 mV range and to a lesser extent on the 3 mV range. Therefore when measuring voltages below 10 mV it is necessary to temporarily switch to the 1 mV range, ensure that r.f. input to the probe is zero, and adjust the balance control to zero the meter pointer.

The range control not only switches the balanced attenuator but also the amount of negative feedback applied to the amplifier system. By this means the sensitivity is varied while maintaining a high degree of negative feedback appropriate to the range concerned, i.e. the feedback ratio is *not* determined once and for all by the requirements of the most sensitive range. This system ensures that maximum long-term stability is achieved.

A further aid to stability is contained in the phase lock system. In order to allow battery operation of the instrument the chopper is driven by a 100 c/s oscillator. Consequently the chopper is chosen to be of the mechanically resonant type because of its comparatively small drive power requirements. Unfortunately, variations of ambient temperature cause small changes of resonant frequency in the high Q mechanical system, this results in an unwanted phase shift between the chopper drive and its output signal, the ocillator frequency remaining constant. Without correction this could give rise to an error in meter reading of up to 1%, as the chopper drive is in phase with the switching voltage at the phase sensitive detector. To prevent this happening a sample of the chopped signal is taken from an early part of the filter, is amplified, shaped and used to lock the multivibrator oscillator. In other words the high Q mechanical system of the chopper determines the instant of switching at the oscillator, hence any variation of (mechanical) resonant frequency pulls the oscillator with it thus preventing any phase shift and consequent error.

Scale linearizing is achieved by means of a silicon diode shaping system which in effect shunts the meter by a progressively greater amount as f.s.d. is approached. The range switch adjusts the system so that it has less effect with higher r.f. input voltages where the probe is more linear; it is switched out altogether on the 1V and 3V ranges.

The meter voltage scales are five inches long, virtually linear and adjacent to a dB scale, 0 dB coinciding with full scale deflection. The 1 mV scale is an exception: it is $3\frac{3}{4}$ inches long, square law and the dB scale does not apply. On this range the linearizing system is switched out in order to avoid exaggeration of noise fluctuations at the lower end of the scale.

Accessories

100 : 1 Multiplier type TM 7947; this is a capacitive voltage divider whose 'nose' is identical in size and shape to that of the millivoltmeter probe which is a tight push fit inside the multiplier. The multiplier can be used throughout the frequency range 500 kc/s to 500 Mc/s, and allows voltage measurements from 30 mV to 300 V with an input impedance considerably higher than the thermionic diode valve voltmeter can offer over the same voltage range. This accessory extends the true r.m.s. measuring capability up to 3 V.

Probe accessories. The multiplier (bottom left) and case are supplied with the instrument. The two adapters, 'T' connector and load are optional accessories

Terminated type N Adapter, type TM 7949, consists of a 50 Ω plug containing a resistor which presents a 50 Ω load. The TF 2603 probe, which is a push fit in the rear of the device, measures the r.f. voltage across the 50 Ω load. Power levels up to $\frac{1}{4}$ W can be handled in the frequency range 50 kc/s to 900 Mc/s.

Unterminated type N Adapter, type TM 7950, is identical in shape and function to the terminated adapter, but without the internal load.

Coaxial 'T' Connector type TM 7948 allows voltage measurements in 50 Ω coaxial systems. The accessory is fitted with two type N devices, one plug and one socket together with side entry access for the millivoltmeter probe. It is intended to be inserted between an r.f. source and a 50 Ω load; the latter may be the user's own load or alternatively a high quality termination is available, namely the 50 Ω $\frac{1}{4}$ W load type TM 7967. This consists of a 50 Ω resistor suitably mounted in a type N plug giving a typical v.s.w.r. of 1·02 from d.c. to 1,500 Mc/s.

The combination of the load and 'T' connector with the millivoltmeter probe connected presents a Zo of 50 Ω with a typical v.s.w.r. of 1·1 from 1 Mc/s to 1,500 Mc/s.

All five accessories can be obtained singly or as a kit in Accessory Case type TM 7960.

ABRIDGED SPECIFICATION

Voltage range

1 mV r.m.s. to 3·16 V r.m.s. full scale in eight ranges. Maximum input 8 V r.m.s. Probe will withstand up to 300 V d.c.

Frequency range

50 kc/s to 1,500 Mc/s.

Accuracy (200 kc/s – 50 Mc/s)

10 mV and higher ranges ± 3% of full scale.
3 mV and 1 mV ranges ± 5% of full scale.

Frequency response

With respect to 200 kc/s,
50 kc/s to 200 kc/s +0 – 0·5 dB.
50 Mc/s to 200 Mc/s ±0·4 dB.
200 Mc/s to 900 Mc/s ±1·0 dB.
900 Mc/s to 1,500 Mc/s ±2·0 dB.

Meter scales

0 to 3 and 0 to 10 virtually linear, 5 inches in length. Calibrated in the r.m.s. value of a sine wave. Special scale for 1 mV range. Decibel scale 0 to – 11 dB, 0dB at full scale. Range switch is in 10 dB steps. dB scale not applicable to 1mV range.

Input impedance

INPUT RESISTANCE: Greater than 180 kΩ at 1 Mc/s and 1 V r.m.s.
INPUT CAPACITANCE: Less than 2·5 pF.

Applications

This millivoltmeter can perform a great variety of tasks, many of them attainable only by this type of instrument. The following applications are typical:—

(1) Measurements of low level signals in semiconductor circuits especially transistors and tunnel diodes.

(2) Measurement of transistor parameters, for instance f_T in the 500 to 1,500 Mc/s region.

(3) Voltage measurement on strip-line circuits.

(4) Measurements on battery operated equipments at locations remote from mains supplies.

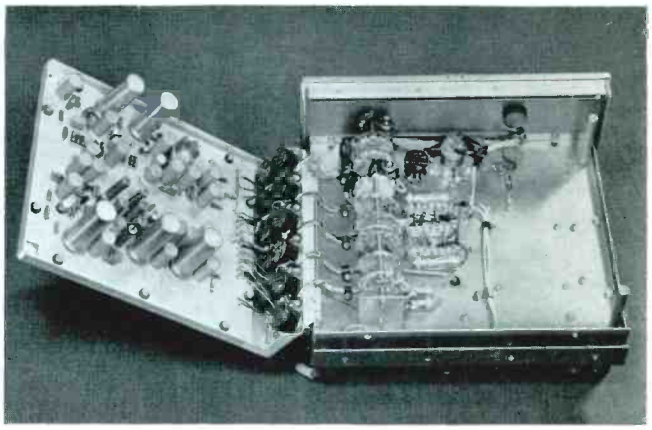
(5) In conditions where accurate voltage measurement is difficult due to circuit earth loops, errors can often be eliminated by using battery operation.

(6) Noise measurements are facilitated by the r.m.s. response up to 30 mV, or up to 3 V if the multiplier is used.

(7) Distortion measurements are possible over a wide frequency range, percentage distortion relative to total signal $= 100\frac{V1}{V2}$, where V1 = voltage due to harmonics and V2 = voltage due to harmonics plus fundamental. V1 should be measured by utilizing the r.m.s. region of the millivoltmeter which is connected to the output terminals of a network capable of sufficiently suppressing the fundamental.

(8) Used in conjunction with Circuit Magnification Meter type TF 1245[4], impedance measurements can be carried out at low voltage levels. This is essential with most transistors or circuits containing them.
To make direct measurements of Q at low levels, the $\triangle C$ method should be used in order to avoid error due to the shunting effect of the millivoltmeter probe. If required a much higher resistance can be obtained by also using the multiplier if the voltage across the Q meter capacitor is 30 mV or more.

(9) Despite all precautions regarding layout, feedback and inclusion of 'stopper' resistors a wide band video multi-stage amplifier may develop spurious oscillations whose frequency may lie anywhere between 1 and 1,000 Mc/s. To carry out a search with tuned receivers is tedious, but a loop connected to the probe and held near each part of the circuit in turn can ascertain if unwanted oscillations are present and remedial action taken.



The amplifier board, in common with the oscillator and power unit boards, hinges open for ease of servicing

(10) The tuning of narrow band amplifiers, filters and other networks where a multiplicity of tuned circuits require adjustment, is made easy by use of the more sensitive ranges of the millivoltmeter. The probe spike can be held close to circuit conductors and the preceding circuit tuned for a maximum voltage reading; because of the loose coupling used, removal of the probe will have negligible effect and little if any tuning correction will be necessary.

(11) Testing of filter frequency response, particularly in the stop band, can be achieved without excessive voltage requirements from the signal generator. For example, 50 dB attenuation can be measured using a generator capable of delivering 0·1 V to the filter input terminals.

(12) In wide band r.f. bridge measurements the millivoltmeter can be used as a null detector in place of several radio receivers, provided sufficient source voltage is available. If necessary, a simple resonant step-up circuit can be inserted between the bridge and the millivoltmeter.

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SOMMARIO DEGLI ARTICOLI PUBBLICATI IN QUESTO NUMERO

MODULOMETRO M.F./M.A. TIPO TF 2300

Viene illustrato un modulometro d'impiego generale, completamente nuovo che si distingue da analoghi strumenti meno recenti per una più vasta gamma di frequenzi modulanti e più ampie deviazioni di frequenza. Presenta inoltre molte delle prestazioni che in passato si potevano ottenere con l'impiego di tre strumenti diversi. Di particolare interesse sono la possibilità di misura della profondità di modulazione d'ampiezza ed un nuovo metodo di controllo a quarzo dell'oscillatore locale. Lo strumento può essere alimentato con tensione di rete in c.a. o con batterie.

Página 34

APPLICAZIONI STEREO A M.F. DEL MODULOMETRO M.F./M.A. TIPO TF 2300

Sono state eseguite misure che dimostrano come il nuovo Modulometro M.F./M.A. tipo TF 2300 possa essere usato come demodulatore standard a M.F. di sistemi stereofonici, oltre alle normali applicazioni nei sistemi convenzionali di comunicazione a M.F.

Abbinandolo al Generatore do segnali M.F./M.A. tipo TF 995A/8M1, si possono eseguire misure di distorsione e separazione di canale su trasmettitori e ricevitori stereo.

Página 39

UN COMPLESSO DI MISURA COMPLETO DI ELEVATA PRECISIONE

Questo complesso di misura a rack è stato assiemato dalla 'Transmission Division' della Plessey inglese per i collaudi di serie dei componenti destinati a sistemi multicanali. Per soddisfare all'elevato grado di precisione richiesto, si usano metodi di misura che consentono di confrontare i livelli relativi con la perdita d'inserzione di attenuatori calibrati. In tal modo la precisione di misura è resa indipendente da quella di taratura dello strumento.

Página 42

MILLIVOLTMETRO ELETTRONICO R.F., TIPO TF 2603

Questo è un millivoltmetro transistorizzato completamente nuovo, destinato per misure di tensione da 300 µV a 3 V per tutta la banda di frequenza da 50 kHz a 1500 MHz. La sonda di 12 mm. di diametro impiega una coppia di diodi al germanio con basso tempo di commutazione, collegati in un circuito a due semionde il cui responso è prossimo al vero valore efficace, per livelli inferiori a 30 mV, ed al valore picco-picco da 0,5 a 3 V. Le scale dello strumento sono praticamente lineari con uno sviluppo di circa 12,5 cm e sono tarate in valore efficace di una forma d'onda sinusoidale. Sono disponibili sei accessori tra i quali un moltiplicatore 100:1 che consente misure di tensione fino a 300 V. Come alternativa all'alimentazione di rete, lo strumento può essere impiegato con una batteria esterna collegata ai terminali posti sul retro.

Página 47

RESUMENES DE ARTICULOS QUE APARECEN EN ESTE NUMERO

MEDIDOR DE MODULACION DE FM/AM, TIPO TF 2300

Se describe un medidor de modulación para usos generales, totalmente nuevo, con el que se pueden efectuar medidas de una mayor desviación de frecuencia, y de unas frecuencias de modulación más amplias que con otros equipos ya existentes. Se pueden efectuar también mayor variedad de medidas, que antes sólo se conseguían con el empleo de tres equipos diferentes. Una de sus nuevas características es que puede medir la profundidad de modulación de amplitud, y otra, es un nuevo método, sencillo, de controlar por cristal el oscilador local. El TF 2300 puede alimentarse de la red de c.a. o por baterías.

Página 34

APLICACIONES DEL MEDIDOR DE MODULACION DE FM/AM, TIPO TF 2300 A LA F.M. EN ESTEREO

Se han efectuado medidas por las que se comprueba que el medidor de modulación de FM/AM, tipo TF 2300 puede utilizarse como un demodulador de f.m. normalizado en estéreo, además de sus otras aplicaciones en sistemas de communicación de f.m. corrientes. Además de esto, se puede emplear con el generador de señal de FM/AM, tipo TF 995A/8M1 para efectuar medida de distorsión y separación de canales, en receptores y transmisores estereofónicos.

Página 39

CONJUNTO DE PRUEBA, COMPACTO, DE ALTA PRECISION

Este conjunto de prueba, montado sobre bastidor, lo ha proyectado la División de Transmisión de Plessey Electronic Group, para la prueba de producción de componentes de sistemas multicanales. Para cumplir con las exigencias de alto nivel de precisión, se emplean unos métodos de medida en los que se comparan niveles relativos con las pérdidas de inserción de un atenuador calibrado. De este modo, la precisión de la medida se independiza de las calibraciones del medidor.

Página 42

MILIVOLTIMETRO ELECTRONICO DE R.F. TIPO TF 2603

Se trata de un nuevo milivoltímetro, completamente transistorizado, para medidas de tensión desde 300 µV hasta 3 V, para un margen de frecuencia de 50 kHz a 1.500 MHz. La sonda de prueba, de 1,25 cm. de diámetro, lleva un par de diodos de germanio rápidos en un circuito de onda completa, cuya respuesta se acerca a la r.m.s. verdadera, con entradas inferiores a 30 mV, y es de pico a pico en la región de 0,5 a 3 V. Las escalas del medidor son, prácticamente, lineales, y de una longitud de 13 cms. aproximadamente, calibradas en valores medios. Se han fabricado seis accessorios; entre ellos, un multiplicador de 100:1, con lo que se pueden efectuar medidas de tensión de hasta 300 V. Como alternativa de alimentación normal de la red, el equipo puede funcionar por baterías conectadas a los terminales situados en el lado posterior.

Página 47

SIGNAL GENERATORS

SWEEP GENERATORS

FREQUENCY COUNTERS AND METERS

OSCILLOSCOPES

NOISE GENERATORS

OSCILLATORS

PULSE GENERATORS

MODULATION METERS

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