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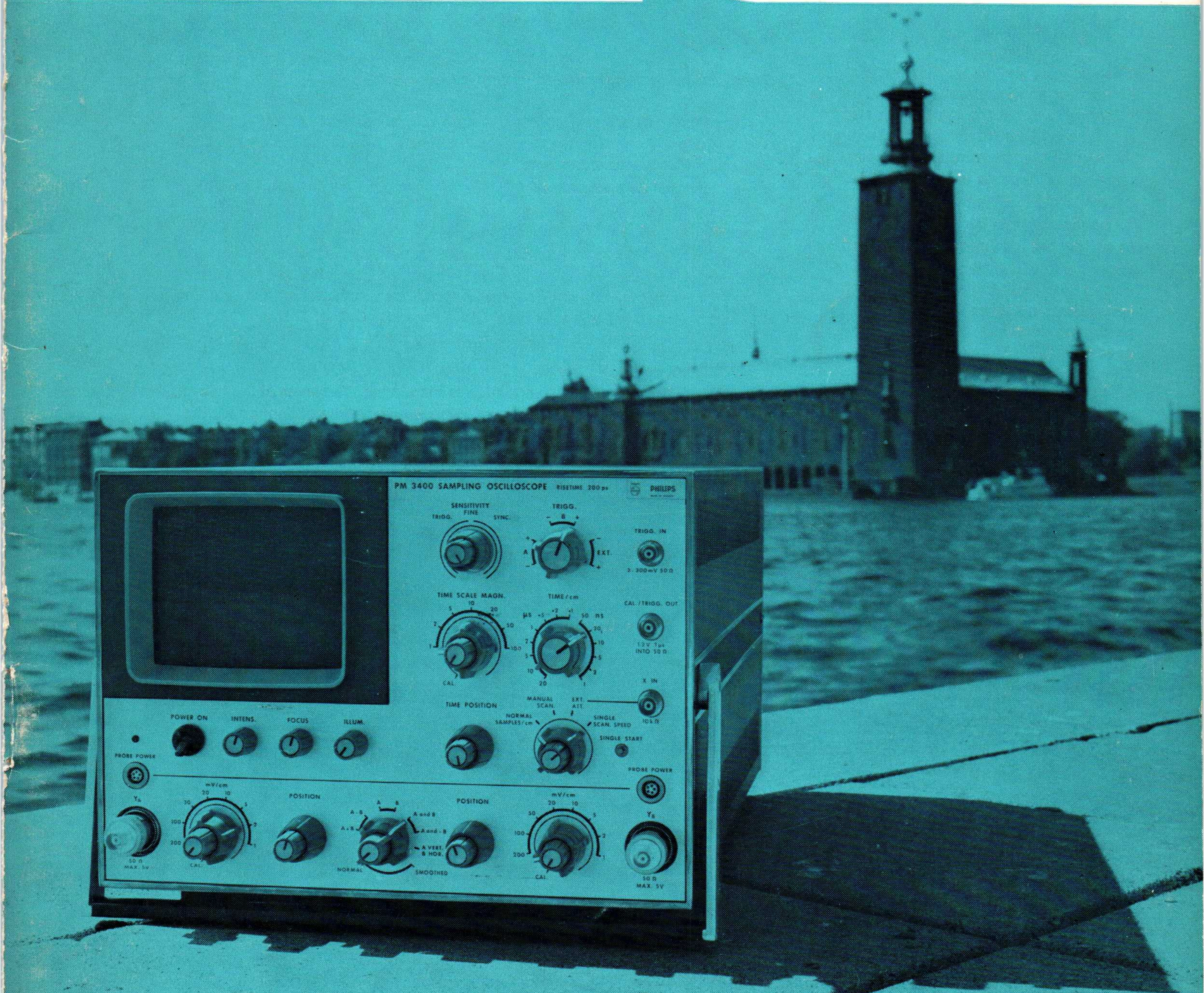

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electronic measuring and microwave notes

Introduction

The quarterly periodical Electronic Measuring and Microwave Notes provides information about the application and design of Philips electronic measuring and microwave instruments, and also surveys the new instruments which are regularly added to the Philips programme.
The information is intended to assist users in getting the maximum benefit out of instruments which they already posses and to help them in choosing new instruments which will best meet their particular measuring or microwave needs.

The front cover

of this issue shows the PM 3400 sampling oscilloscope which combines continuously variable control of sampling speed with a vertical amplifier rise time of 200 ps.
This instrument was designed by the development group in Sweden and is also manufactured in that country. The picture shows it in front of the Stockholm Town Hall.

In this issue

General information
If you are interested in regularly receiving the periodical Electronic Measuring and Microwave Notes and also in more information about the instrument please ask your Philips organisation. If there is no Philips organisation in your country enquires may be sent to n.v. Philips' Gloeilampenfabrieken, Test and Measuring Instruments Department, Eindhoven, the Netherlands.

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Combined colour/monochrome pattern generator PM 5544

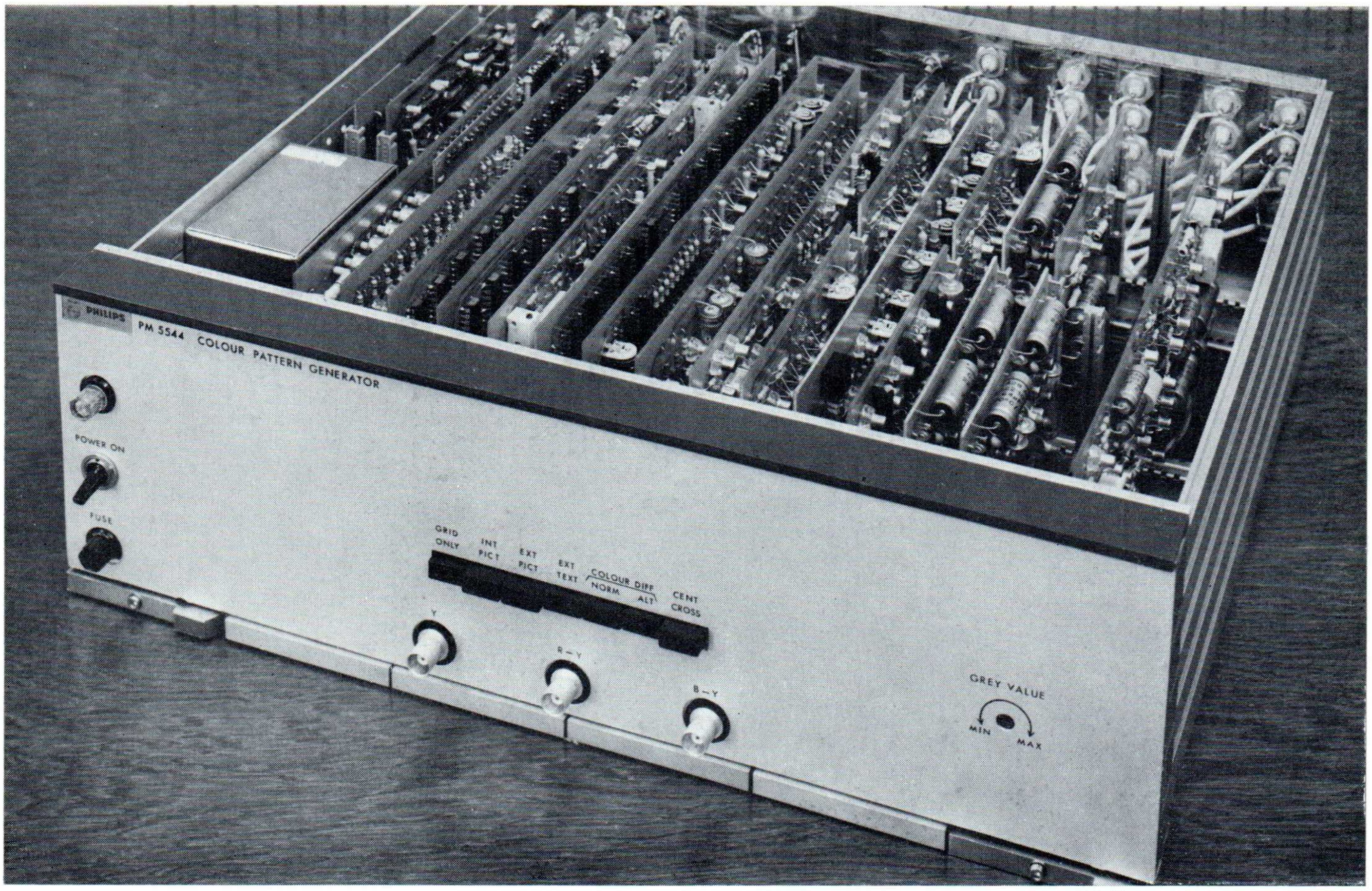
by F. Hendil, Philips A/S Copenhagen, Denmark

After the picture was fixed on paper our next problem was whether we should use TTL or DTL since the available space and the trend in the electronical markets showed us that integrated circuitry was a must. We felt the best choice for the future was TTL. The only suggested advantage for DTL "wired or" possibilities has proved to be of little importance. The speed of TTL is in many circuits in the PM 5544 most decisive.

The application of PM 5544 will be treated separately, see pag. 28, and the following description therefore mainly concerns the electrical philosophy.

The block diagram of the PM 5544 is shown in fig. 1. The circuitry can be split into three main functional groups:

1. *the digital divider and gate circuits*



Introduction

The test-pattern generator PM 5544 may be considered as a successor to our black-and-white generator PM 5540. It produces all the monochrome signals offered by the PM 5540 (and a few additional ones), and it also has a full range of colour test signals. Nevertheless, it is no bigger than the PM 5540, thanks to the use of integrated digital techniques.

Much use was made of the experience gained with the PM 5540 in determining the choice and arrangement of the individual test signals.

The main philosophy behind the apparatus was, without technical compromises, to realize a sophisticated all-round colour test pattern, suitable for use in laboratories, TV studios, transmitters and TV factories, with as much information as possible displayed directly on the TV screen.

The test pattern produced by the PM 5544 is shown in fig. on pag. 5. For the sake of clarity, the function of the various parts is superimposed on them. (This text is naturally not seen on the screen).

Most of the well known bl/wh and colour test signals are included in the pattern. There are no international recommandations for the lay-out of a mixed test pattern. We have therefore done our best to combine all those TV test signals which seem to be of lasting utility into a pleasing and harmonious whole.

2. *the circle generator*
3. *the linear circuits*

We shall now describe briefly the operation of these groups in turn.

The digital divider and gate circuits

The only input information required is sync. and blanking signals. The line and frame drive pulses are derived from the sync. signal, while the blanking signal is used as such to control the border limitations of the picture.

The picture generation is based on two divider chains, one for the vertical direction and one for the horizontal direction.

The vertical divider

The vertical divider consists of a 21 divider followed by a 16 divider. One output from the 21 divider goes to the circle generator for selection of one of 21 lines for the circle read-out decoder, and the other determines the position of the horizontal white lines in the grid raster (cross-hatching) around the circle. The distance between these horizontal white lines is the same as in the standard 14 x 19 grid raster. The white line signal is fed into the 16 divider which then via a decoding network determines the various picture areas as horizontal hars.

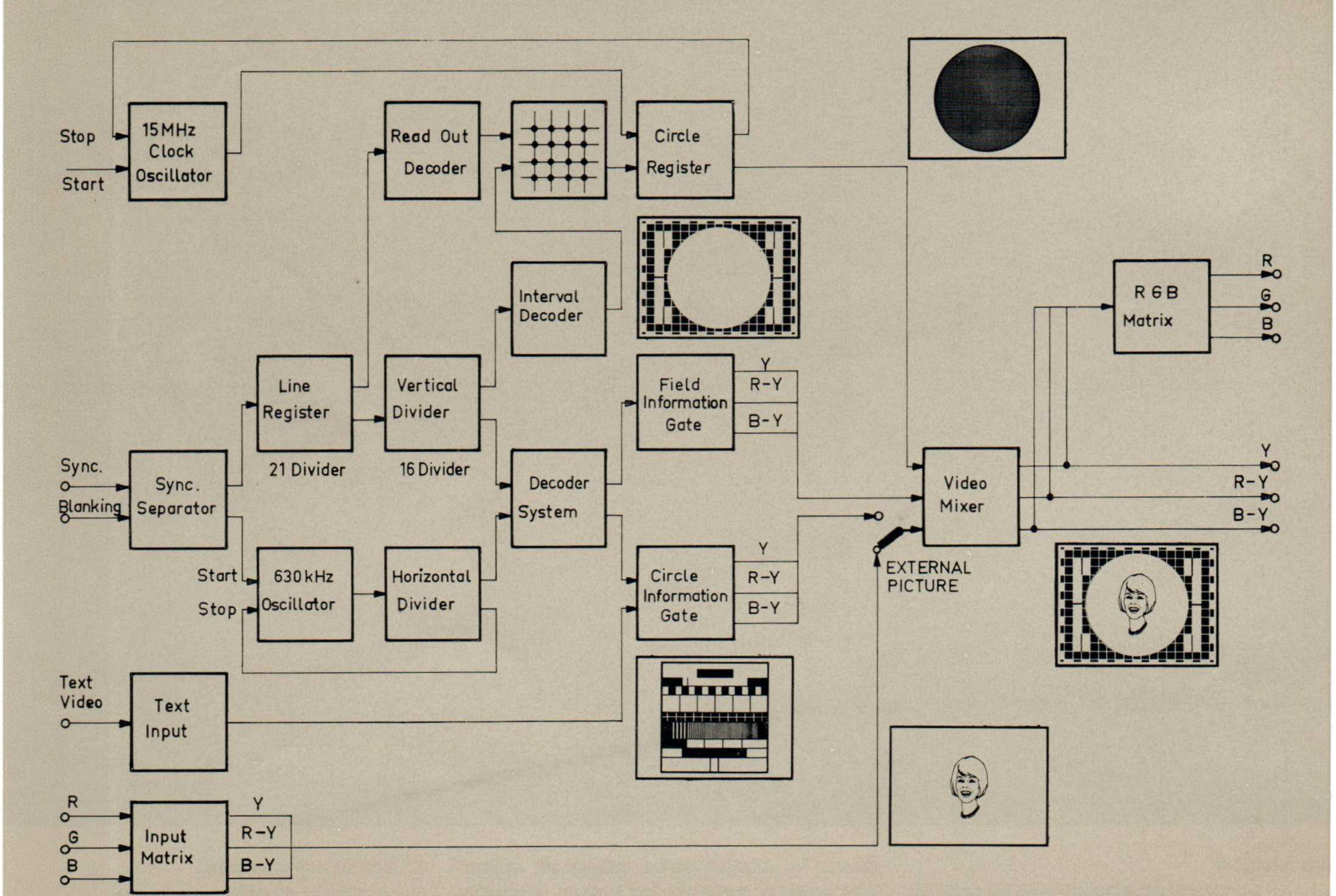
The vertical divider chain is fed with line pulses, and its operation is initiated by a frame pulse. After the frame pulse, the line pulses to the divider are omitted for a variable time so that the vertical position counter advances one step for each vertical line of the grid raster, while the other advances one step for every pulse just in the middle of the vertical grid lines. The first divider controls the picture content outside the circle, and the second that inside the circle.

Since the accuracy of the horizontal timing has to be very high, a normal binary counter could not be used. It was decided to use the Johnson type as this gives very simple gate circuitry for the decoding. Moreover, only one flip-flop changes at a time in this counter, which eliminates the "hazard phenomenon", which might otherwise give inaccurate transitions in many of the gating signals derived from the counter. The width of the vertical white lines is chosen as 0.23 μs.

Fourrier analysis shows that this width discriminator) by the time between the last white vertical line and the following line sync pulse. This time difference is stabilized, which reduces oscillator drift almost to zero. The left-hand and right-hand borders of the picture can thus be adjusted independently. Furthermore, the picture will remain symmetrical for variations of more than $\pm$ 2% in the line frequency (as found e.g. with the sync. generator PM 5530 in the jump mode).

One-shot multivibrator for adjustment of colour blocks

To ensure that the coloured blocks (R-Y, B-Y and G-Y=O signals) are situated inside the grid raster, the width of a grid line (0.23 μs) must be subtracted from the original gate signals. Moreover, since the horizontal colour transition between the



1. Block diagram of the PM5544

of the picture can be adjusted for symmetry with respect to the top and bottom of the screen, for TV systems with field blanking periods from 18 to 25 lines. This facility is necessary as the duration of the field blanking interval has not yet been standardized.

The horizontal divider

The horizontal divider consist basically of two counters of the Johnson type. One gives fewest spectral components at the subcarrier frequency, thus reducing the crosstalk from the white lines to the colour channel in a receiver to a minimum.

The accuracy of the horizontal oscillator frequency determines the accuracy of the squares formed by horizontal and vertical white lines.

The horizontal oscillator is frequency- and phase-controlled. The starting phase of the oscillator for each line is determined by the line pulses via a variable time delay, and the frequency is determined (via a signal G-Y = O and the neighbouring colours should be symmetrical with respect to the grid lines, an additional half grid-line width must be added to or subtracted from the gate signals for the colours in question. This led to the development of a special one-shot with very short delay time from the input to the leading edge of the output, see fig. 2.

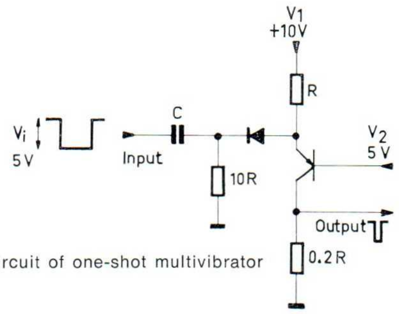
It may be seen from this that the one-shot

employs current switching; the initial delay will therefore be very short, and the width of the output pulse (t) is roughly determined by the equation:
$t = 0.4\ C\ R$

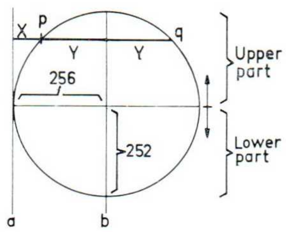
The circle generator

The most important and interesting signal generated in the PM 5544 is the electronic circle. This is produced by digital techniques, which allows the curvature to be made extremely exact.

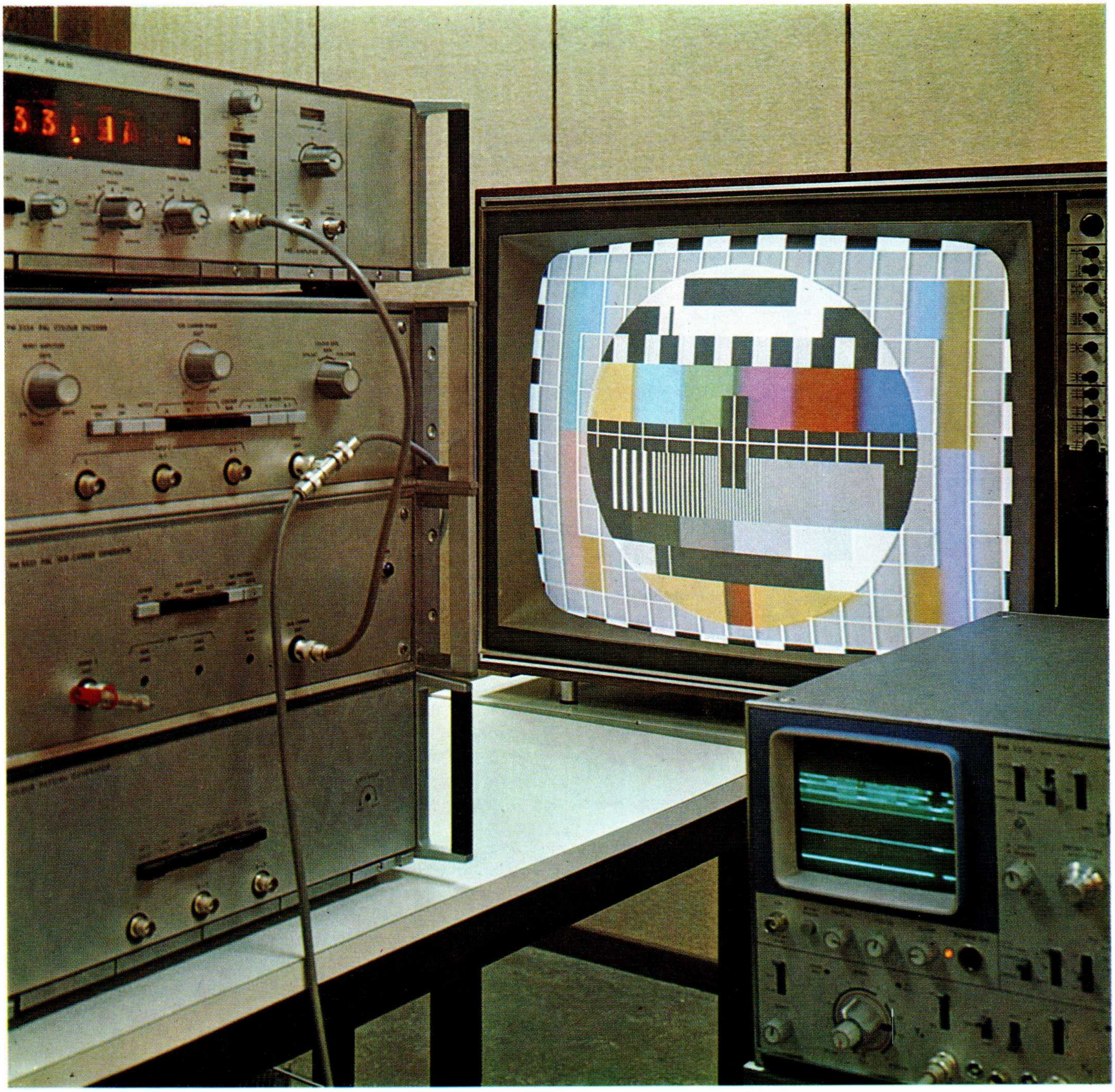
The circle is built up by horizontal scanning. For each scanning line, two registers (shown as one single "circle register" block in fig. 1) are preset to the distances X and Y which determine the shape of the circle (see fig. 3). Starting from the left hand vertical line **a**, the first register is fed

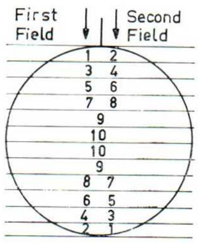


2. Circuit of one-shot multivibrator

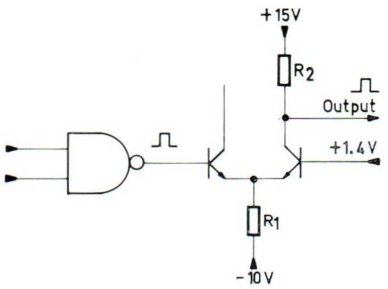


3. Method employed to build-up circle in PM5544's pattern

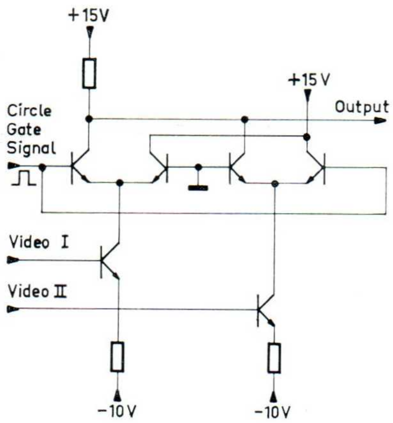




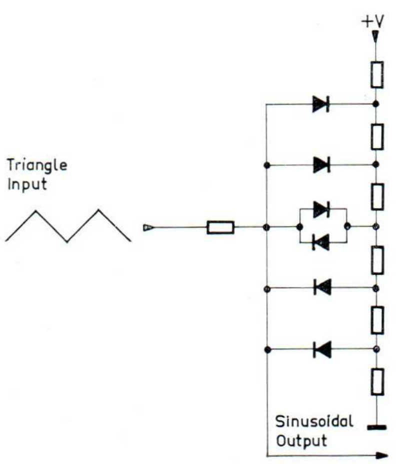
4. Total circle made of different intervals



5. Circuit of the linear section



6. Circuit for the picture within the circle



7. Diode shaping stage

with clock pulses (frequency 15 MHz) and counts down to zero. When the register is empty, the point p is found. The second register starts counting at the centre line b, and defines point q in a similar way. The values of X and Y for all scanning lines in the upper half of the circle are stored in a read-only memory ("circle memory" in fig. 2); the lower part of the circle is defined by the same memory by reversing the line selection register.

The circle is in vertical direction built up of 6 x 42 lines = 252 lines which determines the vertical resolution, while the horizontal resolution is $2^8 = 256$ — somewhat higher.

The interval selector gives the outputs shown in fig. 4. It will be seen that the circle is largely built up of two curves one for each field.

The interval selector is controlled by the output of the vertical 16 divider and the interval decoder; a specially controlled flip-flop distinguishes between the first and the second field.

The line selection register (the 21 divider in the vertical divider system) is coded to be as symmetrical as possible. This means that the line selection can easily be reversed just by inversion of one of the outputs from this divider.

The linear section

The main function of the linear section is to transform the gate signals into linear signals with a well defined amplitude and rise time.

For most of the signals, this is done by the circuit of fig. 5.

The output amplitude is defined by R_1 and R_2 together with the DC voltages applied (+15, +1,4 and —10 volts).

The linear section has the main functions as shown in the block diagram of fig. 1, (field information gate, circle information gate, video mixer and RGB matrix).

In the **video mixer,** the switching between the grid picture (video I) and the picture within the circle (video II) is done by means of the circuit of fig. 6. (schematically).

There are 3 separate mixers, for the Y, R-Y and B-Y signals. This switching technique gives the fastest possible transition between the two input signals. These two input signals are formed in two separate sections.

In the field information gate, the grid signal is mixed with the variable grey background and the colour difference signals to give Y, R-Y and B-Y signals.

The **circle information gate** generates and combines 4 sets of signals, which together define the test pattern inside the circle:

1. *the monochrome signal*
2. *the R G B colour signals*
3. *the sinusoidal definition lines, and*
4. *the grey scale*

The external text can be gated into the monochrome signal, so that the text amplitude equals the rest of the monochrome signal. In the input stage, the text video signal is passed through a Schmitt trigger.

The R G B colour signals are perhaps the most interesting of the four. They consist of the 250 kHz signal, the colourbar signal, and the yellow-red-yellow transitions/transients. Since all these signals are at 75% contrast, the gate signals control the switching of the R, G and B components; the Y, R-Y and B- signals are formed from these in linear matrix amplifiers.

This technique ensures that all the signals have exactly the same amplitude (75%), which is especially important for the comparison between the 250 kHz bl/wh signal and the colour bar just below (used for checking the colour saturation in a receiver).

The sinusoidal definition lines are generated by a frequency-variable triangle generator, the output from this generator being made sinusoidal by a diode shaping stage, see fig. 7. This technique gives the smoothest transition between two frequencies even when the change-over time is very short.

The staircase signal of the grey scale is generated in 10 steps but a 5- or 6-step staircase can be obtained by removing half of the input signals. The latter is likely to become standard, as it gives 20% steps which is very convenient for linearity checking with an oscilloscope. The output from the circle information gate is in the form of R-Y and B-Y signals.

Since the whole video information applied to the video mixer is present as Y, R-Y and B-Y signals, it is advisable to use these signals directly in an encoder, thus minimizing the matrix faults in the encoded signal.

For R G B monitoring or for use in encoders with only R G B inputs, the PM 5544 is supplied with an RGB matrix delivering R G B outputs signals.

The whole part of the test pattern within the circle (i.e. the output of the circle information gate) can be replaced by an external colour signal, from a camera or a flying spot scanner, by means of a push-button. This allows the advantages of the electronic circle to be combined with those of a more artistic picture.

TEST AMPLIFIER

The PM 5544 has its own built-in test-amplifier, which can display any digital signal inside the apparatus as a video signal on a TV monitor. The circuit proved itself during the development of the test-pattern generator, and we felt that it could be of value for servicing purposes. The test-amplifier output can be used as a separate video output for the grid signal. This signal is not very well defined but it may be useful e.g. for convergence adjustments.

Technical data

Composition of the pattern

a. Circle with b/w and colour information
b. Colour information next to the circle
c. Background with a.o. crossed lines

Sub a: Front top to bottom:

1. Black rectangle on white background
Width of rectangle: about 10 μsec
2. Black/white step with needle pulse
Width of needle pulse: 230 nsec ± 10 %
3. Square wave signals
Repetition frequency: 250 kHz
Amplitude: 75 % of white amplitude (1 same amplitude as R, G and B signals in colour bar and colour step to check saturation in decoders)
4. Colour bar signal
Colours: Yellow, cyan, green, magenta, red, blue
Saturation: 100 %
Gain: 75 %
5. Crossed lines
Width vertical lines: 230 nsec ± 10 % (to give minimum cross talk in colour channel)
Structure of horizontal center line:
2 lines, one in each field, reversed in sequence with lines of background (check of interlace).
A convergence cross can be switched into the centre of the pattern

The video content within the circle can be replaced by an externally applied video signal e.g. from a slide scanner or t.v. camera. This signal may have full screen size.

Sub b: Colour information next to the circle

Left hand side of circle:

1. Vertical bar with line alternating positive and negative R-Y signal
2. Vertical bars with positive and negative R-Y signal
3. Two rectangles with signal G-Y 90°

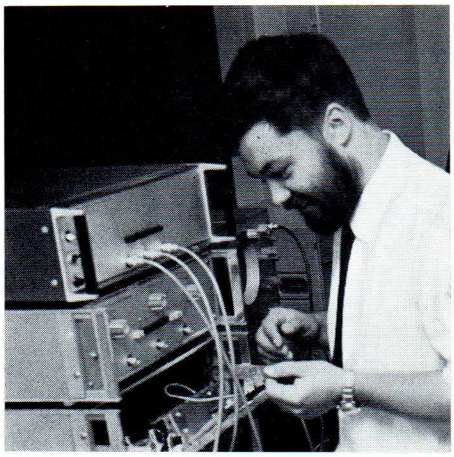
Right hand side of circle:

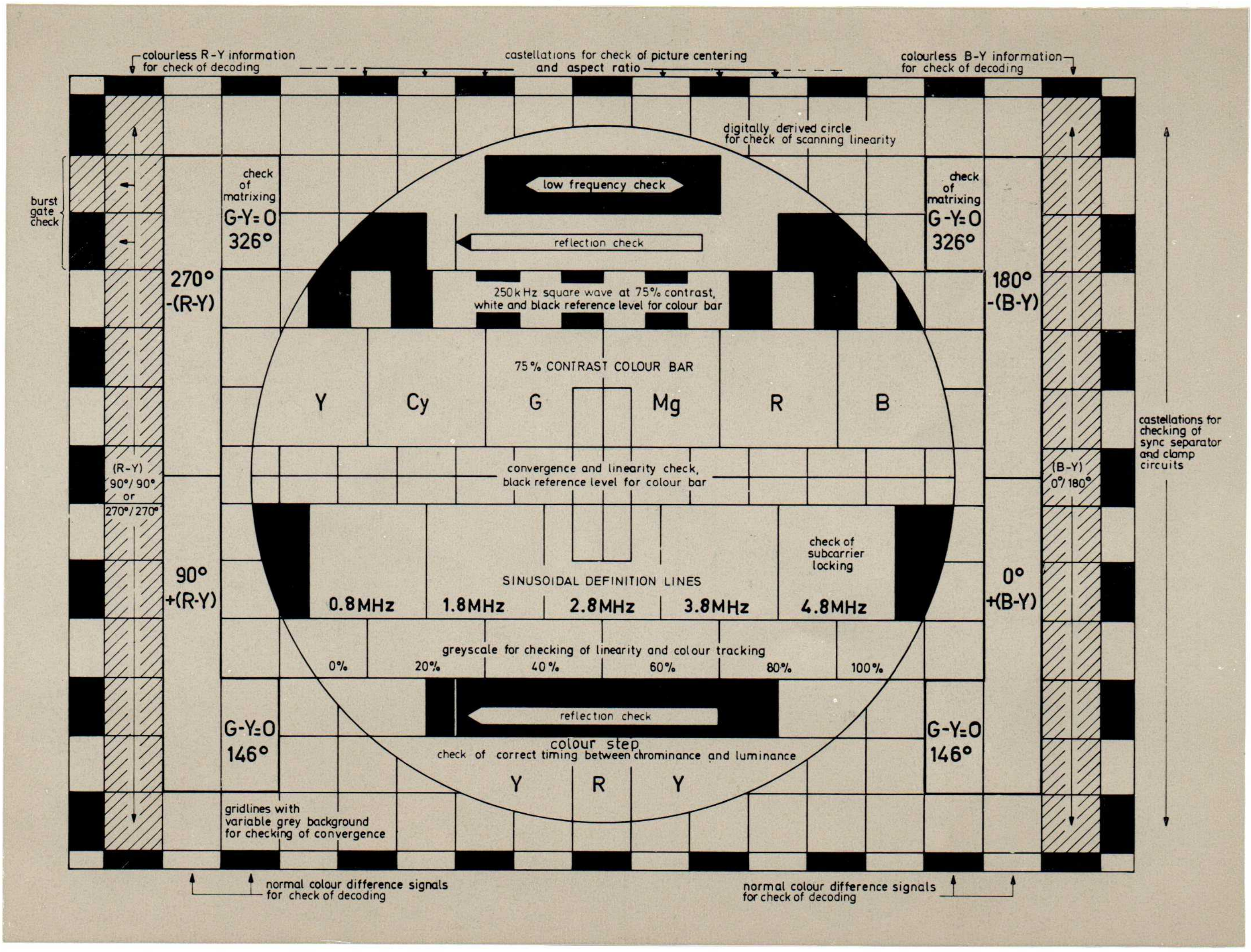
1. Vertical bar with line alternating positive and negative B-Y signal
2. Vertical bars with positive and negative B-Y signal
3. Two rectangles with signal G-Y 90°

The various signals sub b. can be switched off separately.

Sub c: Background

1. Crossed lines
Number: 14 horizontal x 19 vertical lines
Width: 230 nsec ± 10 %
2. Background
Level: adjustable 0 - 80 %
3. Black/white border castellations





6. Definition lines
Frequency: 0.8, 1.8, 2.8, 3.8 and 4.8 MHz, sine waves
7. Staircase
Number of levels: 6 (modification to 10 levels easy possible)
8. White black step with needle pulse
See 2
9. Colour step
Colours: Red on yellow background
Width: about 3 μsec
Gain: 75 %
10. Circle
Mode of generation: Binary generated circle with ferrite core memory
Diameter: about 83 % of active vertical amplitude
Error of diameter: < 1 %

Input signals

Composite synchronization and blanking signals: 2 - 8 V_{pp} negative, loop through
External identification signal: 0.5 - 2 V_{pp}, positive, loop through with or without sync.
External inner circle R, G and B signal:
0.7 V_{pp} without sync. positive, loop through
Frequency response: 6 MHz (3 dB)

Output signals

Y, R-Y and B-Y signals: 0,7 V_{pp} without sync. positive, impedance 75 Ω
R, G and B signal: 0.7 V_{pp} without sync, positive, impedance 75 Ω, matrixing error: < 2 %

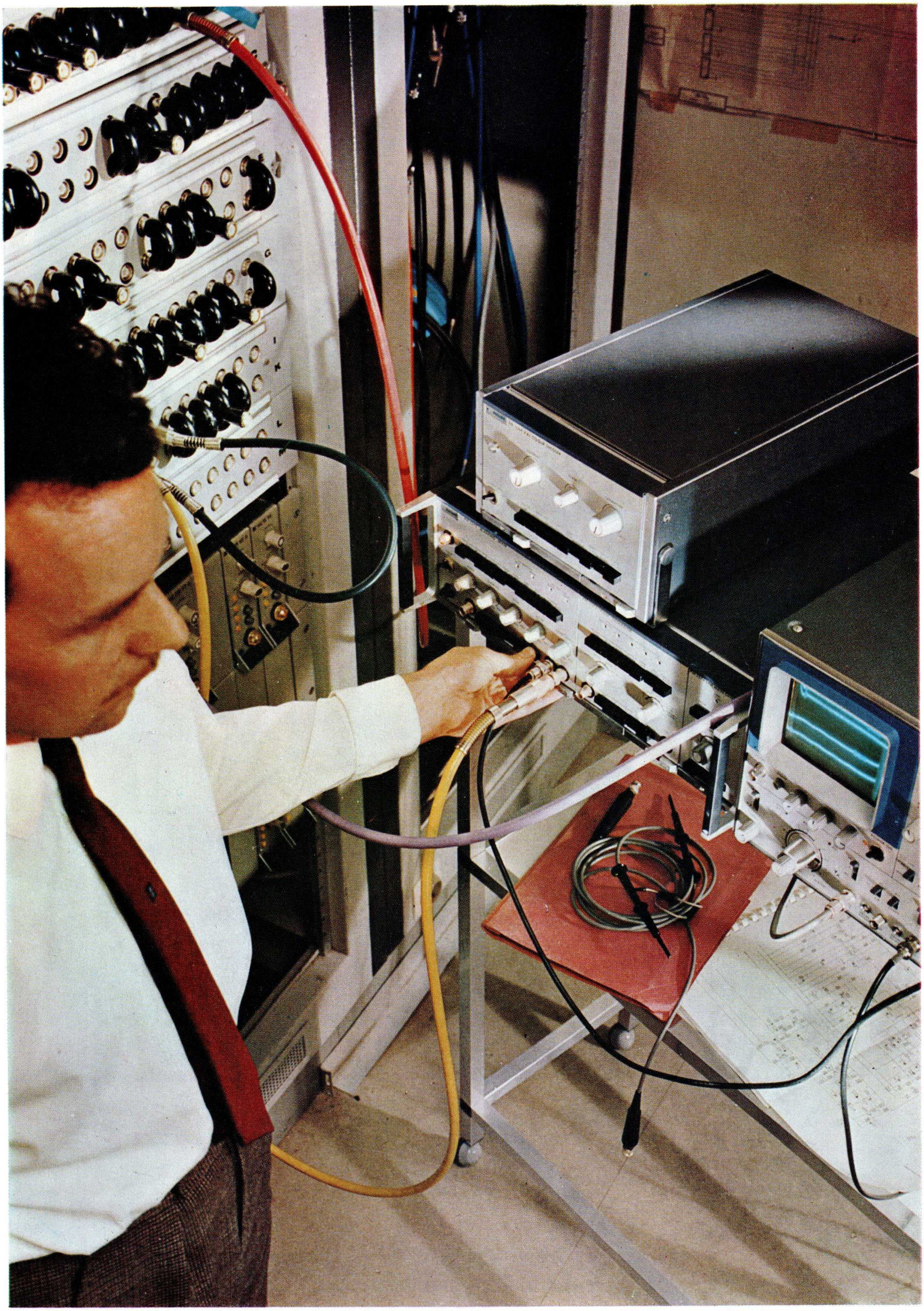
Power supply

Voltage: 115/230 V ± 20 %, 2 positions
Frequency: 50 - 60 Hz
Consumption: 45 W

Temperature range: 0 to +50 °C

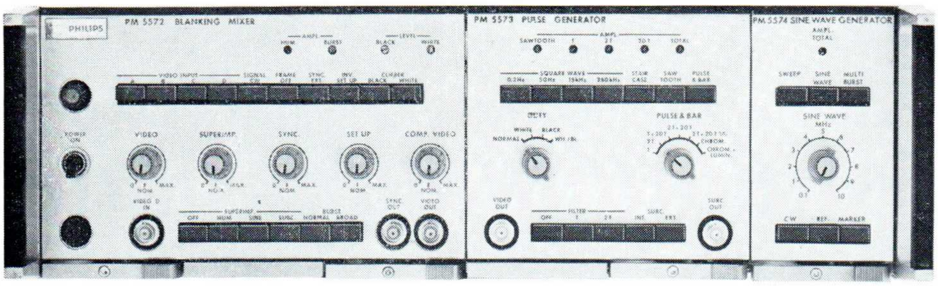
Mechanical data

Full 19″ cabinet of the Philips universal cabinet system.
Height: 132 mm
Depth: 444 mm
Width: 435 mm



New test-signal generator for transmitter and studio measurements

by Preben Hejberg, Philips A/S Copenhagen, Denmark



Summary
This paper deals with a new video test-signal generator specially developed for use with transmitters, transmission links and studios. The instrument makes use of integrated circuits and silicon semiconductors. It is constructed in modular form, thus giving flexibility and the possibility of expanding the system with the aid of extra units in the future.
The aim of the development work was to design in one single 19″ rack cabinet an instrument giving all TV test signals used in the above-mentioned fields today. The test signals include signals recommended by the CCIR and the ARD in Germany, and signals in use by various national post-office authorities and studios. Some new signals have also been introduced, e.g. 20T sine-squared pulses with luminance or chrominance or luminance plus chrominance information, jumping white/black duty staircase or sawtooth signals for linearity measurements and a multiburst sine-wave signal with white and black reference lines.

Introduction
The changeover from monochrome to colour television sharpens considerably the demands one has to make on the equipment involved in the transmission and distribution of TV signals from the studio to the viewers. Transmission errors which give more or less noticeable flaws in the black/white picture may spoil a colour picture very seriously.
The only way to ensure good quality of the transmitted colour picture is to keep the transmission characteristics of all equipment from camera to transmitter aerial within very close tolerances. This makes it necessary to use accurate and reliable measuring equipment and elaborate measuring methods. A number of measuring (or test) signals has been developed during the past years, some of which have been standardized by international organizations like the CCIR and EBU, while some are proposed or used by the various national authorities. These signals are composed so that they are mainly sensitive to one or two types of distortion only, thus making it easier to distinguish between the various types of distortion which may be present in a transmission system.

Application
The test-signal generator PM 5572/73/74 has the required accuracy and versatility for measuring and testing equipment used in TV transmission chains. The generator provides test signals for measuring the following characteristics:
1. Insertion loss
2. Linear distortion:
   a. Amplitude response
   b. Low-frequency response
   c. Transient response
   d. Pulse response
   e. Colour performance
3. Non-linear distortion:
   a. Static non-linearity
   b. Chrominance non-linearity
   c. Intermodulation

These points are dealt with in turn below, together with the proposed measuring signals.

INSERTION LOSS
This is defined as the total loss from the input to the output of the equipment under test. Normally this is measured with the aid of a "white level reference pulse", whose repetition frequency is equal to the line scanning frequency (15 kHz).

The following signals can be used:
— 15 kHz square-wave signal
— Sawtooth and staircase signal with white duty
— Pulse and bar signals
— All-sine-wave signals with white reference pulse

If 1 MHz is taken as the reference level, the following signals can be used:
— Multiburst signal
— Fixed-frequency signal
— Sweep signal (the marker will indicate 1 MHz).

LINEAR DISTORTION
a. **The amplitude response** is the gain as function of the frequency. This has to be measured with a sinusiodal waveform, e.g. one of the following available from the sine wave generator:
— sweep signal
— multiburst signal
— fixed frequency signal

The frequency may be time-controlled (sweep and multiburst signal) or manually controlled (fixed frequency signal).

The sweep signal gives a frequency varying from 100 kHz to 10 MHz in a linear, continuous sweep. Any frequency within this band will be present but only for a vanishingly short time. The sweep repetition frequency is 50 Hz, synchronized to the vertical information of the sync signal. The sweep rate is slow enough for all types of video equipment without high Q dips or spikes in the amplitude characteristic.
The sweep signal is used whenever detailed information on the amplitude response is wanted. The signal is also suitable for photographic recording. The marker and the white reference features facilitate the interpretation of recordings like the one shown in fig. 1. (Sharp cut-off filter without phase compensation.)
The multiburst signal is a discontinuous type of sweep signal, where a definite frequency is generated during a certain time. Because the information in this signal is very limited in comparison with the continuous-sweep signal, the repetition frequency can be much higher; in this case it has been chosen equal to the line scanning frequency.
The multiburst signal is used where a high repetition rate is demanded or where the high resolution of the continuous sweep is of no interest. This is the case

for vertical interfield test signals and professional video tape recorders etc. Fig. 2 shows the characteristics of the same filter as in fig. 1 with the multiburst applied instead of the sweep signal. The feature of alternating white and black reference lines has been utilized.

The fixed-frequency signal is useful for making graphic plots of the amplitude response, since only one frequency is present at the same time. Here again, white reference pulses may be applied.

Superimposed sine wave. Any of the sine-wave signals can be superimposed on any video signal in order to see whether the amplitude response depends on the grey level of the sine wave. In practice one might use either a line frequency sawtooth or a constant grey level (set-up) as video information, with a fixed frequency sine wave superimposed on the sawtooth and either the multiburst signal or the sweep signal on the grey level.

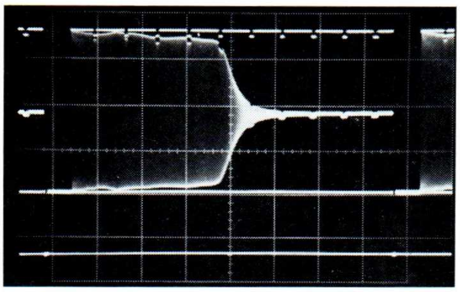
b. **Low-frequency response.** Here one has to distinguish between video equipment with and without a DC restorer circuit (clamp circuit).

In the first case the DC level is restored by the line sync pulses, thus removing any low-frequency error below the line scanning frequency. The only low frequency error left is that of the line scanning frequency itself, appearing as line tilt due to discharging of the coupling condenser in the clamp circuit. This can be checked by means of the 15 kHz square-wave signal.

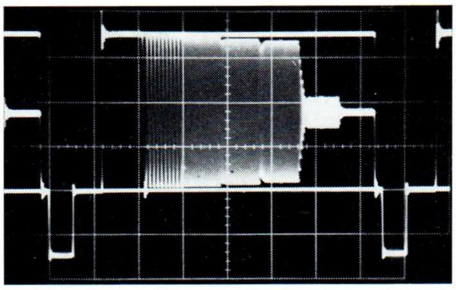
The proper functioning of the clamp circuit is checked with the 50 Hz and 0.2 Hz square-wave signals. The black level of the signal should be constant and independent of the video information.

Video equipment without clamping circuit is checked by means of the 50 Hz square-wave signal. The imperfection of the frequency response detected by this measurement is often called frame sag or tilt, see fig. 3.

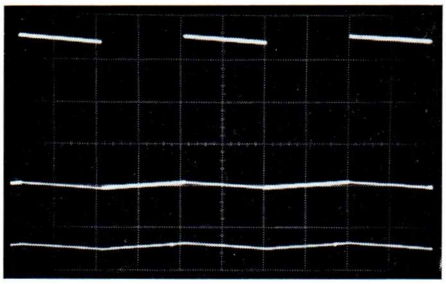
For transmitters the 0.2 Hz square-wave signal (transmitter bump) is used for checking both the clamping and the power performance; this test signal is particularly useful because of the extreme change in radiated power:



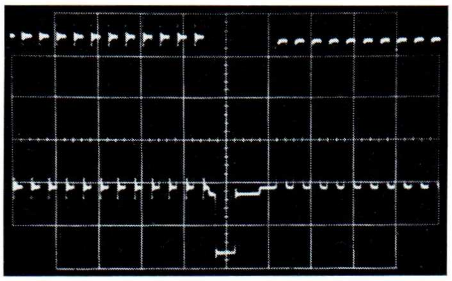
1. Sweep signal with marker and white ref. applied on sharp cut-off filter



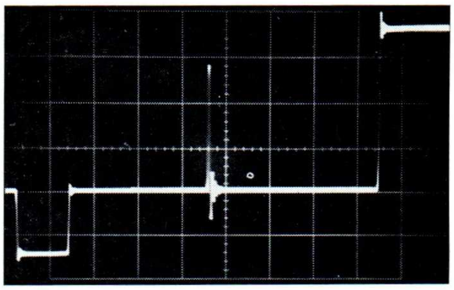
2. Multiburst with alternating white and black lines applied on sharp cut-off filter



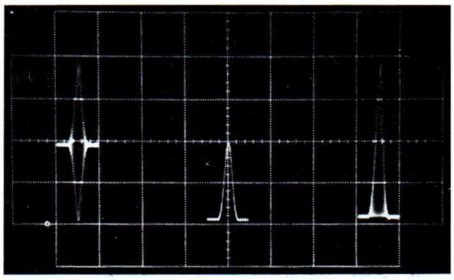
3. 50 Hz square wave displayed on oscilloscope. AC mode input is used to provide frame tilt



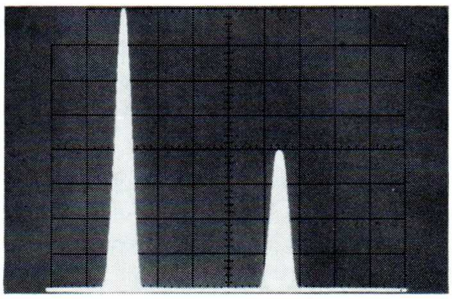
4. Transient response of sharp cut-off filter using 250 kHz square wave (rise times 90 and 180 nsec respectively)



5. Pulse response of sharp cut-off filter to T pulse

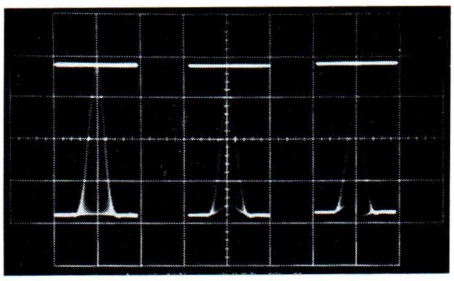


6. Composition of carrier-borne 20T pulse (chrom. + lum. form composite pulse)

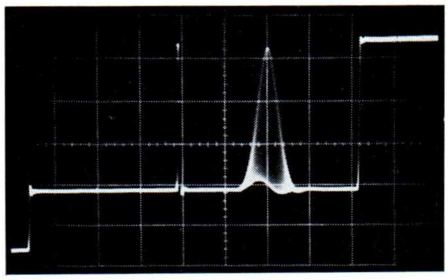


0 Hz 5 MHz

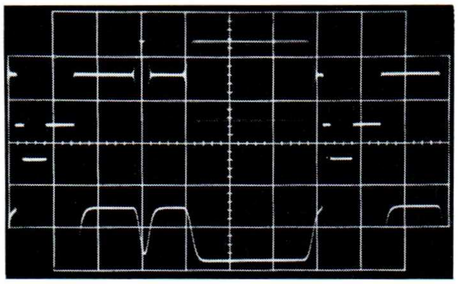
7. Spectrum of carrier-borne 20T pulse



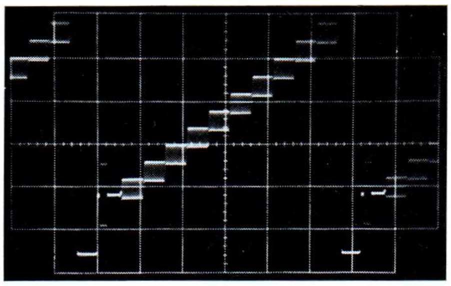
8. Carrier-borne 20T pulse without distortion, with pure amplitude distortion and pure group delay distortion (phase distortion)



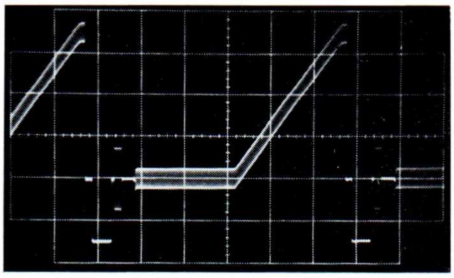
9. 2T, 20T carrier-borne pulse and bar after it has passed through the sharp cut-off filter



10. 20T pulse plus bar carrier-borne (chrominance) pulse after passage through non-linear network



11. Staircase with superimposed subcarrier and burst



12. Line frequency sawtooth plus superimposed subcarrier with black duty

white part of the signal: 15% of peak sync power
black part of the signal: 58% of peak sync power
(70/30 % video, 10 % carrier)

c. **Transient response.** This response is checked by means of one of the following signals:
— 250 kHz square-wave signal
— 15 kHz square-wave signal.

The 250 kHz square wave signal is used for study of the positive and the negative steps individually. The repetition frequency of 250 kHz gives a clear, bright display on the oscilloscope even at very fast sweep rates. The rise and fall times of the signal can be chosen as about 40 nsec., 90 nsec. or 180 nsec. It is important that the rise and fall times should correspond to the bandwidth of the equipment under test if true measurements of overshoot is to be obtained. In a 5 MHz bandwidth system, rise and fall times of 180 nsec. are required. Fig. 4 shows the pulse response for the same filter as used in fig. 1.

The 15 kHz square-wave signal can be used instead of the 250 kHz if only one positive and one negative step per line is wanted.

d. **Pulse response.** The response of the video equipment to narrow pulses is checked by means of sine-squared pulses, which are characterized by having well defined frequency spectrums. The T, 2T and 20T pulses contain harmonics up to 10, 5 and 0.5 MHz respectively, where T (50 % pulse width) is 100 nsec. for a normal 5 MHz video channel. It will be clear that the T pulse is **not** passed through a 5 MHz system without distortion, since its frequency content above 5 MHz will not be transmitted. The sine-squared pulses are sensitive to distortion due to imperfection in amplitude response, phase characteristics, and non-linear transient errors (fig. 5).

e. Colour-performance. 20T carrier-borne pulses are used to check whether the equipment under test is well suited for transmitting colour signals or not. The 20T carrier-borne pulse is composed of a normal 20T pulse plus the same pulse modulating a 4.43 MHz colour subcarrier, as shown in fig. 6. The frequency spectrum of this complex pulse cover the range from about 0 to 0.5 MHz for the 20T pulse itself (luminance or bl/wh information) and 4.43 MHz ± 0.5 for the modulated pulse (chrominance or colour information); see fig. 7. Any difference in gain or group delay between the subcarrier-frequency part and the low-frequency part will cause the original straight base line to become either a cosine- or a sine-wave curve. The peak amplitude of this curve compared with that of the signal amplitude is a measure of the amplitude and phase distortion in the equipment under test.
By way of example, fig. 8 shows the distortion of the 20T carrier-borne pulse due to pure amplitude distortion and pure group delay distortion.
Fig. 9 shows the 2T + 20T carrier-borne sine-squared pulse-and-bar signal after it has passed the 5 MHz cut-off filter.

NON-LINEAR DISTORTION
The presence of non-linearity in the equipment under test means that the output voltage is not proportional to the input signal. The non-linearity measured at low frequencies or DC is called static non-linearity, while non-linearity measured at high frequencies is called dynamic non-linearity, or chrominance non-linearity if the subcarrier frequency is the measuring frequency.

a. **Static non-linearity** is measured with the aid of a line-frequency sawtooth- or staircase signal. After the signal has passed the equipment under test it is observed on the oscilloscope screen to check whether the sawtooth is still a straight line or all the steps in the staircase still have the same amplitude. In order to see if the linearity is depending on the mean level of the signal or not, it is useful to let three out of four lines be all white or all black. For a transmitter, the radiated power will then be as follows (70/30 % video, 10 % carrier):

Mean power \ Signal type	Sawtooth lines	3 lines white 1 line sawtooth	3 lines black 1 line sawtooth
Percentage of sync peak power	38 %	20 %	52 %

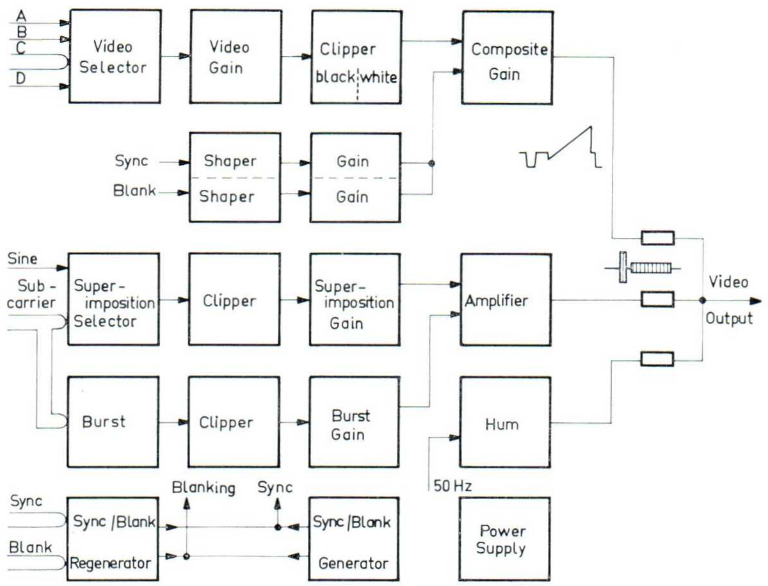
b. **Chrominance non-linearity** is present when the sinusoidal waveform of the colour subcarrier is distorted by passage through the equipment under test. If this distortion is a consequence of a clipping or a compression of the sine wave, a low-frequency component will be added to the signal, as can easily be checked by the signal of fig. 10 (top). Below in this figure is shown the same signal with the subcarrier information removed, thus leaving the LF component only.

c. **Intermodulation** from the luminance signal to the chrominance channel is called differential distortion. Differential gain means the gain of the subcarrier as a function of the luminance level, while differential phase means the phase of the subcarrier as function of the luminance level compared with e.g. the colour burst phase. These quantities can be measured with a signal having both luminance information, e.g. a sawtooth or staircase signal, and chrominance information of constant phase and amplitude (superimposed subcarrier) plus a colour burst signal if required (see fig. 11). A differential distortion meter is necessary for detecting the distortion of the signal after it has passed the equipment under test.* As with the static non-linearity measurements, it may also be useful here to apply different mean luminance levels by letting three out of four lines be white or black. The subcarrier may or may not be suppressed during these lines.
If necessary, the repetition frequency of the duty-cycled sawtooth or staircase can be 15 kHz; the black- and white clipper should then be used to modify the normal sawtooth signal as shown in fig. 12.
Differential distortion measurements can be extended beyond the black level by adding inverted set-up to the signal.

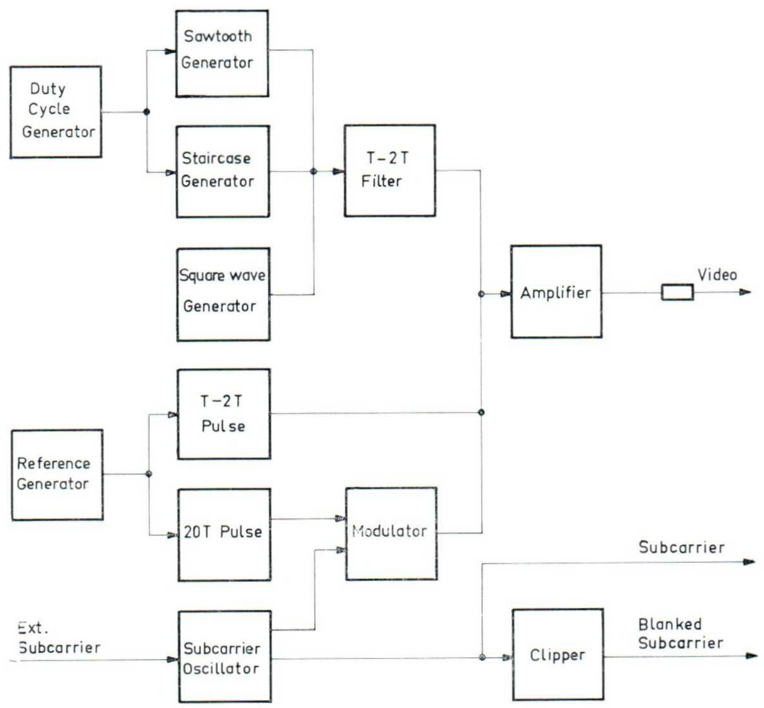
Mechanical construction
In order to give a flexible system, the test-signal generator is split up into three units, which together with the cabinet form a standard 19" rack instrument. The main unit is the blanking mixer, which contains a common power supply for all three units as well as the synchronization circuitry necessary for driving the two generator modules.
Moreover, the blanking mixer controls such parameters of the output signal as video content and amplitude, sync amplitude, set-up polarity and amplitude, superimposed signal amplitude, etc.
The second unit is the pulse generator, which generates a variety of signals such as square-wave signals, sawtooth and staircase signals, plus pulse and bar signals.
The third unit is the sine-wave generator, which gives sinusoidal wave-forms with or without blanking information.
The three units are linked together with multicore cables, which transmit power and drive pulses, and four coaxial connections for video and superimposed signals. A fixed rear plate with cabling for convenient plug-in is optional. All controls work with DC voltages, thus making remote control possible.

Blanking mixer PM 5572
The blanking mixer performs the following functions:
1. Conversion of the video signals from the pulse generator, the sine-wave generator or any other video source

* The special features of the PM5564 decoder can be used for measurement of differential distortion. This application has been described in the 1969/1, issue of these Notes.



13. Block diagram of the blanking mixer PM 5572



14. Block diagram of the pulse generator PM 5573

into composite video signals (video, sync and set-up).

2. Combining the composite video signal with a superimposed signal which can be either a subcarrier from the pulse generator module, sine wave from the sine-wave generator or 50 [60] Hz hum. A colour burst may be superimposed.
3. Generation of the sync and blanking signals (internal generator) or synchronization with external supplied sync and blanking signal.
4. Supplying of the necessary low voltage power for all the modules.

The block diagram of fig. 13 gives an impression of the function of the blanking mixer. The upper row of blocks forms the video channel, consisting mainly of the video selector, which chooses the video signal (e.g. a sawtooth signal from the pulse generator). The second block is gain control, determining the amplitude of the video component in the output signal. The third block contains a black and a white limiter plus a blanking clipper. By means of this it is possible to convert picture signals into television signals and to make new wave-forms out of e.g. the sawtooth signal. The fourth block forms the composite video signal by addition of sync and set-up. It also contains a gain control and an output amplifier.

The second row shows the pulse shaper circuit and gain control of sync and set-up pulses. The set-up can be inverted so that e.g. the differential distortion measurements can be extended to levels below the black level.

The third row is the superimposition channel starting with a selector giving either no signal or subcarrier or sine wave (1 — 10 MHz) as superimposition signal. The following block removes the signal during either the sync-pulse period or the blanking-pulse period. After gain control, the signal is added to the burst pulse and passed through an output amplifier.

The fourth row shows how the burst is derived from the subcarrier, formed in a clipper circuit and controlled in a gain control. The last block indicates the superimposed hum facility. The video signal, the superimposed signal and the hum are added in a resistor matrix giving an output impedance of 75 Ω. From this block diagram it can be seen that there are practically no limitations on the signal combinations that can be made, since the video and the superimposition channels are completely independent. Furthermore, it can be seen that the video signal and the superimposed signal are not passed through any common amplifiers, giving extremely low differential gain and phase distortion (less than 0.1% and 0.1° respectively) for a signal consisting of e.g. a sawtooth with superimposed subcarrier.

Finally, the block diagram shows the synchronisation circuitry (either externally or internally controlled) and the power supply.

Pulse generator PM 5573

The pulse generator generates all the pulse waveforms plus the subcarrier frequency (crystal oscillator). The output signal is 0.7 V_{pp} video with blanking information.

Fig. 14 shows a simplified block diagram of the pulse generator. As can be seen there are three generators, one for sawtooth, one for staircase and one for square-wave signals, from which the signals can be passed through Thomson filters giving them rise and fall times of 90 or 180 nsec. The duty-cycle generator determines whether the sawtooth or staircase should be generated on every line or on every fourth line only, the remaining lines being white or black or jumping automatically white/black every 2.5 sec.

The lower half of the block diagram shows the sine-squared pulses generator. The pulses are made from very narrow pulses which are fed through Thomson filters of 100, 200 and 2000 nsec rise and fall time (T, 2T and 20T pulses). The 20T pulse may be modulated on the colour subcarrier, thus giving the various signals for chrominance to luminance measurements. The reference generator determines whether the pulses are generated on every line or on every second line only. The other lines are then white, and by proper selecting of the oscilloscope time base they will act as reference lines for the sine-squared pulses. The subcarrier for the carrier-borne pulses can be either internally generated (crystal controlled) or supplied from outside. The subcarrier or the blanked subcarrier is fed to the superimposition channel of the blanking mixer. If the blanked subcarrier is used the superimposed subcarrier will be suppressed during the white or black lines in the duty-cycle sawtooth or staircase signal.

Sine-wave generator PM 5574

The heart of the sine-wave generator (fig. 15) is a voltage-controlled triangle generator, which is controlled by a frame-frequency sawtooth if the sweep signal is wanted, a constant DC level for a fixed-frequency signal or a line-frequency staircase for a multiburst signal. The output from the triangle generator is shaped to a sinusoidal waveform by means of a diode clipping network.

The reference generator determines whether there should be a white reference pulse at the beginning of each line in the sweep signal and the fixed frequency signal or if the multiburst signal should be generated on every second line only, the others being alternately white and black. The output from the sine-wave shaper is mixed with a narrow pulse from the 1 MHz oscillator. The output from the mixer is filtered in a low pass filter which will pass a marker signal every time the sweep signal is passing the harmonics of the 1 MHz signal. The marker signal triggers a one-shot which gives a slight attenuation of the output signal during the time it is in the active state.

The sweep and the fixed-frequency signal may be generated without any TV information.

Circuit details

The staircase circuit of pulse generator PM 5573 and the sine-wave generator unit PM 5574 will now be discussed as representatives of circuits composed of integrated digital circuits and discrete components respectively.

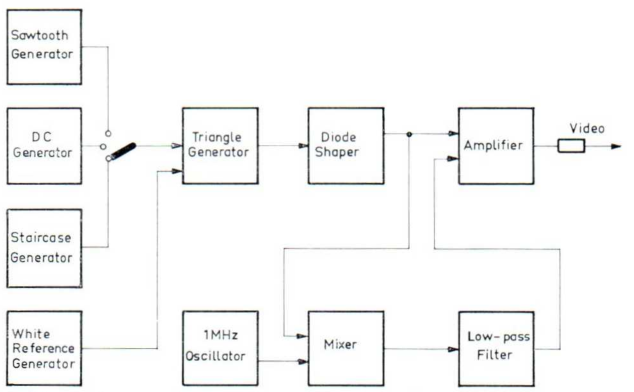
The staircase generator is shown in fig. 16. The clock-pulse oscillator starting by the horizontal line pulses is driving the first flip-flop, which is coupled as a normal binary scaler. The other flip-flops are working as a shift register.

At the beginning of a line all flip-flops are in the zero state and consequently the outputs from all the NAND gates are in the "one" state. The analogous output voltage is therefore equal to the "one"-state potential of the gates (fig. 17). The first clock pulse after the line pulse shifts the state of FF 1 to "1". The output of G 1 goes to zero, causing the output voltage to drop an amount determined by the ratio between R2 // R3 // R4 // R5 // R6 and R1. The second clock pulse will reset FF 1 to state 0 and set FF 2 to state 1. R2 has such a value that these two changes together will cause a voltage drop of the output equal to the first step. The third clock pulse retriggers FF 1 and we get the third step in the negative-going staircase signal. The fourth clock pulse sets FF 3 in state 1 and FF 1 in state 0, and so on. After clock pulse No. 11, all flip-flops are in state 1 and the output signal following zero. By adjusting the clock-pulse frequency, we can give the staircase from 8 to 12 levels (black level included). Disconnecting G 1 from the matrix gives a 6-level staircase. The signals Fl/4 introduce either the white or black lines in the duty-cycle staircase signal.

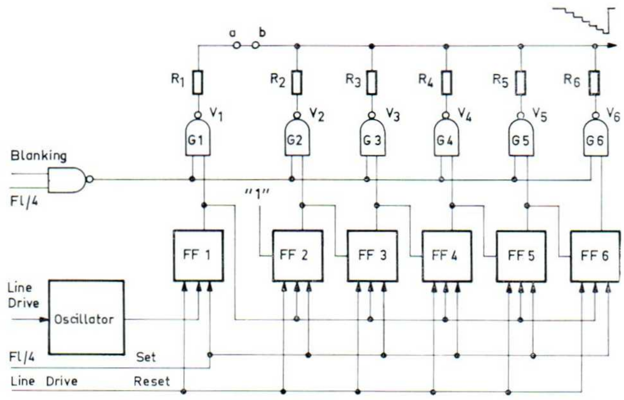
In spite of the fact that every second step is in fact the result of two steps, a negative-going step and a smaller positive one, there are no spikes in the output signal, mainly because the high-speed TTL logic is used (fig. 18).

The photo of fig. 18 shows the 10-step staircase without any filter. The rise and fall time is approximately 40 nsec.

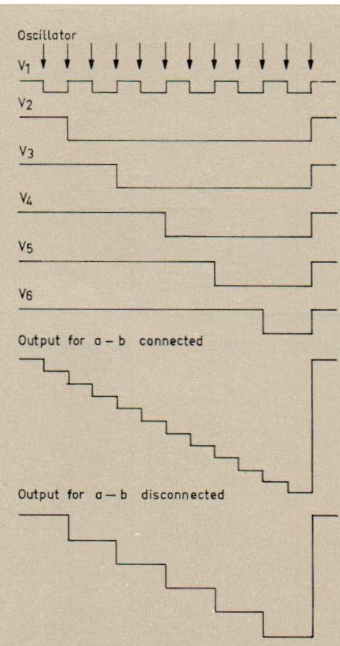
A simplified circuit diagram of the triangle generator used in the sine-wave generator is shown in fig. 19. The lower part of the diagram depicts a voltage-to-current converter, which transforms the input voltage Vin to the current I = Vin/R. The circuit gives good linearity over more than four decades of the input voltage. The current I may be drawn from either transistor 1 or transistor 2, depending on the state of the tunnel diode. Let us assume that the tunnel diode is in its low state. The base of TS_1 is then more positive than the base of TS_2, and consequently the current I will flow through TS_1 and TS_3. Since the two emitter resistors of TS_3 and TS_4 are equal a current of the same magnitude as I will flow through TS_4 and charge the capacitor C so that a linear ramp voltage appears at the output. The increasing output voltage increases the current through the tunnel diode until it rapidly switches to the high state. TS_1 now switches off, and so do TS_3 and TS_4. The capacitor C is now being discharged with the current I, giving a



15. Block diagram of the sine-wave generator PM 5574



16. Simplified diagram of staircase generator



17. Pulses related to fig. 16

negative ramp voltage equal to the positive one at the output. This will decrease the current in the tunnel diode until it switches back again to the low state causing the positive ramp to start again. The peak-to-peak amplitude of the triangle is constant as long as the switching time of the tunnel diode is much smaller than the triangle period. That is the case up to about 7 MHz. Beyond this frequency the amplitude increases little, but that is compensated by the diode clipper which has a roll-off at high frequencies.
Finally fig. 20 shows a detail of the multiburst signal. One sees part of the white reference pulse, together with 1 MHz and 2 MHz sine-wave bursts. Notice the very smooth shift from the one frequency into the each other.

Technical data

Signals (summarized)
SINE-WAVE GENERATOR

— linear sweep signal 0.1 — 10 MHz, 50 [60] Hz repetition rate, frame synchronized, with or without white reference pulses and/or 1, 2, 3.. ...., 10 MHz marker indication.

— multiburst signal 1 — 6 MHz plus white reference pulses, 15625 [15750] Hz repetition rate, line synchronized, with or without black and white reference lines.

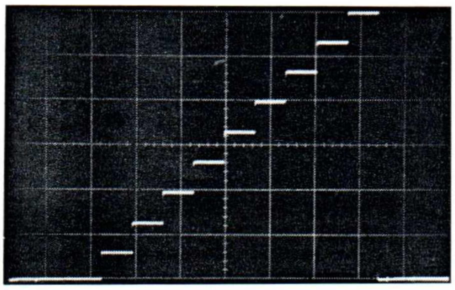
— fixed frequency signal 0.1, 1, 2, ..., 10 MHz manually controlled, with or without white reference pulses.

All signals consist of 0.7 V_{pp} picture information, in accordance with the blanking signal supplied. The blanking information is switchable in the sweep signal and the fixed frequency signal (cw).

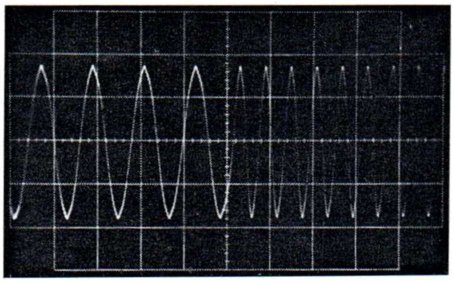
PULSE GENERATOR

— transmitter bump 0.2 Hz square-wave signal. (The bumps can be controlled manually by means of the DUTY knob.)

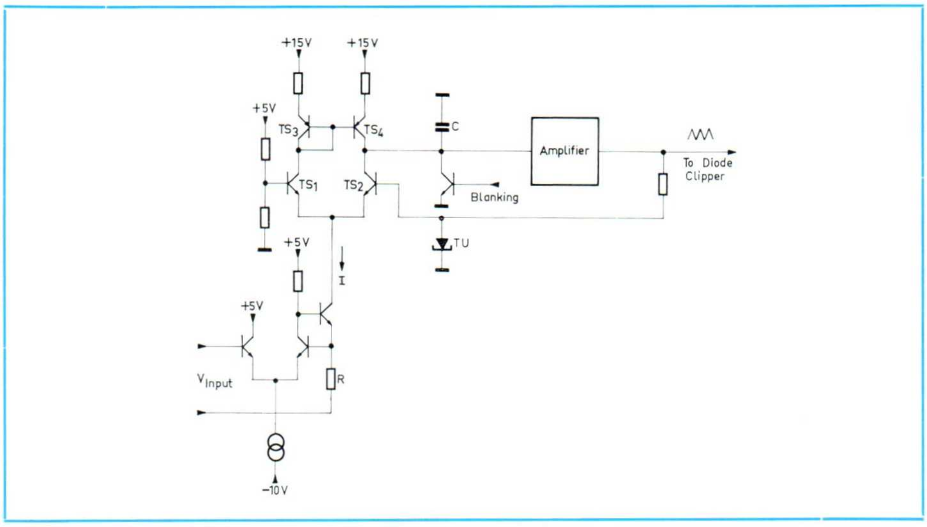
— 50 [60] Hz square-wave signal, frame synchronized.



18. Photo of staircase signal



20. Detail of multiburst signal



19. Simplified diagram of triangle generator

— 15 kHz square-wave signal (15625 [15750] Hz), line synchronized.

— 250 kHz square-wave signal, line synchronized.

Rise and fall time for all square-wave signals: about 40 nsec without Thomson filter, 90 or 180 nsec with T or 2T Thomson filter [125, 250 nsec].

— staircase signal, 10 or 6 levels including black and white levels, 15625 [15750] Hz repetition rate, line synchronized.

— sawtooth signal, 15625 [15750] Hz repetition rate line synchronized

Rise- and fall times for staircase: same as for square-wave signals.

Duty cycle: By means of the DUTY knob the staircase and sawtooth signals can be generated on every fourth line only, the others being either white or black or automatically alternating white/black with a repetition frequency of 0.2 Hz.

Superimposition: Colour subcarrier, sine-wave signals or hum can be superimposed on the staircase and sawtooth signals.
The black and white lines in "duty signals" may be with or without superimposed signal.

Sine-squared pulses:
— T - pulse and white reference bar.
— 2T - pulse and white reference bar.
— T - pulse, 20T - pulse and white reference bar.
— 2T - pulse, 20T - pulse and white reference bar.

— 2T - pulse, 20T - pulse (luminance + chrominance) and white reference bar.

— 20T - pulse and bar (chrominance only).

— 20T - pulse and bar (luminance + chrominance)

All signals : 15625 [15750] Hz repetition rate can be switched line sequential with white reference lines.

50 % width of sine-squared pulses : T = 100 [125] nsec, 2T = 200 [250] nsec, 20T = 2 [2.5] μsec.
The colour subcarrier is generated internally or can be supplied from outside.

Signal amplitude : 0.7 V_{pp} with blanking information.

FUNCTION OF BLANKING MIXER

— supply of low voltage supplies and sync pulses.

— selection of video source (4 inputs).

— selection of superimposition signal (subcarrier, sine wave, hum, burst, broad burst).

— set-up of output signal (video amplitude, superimposition amplitude, sync and set-up amplitude, composite video amplitude, set-up polarity and burst amplitude).

— selection of sync base (Int — Ext).

— switching of frame information.

— conversion of non TV signals into video signals.

— modification of sawtooth signal (black and white clipper).

With all knobs in their click positions the output signal will normally consist of:

Video amplitude	0.7 V	} 1 V_{pp}
Sync amplitude	0.3 V	
Set-up amplitude	0	
Superimposed signal	0.1 V_{pp}	
Burst amplitude	0.3 V_{pp}	
Hum	1 V_{pp}	

* *The values between brackets are for the FCC 525-line 60-Hz system*

The PM 3400, a new sampling oscilloscope with a rise time of 200 ps

L. E. Orrevall, Philips Industrielektronik AB, Solna, Sweden

Introduction

Philips have been working on sampling oscilloscopes since 1950; they were the first in this field, in fact.*

Four years ago a Philips' team brought out a plug-in model with a rise time of 350 ps, which proved a great success. However, the higher and higher frequencies used in all branches of electronics and telecommunications soon made it desirable to bring out an even faster sampling 'scope. Experience had shown that the plug-in units stayed plugged in 90% of the time, so it was decided to make the new model with all controls built in.

The result is the PM 3400, a compact instrument with stable internal triggering up to 1700 MHz, ergonomically designed controls making for the greatest possible ease of operation, and a price which compares well with that of a conventional 50 MHz oscilloscope. It has been developed by the same engineers who made plug-in model. The oscilloscope is light enough to carry around with you if you need to. Further features of the PM 3400 are:

rise time 200 ps;
bandwidth 1700 MHz at 1 mV/cm;
large display (8 x 10 cm screen);
dual trace;
60 dB isolation between channels;
long-persistence phosphor;
low power, no fan.

* Jansen: ,,An experimental stroboscopic oscilloscope for frequencies up to about 50 MHz" Philips Technical Review, vol. 12, 1950, no. 2 and 3.

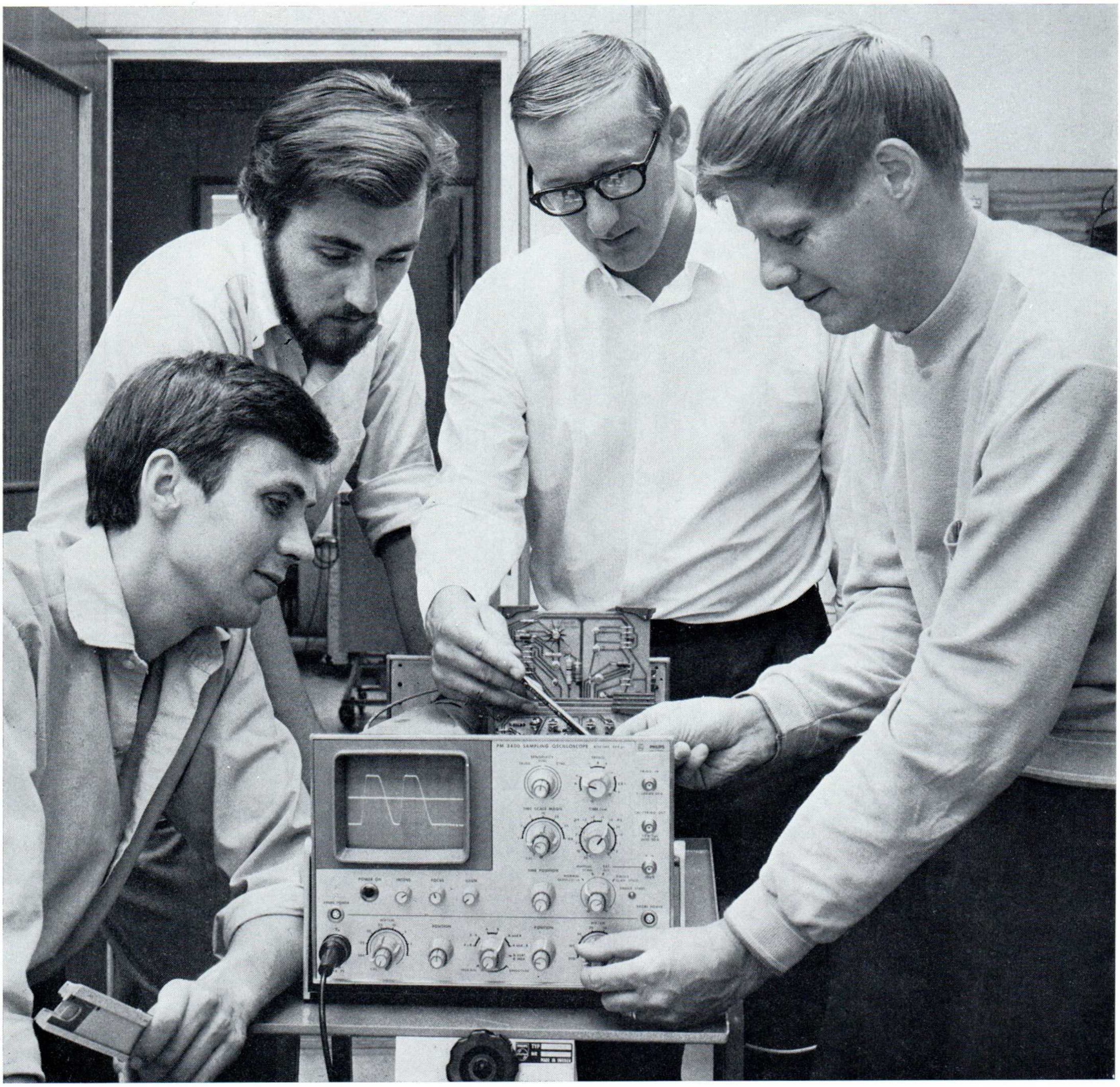
Ergonomically designed controls

Inspection of the front plate lay-out of the PM 3400 will show that the controls are arranged in a simple and logical way. You can put your fingers on knobs of reasonable size and operate them without any risk of disturbing other settings at the same time.

A graphic demonstration of the functional arrangement is given by fig. 1, where the block diagram of the oscilloscope is superimposed on a photo of the front plate to show the signal flow from control to control.

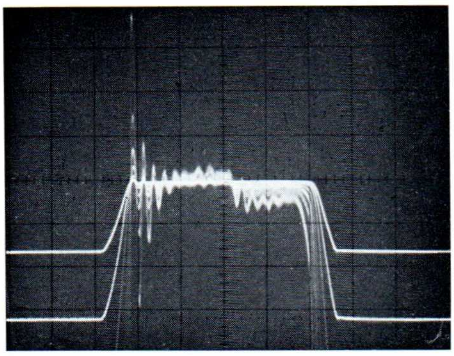
The astigmatism control has been completely eliminated by the use of novel circuitry.

There is only one switch for selecting the triggering mode, and setting of the triggering sensitivity is a "one-knob adjustment"



The sampling oscilloscope PM 3400 with four members of the project team; from left to right: L. O. Johansson, Ragnar Söderling, Birger Jacobsson and Bengt Hagström

in practice. This, and the remarkable triggering circuits behind the panel, makes it a very simple task to get a stable picture on the screen.
The time base can be made free-running, which gives a base line even in the absence of an input signal. This makes it easy to find the trace on the screen.
Other important features relate to the manner of positioning and magnifying the picture. In the PM 3400 there is only one control (coarse and fine) with which the trace can be moved vertically, namely the Y-POSITION control. This does away with the interaction between two controls (DC OFFSET and VERTICAL POS.) found in many other oscilloscopes. Thanks to this arrangement, adjustment of the vertical deflection factor is a simple matter in the PM 3400. The signal is simply positioned in the middle of the screen (symmetrical around the X-axis) by means of the POSITION control. The deflection factor can then be varied with the aid of the "mV/cm" knob until the image on the screen has a suitable size, without having to turn another knob to get your image back on the screen every time the deflection factor is changed (see fig. 2).



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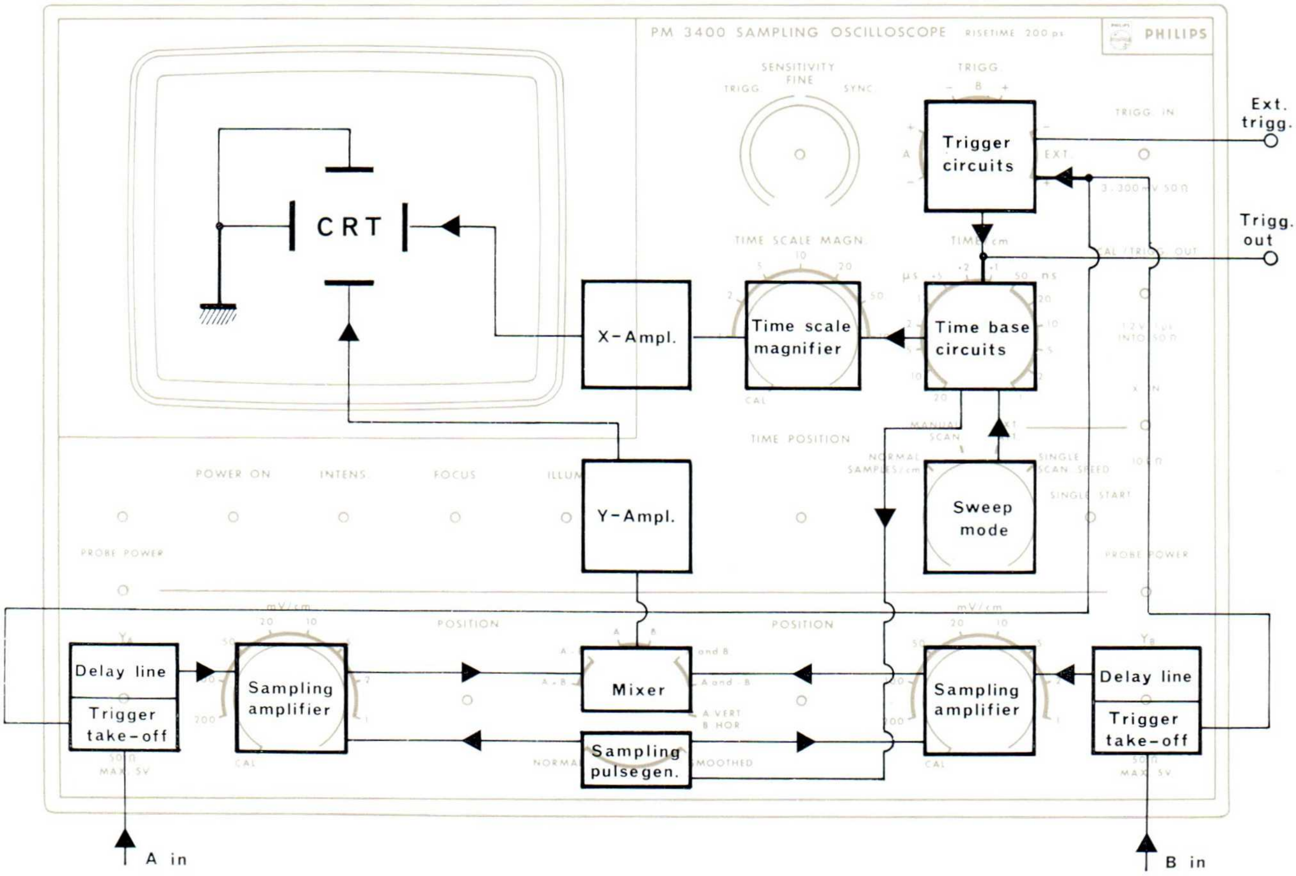

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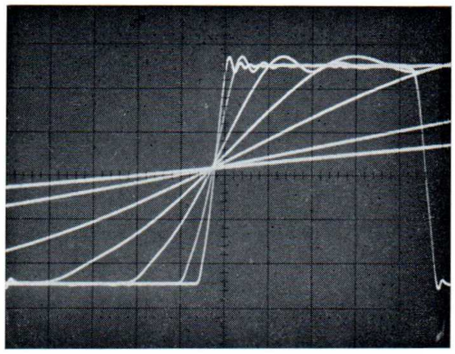

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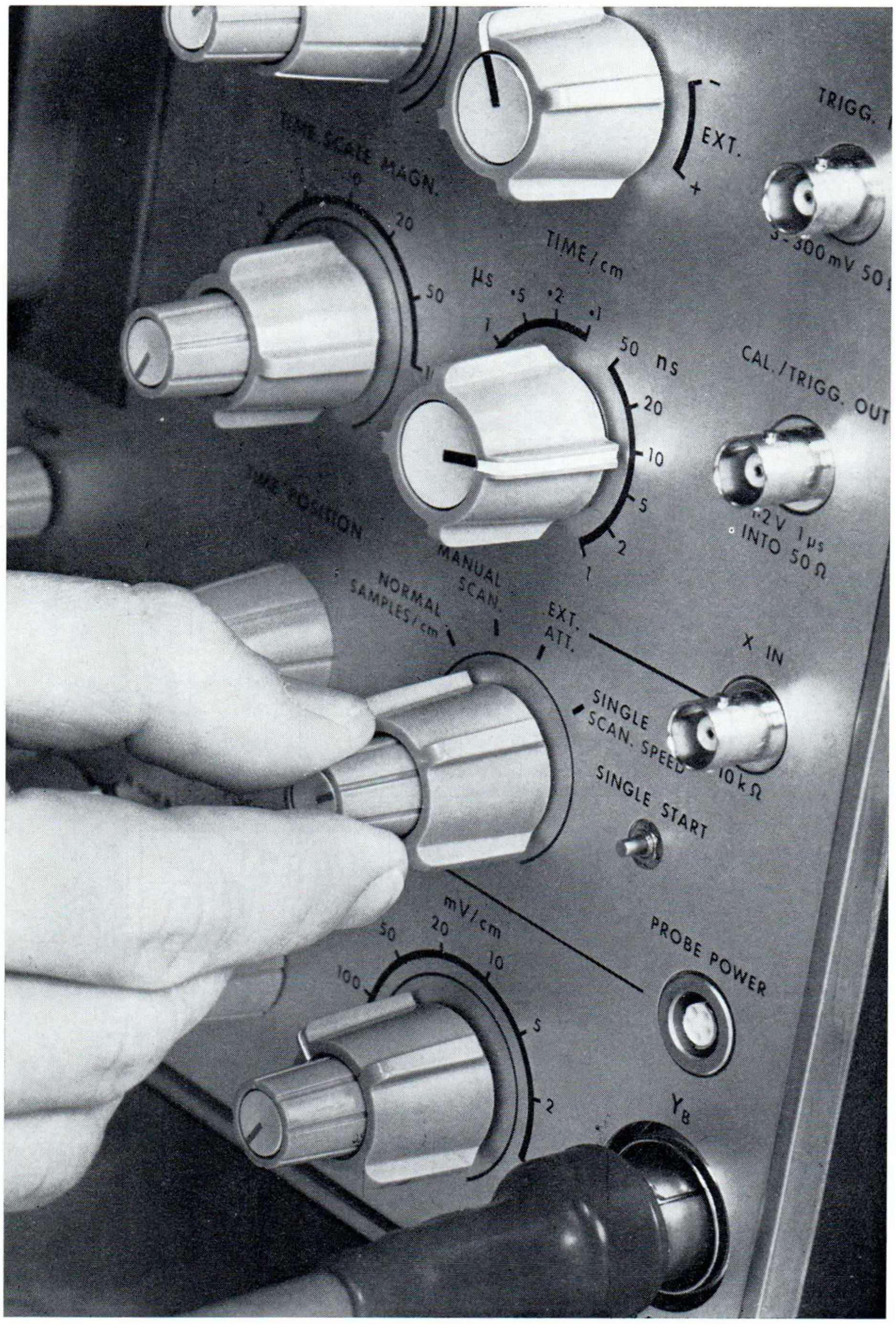
The same simple rule applies to the TIME SCALE MAGN. (magnification) control. The part of the image of interest is positioned in the middle of the screen (symmetrical around the Y-axis) by means of the TIME POSITION and TIME/cm controls. The TIME SCALE MAGN. knob can now be operated without shifting the image off the screen. (see fig. 3).
There is also a switch inside the oscilloscope which can be used to shift the point of magnification from the middle of the screen to the left-hand edge. This takes care of those cases where one wants to magnify the start of the sweep, e.g. when studying a pulse train with a high TIME/cm.

The horizontal deflection mode can be selected by means of a switch with the positions: NORMAL, MANUAL, EXT and SINGLE. The inner knob gives a continuous variation of a quantity selected by the switch: in the repetitive mode (NORMAL), this inner knob controls the number of samples/cm, in the MANUAL mode it defines the horizontal position of the spot, in EXT it serves as an attenuator of the externally applied sweep voltage, while in the SINGLE mode it gives the time of the total sweep (1—60 seconds), see fig. 4.



4

Compact construction

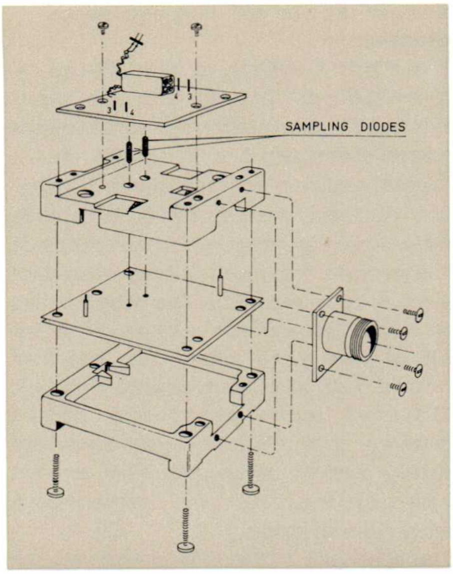
Thanks to its all solid-state circuitry, the high-performance PM 3400 looks almost tiny compared with a big oscilloscope made with vacuum tubes. It weighs only 16.5 kg (36 pounds), so that you can take it with you for field work when you need to. And the warm-up time is only 20 seconds. The low-power consumption (80 VA) makes a fan unnecessary, thus getting rid of acoustic noise and dust filters, which need to be cleaned. The low operating temperature also improves reliability.

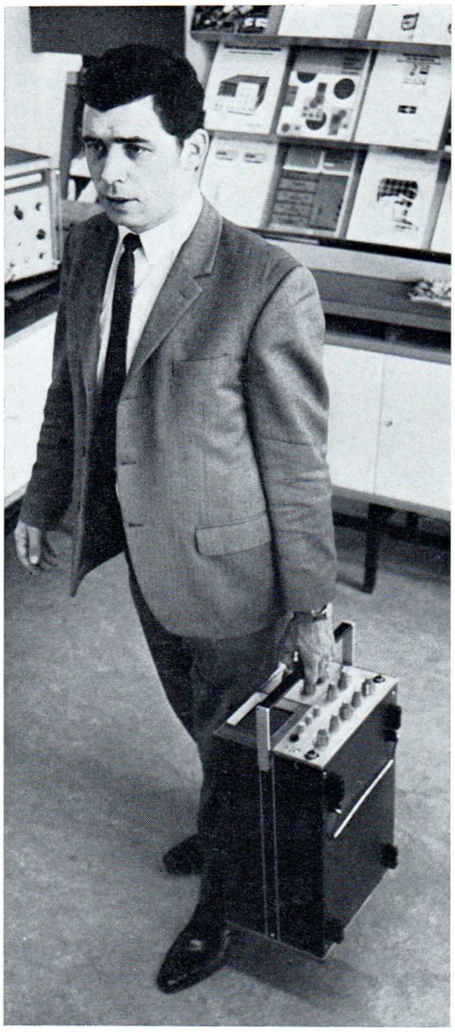
Mechanical construction and serviceability

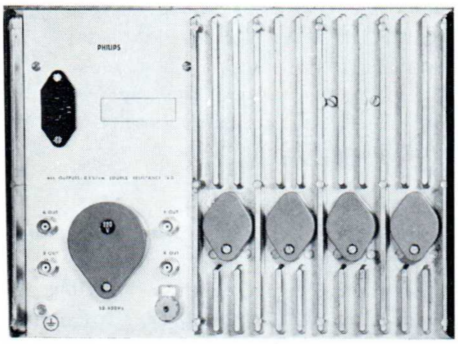
The frame of the PM 3400 consists of a front and a rear wall of diecast aluminium, connected by profiles and plates. The power transistors and the mains transformer are mounted on the rear wall, which serves as a heat-sink. The same wall is also provided with two rubber ridges, so that the oscilloscope can be conveniently placed on end. The ruggedness of the mechanical design has been proved by a bump test (35 G acceleration and a total of 10.000 bumps in three different directions, without the CRT).

The interior of PM 3400 is made accessible by removing two skin-plate covers provided with quick fasteners. The upper compartment contains the CRT and 8 printed-circuit boards, which plug into a common mother board. All power-supply and other connections between the boards are made as printed wiring on the mother board. The few remaining connections to switches on the front plate are made by connectors, which are colour-coded for easy identification. Extender boards are available so that measurements for service purposes can be made in the circuit while the oscilloscope is working. The two sampling amplifiers with their delay cables and sampling heads, and the common sampling-pulse generator, become visible when the lower cover is removed. Here too, practically everything is plug-in. Even the sampling heads can be taken out after a few screws have been loosened. The sampling heads for channel A and B can be replaced without making extensive mechanical and electrical adjustments (some potentiometer adjustments may have to be made).

PM 3400 has a built-in calibrator which delivers pulses of 1.2 V amplitude and 1.0 μs width. The user can therefore easily check the amplitude and time scales. All voltages in the power supply are provided with electronic short-circuit protection, so that the supply is immediately cut off in case of a short-circuit. Thus, no secondary damage can be caused to the circuitry.





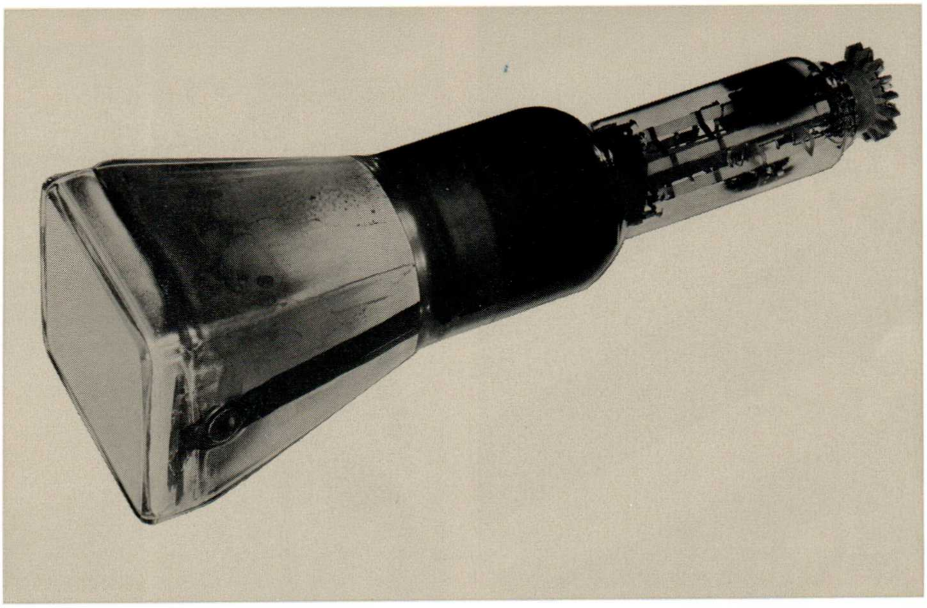


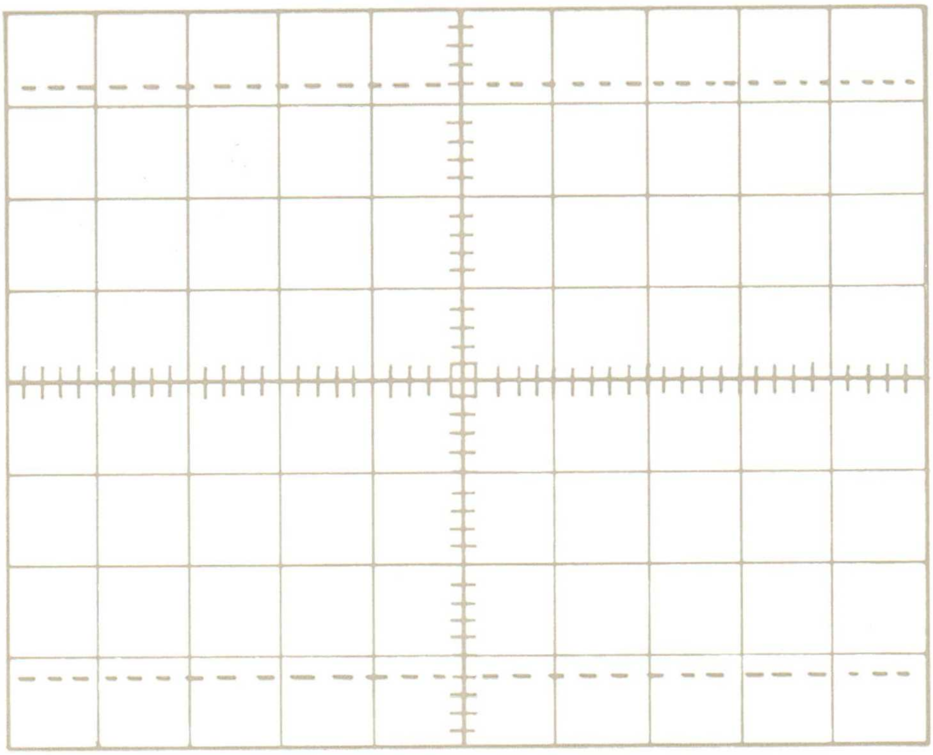
Cathode-ray tube with long-persistence phosphor

The PM 3400 utilizes a new, Philips-designed CRT, the D14-120. This tube is provided with a rectangular, metal-backed screen measuring 8 x 10 cm (fig. 5). An internal graticule with continuous illumination eliminates parallax errors. In order to make it easy to measure rise and fall times the graticule has been provided with dotted lines at 10% and 90%. The tube is used at a total acceleration voltage of 10 kV, which gives a very sharp line, less than 0.3 mm wide at a beam current of 10 μA. The large screen allows easy, precise measurements, while the bright traces are visible even in areas with high ambient light. Less eye strain and fatigue means fewer human errors.

The alignment of the X-deflection with the graticule axis is done electrically. The electronic circuitry also provides automatic compensation of the slight non-linearity of the tube. This means that 1 cm at the middle of the screen means the same as 1 cm at the top. Compare the linearity of the PM 3400 to that of any other 'scope, and you will see difference.

We have selected a new phosphor with long persistence. This is especially useful with sampling oscilloscopes because annoying flicker can be minimized when phenomena with a low repetition time are to be displayed. In fact, the long persistence in combination with the very low dot slash makes it feasible to view fast pulses at repetition rates as low as 10 Hz.





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Rise time and bandwidth

The rise time required of an oscilloscope can be derived from the following expression:

$$t_{obs} = \sqrt{t^2_{signal} + t^2_{osc}}$$

When t_{signal} is the rise time of the signal to be measured, t_{obs} is the observed rise time and t_{osc} is the intrinsic rise time of the oscilloscope.

Table 1 shows the expected error when a rise time of 7 ns is measured with different types of oscilloscopes.*

Rise time and bandwidth are related by the approximate expression:

$$t_r \approx \frac{0.35}{f_g} \qquad \begin{matrix} t_r \text{ in ns} \\ f_g \text{ in GHz} \end{matrix}$$

It follows from Table I that the oscilloscope should have a bandwidth of 150 MHz or more in order to measure such a moderate rise time as 7 ns with an error of 5% or less.

The error in measuring rise time can also be expressed graphically as shown in fig. 6, where the percentage increase in the observed rise time is plotted as a function of the ratio between signal rise time and oscilloscope rise time. For example, it the signal rise time is 600 ps and the oscilloscope rise time is 200 ps (PM 3400) then the ratio is 3 and we may see from the graph that the increase in rise time is about 5%.

Fig. 7 gives an alternative presentation. The percentage increase is here plotted as a function of the signal rise time for various oscilloscopes of different bandwidth. For instance, if one wants to measure a rise time of 3 ns with a 250 MHz oscilloscope, the error is approximately 10%. The same measurement performed with the PM 3400 gives a negligible eror.

Input Impedance

The usual input impedance of a low-frequency oscilloscope is 1 MΩ, which represents a negligible load at the frequencies in question. However, the effective input capacitance of the order of 15—30 pF in parallel with the 1 MΩ means that the input impedance decreases rapidly with increasing frequency. For example, 20 pF corresponds to 790 Ω at 10 MHz, and to 79 Ω at 100 MHz. This means that the input impedance is nothing like 1 MΩ in high-frequency measurements. This figure of 1 MΩ is relevant only in that the resistive component of the load does not change the DC conditions at the point of measurement. However, the high-frequency components are seriously influenced.

We shall now consider the implications of this for pulse measurements and sine-wave measurements separately.

Pulse measurements

The circuit of a generalized pulse circuit is shown in fig. 8. R_s represents the source resistance at the point where the measurement is made. It is not possible to connect

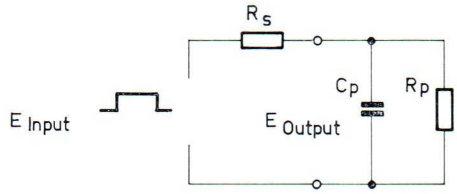
Table 1

signal rise time	Oscilloscope bandwidth MHz	Oscilloscope rise time	Observed rise time	Error %
7	35	10	12.2	74
7	50	7	10	41
7	100	3.5	7.8	10.2
7	150	2.4	7.4	5.5
7	250	1.4	7.1	1.7
7	1000	0.35	7.0	0.1
7	1700	0.2	7.0	0.0

* 7 ns has been chosen for the rise time as being a representative value for TTL circuits

a cable directly from that point to the oscilloscope, as that would add even more to the input capacitance (about 100 pF/m). The normal approach is to use a resistive probe with a resistance of 10 MΩ in parallel with about 10 pF. However, the decrease in capacitance by a factor of 2 is obtained at the expense of 10-fold attenuation. C_p in fig. 8 can be regarded as the probe capacitance, which we take as 10 pF in in our example.

10—90% rise time = 2.2 x R_sC_p



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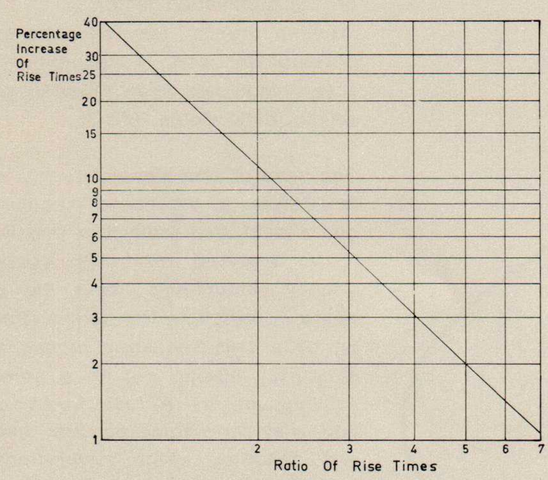

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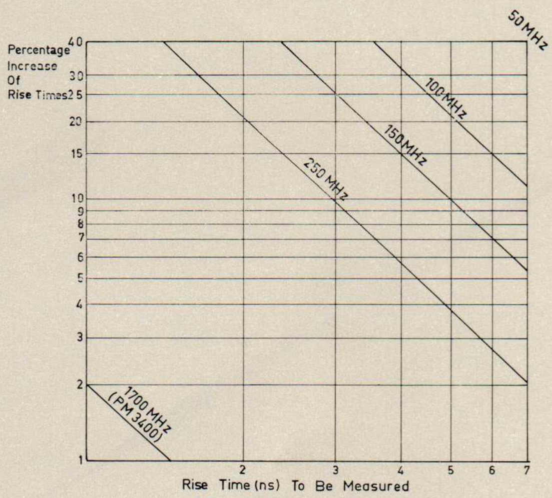

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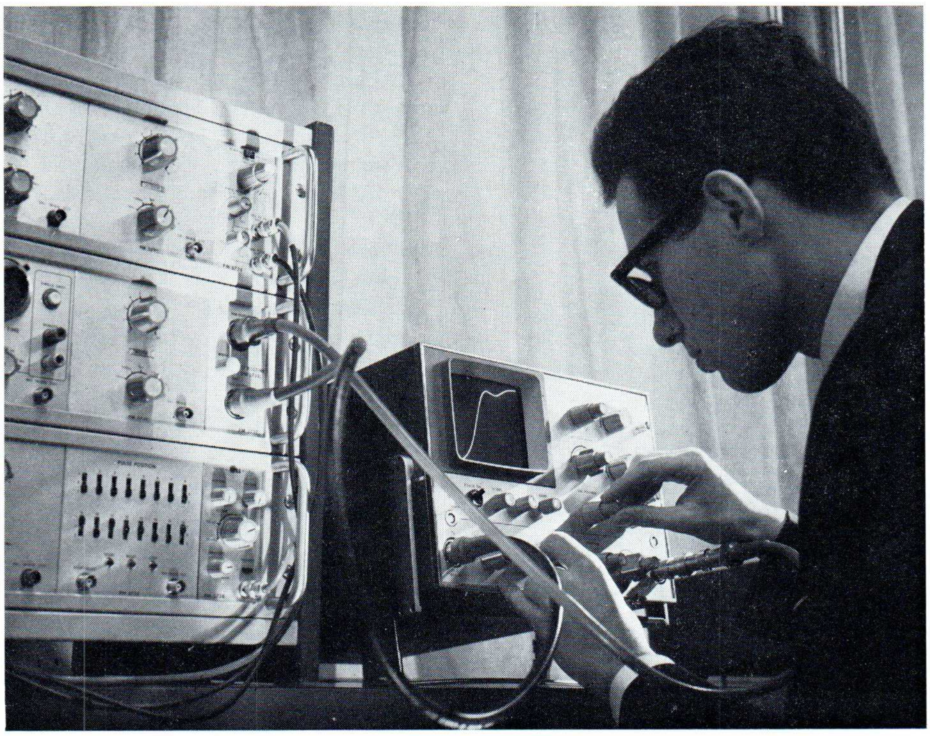


R_s and C_p form an integrating circuit with a rise time of 2.2 x R_sC_p. If R_s is equal to 500 Ω, the rise time becomes 2.2 x 500 x 10 x 10^{-12} = 11 x 10^{-9} s = 11 ns

The rise time of the combination of probe and oscilloscope is sometimes stated in specifications. The figure is usually given for a source impedance of 25 Ω, in which case the capacitive loading effect can be neglected. In practice this is not always the case, and the capacitive loading has to be taken into account as follows:

$$t_{obs} = \sqrt{t^2_{probe+osc.} + t^2_{2.2\,RsCp} + t^2_{signal}}$$

For example:

$t_{probe+osc.}$ = 2.4 ns

$t_{2.2\,RsCp}$ = 11 ns

t_{signal} = 5 ns

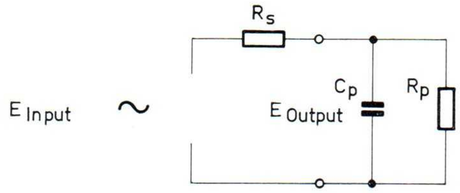
$$t_{obs} = \sqrt{5.8 + 121 + 25} = 12.3 \text{ ns}$$

which is much higher than 5 ns.

Obviously then, any performance claim of 2.4 ns rise time at the probe tip is somewhat meaningless for the reasons given in the example in this article.

There are other problems too, associated with measurements on fast pulses with too slow an oscilloscope. For example, with needle pulses, a degradation in rise time also means a decrease in the observed amplitude.
Another problem occurs in measurements of the delay between pulses from sources of different impedances. Capacitive loading then gives different increases in rise time with the different pulses. As the delay is measured at 50% of the pulse amplitude, half of the difference in increase of the rise time may be erroneously interpreted as delay.

Sine-wave measurements
The same equivalent circuit (fig. 9) is valid as in the previous case, but the effect can now better be expressed in terms of signal attenuation and phase shift. At 50 MHz the signal loss is 5.3 dB and the phase shift is about 57° for a source resistance of 500 Ω and a probe capacitance of 10 pF.



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$$\text{Signal loss} = \frac{E_{in} - E_{out}}{E_{in}}$$

$$\text{Phase shift} = \tan^{-1} \omega R_s C_p$$

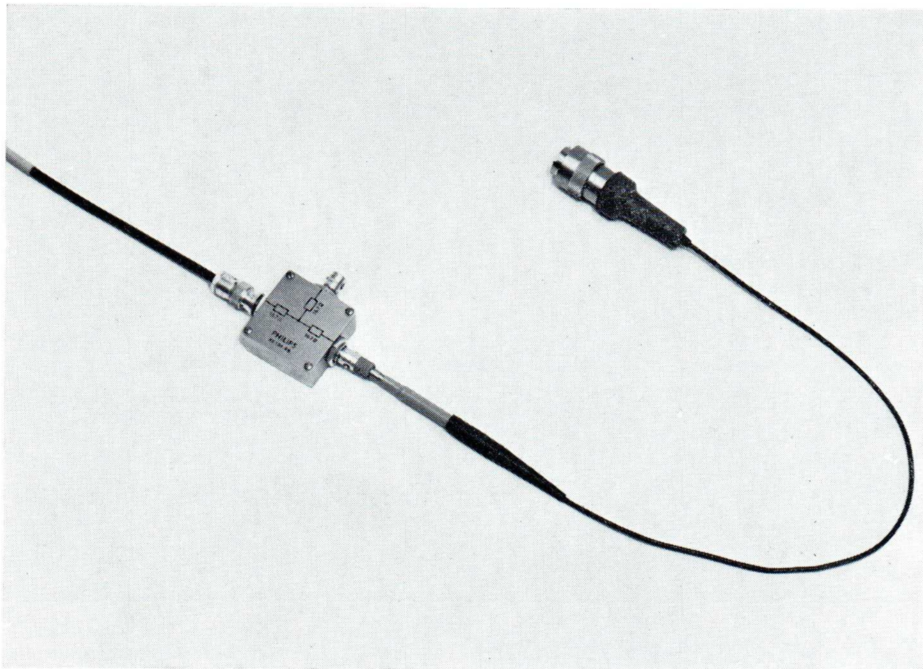
THE SOLUTION: 50 Ω INPUT IMPEDANCE
The PM 3400 uses 50 Ω inputs with a VSWR of $\leqslant$ 1.5 up to 1700 MHz. For those who are working with 50-Ω systems the PM 3400 is the ready-made answer to their measurement problems. Because transmission-line techniques are used the input appears to have a constant impedance, thus eliminating all problems related to capacitance. The 50 Ω input can also be equipped with probes. One choice is to use a passive probe with $C_p = 0.7$ pF, thus giving a rise time of $2.2 \times 500 \times 0.7 \times 10^{-12}$ s $= 0.77$ ns even with a source resistance as high as 500 Ω. The attenuation ratio is 10 : 1 or 100 : 1. If the resistive component (500 Ω or 5000 Ω) of the passive probe (fig. 10) influences the DC conditions too much, use can be made of a cathode follower probe (fig. 11) with very high resistance and somewhat higher capacitance: than the passive probe: 1.3 — 3.6 pF, depending on the attenuation factor.
"Built-in probes" may often be useful for development work. A description of such a technique has been given in an earlier article (EMM Notes 1968/3).

See more of your signals!
In addition to the above mentioned facts one should also remember that the signal to be analysed very often contains frequency components above the expected range. A switching transient is often followed by a high-frequency ringing which is effectively filtered out by a conventional oscilloscope! — A high frequency oscillator may have some parasitic oscillations and distortion which remain undetected by an oscilloscope which only can pass the fundamental. So, see the full spectrum of your signal with PM 3400.
The PM 3400 has got some other valuable features. It can display small pulses or waveform aberrations on top of big pulses or DC-levels, (even at the most sensitive range, 1 mV/cm). The amplifier system is not being overloaded, so no detail is lost or misinterpreted. And the details can be viewed without any loss of bandwidth.

Conclusions
1. The oscilloscope rise time should be at least 3 times less than the rise time of the signal if the error in observed rise times is to be kept below 5%.
   The PM 3400 can thus measure rise times down to 600 ps with less than 5% error.

2. The capacitive loading of the circuit to be measured must be taken into account. This can best be done by using a 50 Ω system as in the PM 3400.

3. The 1700 MHz bandwidth of the PM 3400 has the further advantage of allowing high-frequency details of signals to be clearly displayed.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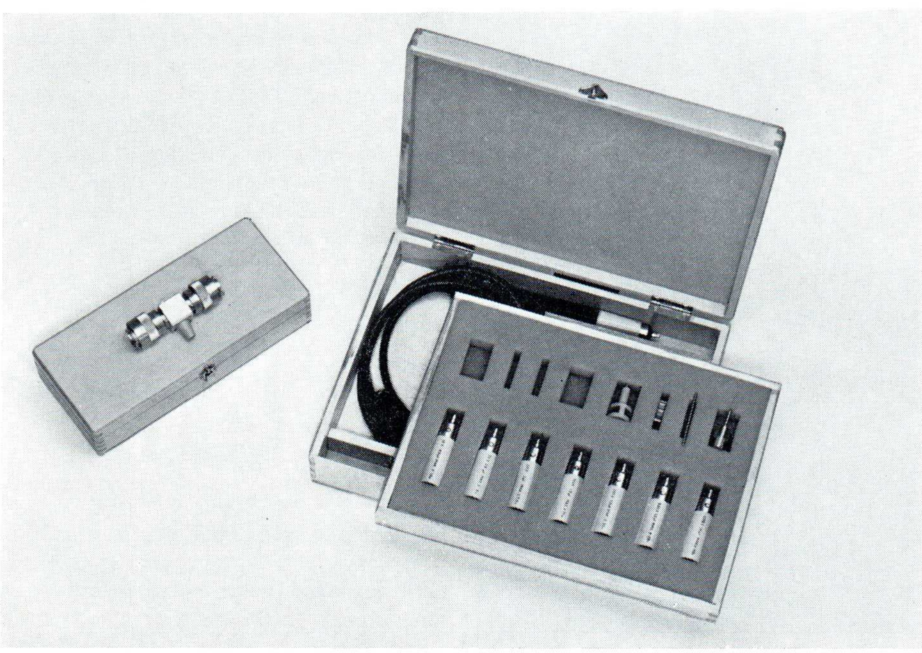
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Application of the PM 3400

GENERAL REMARKS

Advances in solid-state technology have made it possible to produce transistors with a cut-off frequency of more than 1 GHz. These can be used to construct e.g. very fast switching circuits and telecommunication systems. This opened up the VHF band (up to 174 MHz) and later the UHF band (up to 470 MHz) for telecommunication purposes.

Integrated circuits have also become faster, cheaper and more reliable. The well-known TTL family is used all over the world, and extra-fast versions such as the Texas 74 H and the SUHL II are also available.

Motorola emitter-coupled logic is widely used in computer hardware. The MECL 4 circuits which were recently introduced have stage delays of about 0.7 ns and their switching times are of the same order. All these new components need appropriate measuring equipment for development, testing and servicing. The PM 3400 will find wide application in this field.

Measurements on integrated circuits with PM 3400

TTL circuits are so fast that it is impossible to make accurate measurements on them with 50-MHz oscilloscopes. Standard TTL families (Philips FJ or Texas 74) have switching times of the order of 7 ns, and a 50 MHz oscilloscope with its 7 ns rise time will give an error of about 40% in measuring this, as shown in Table 1. The fast TTL's (SUHL II, Texas 74H) need even faster oscilloscopes; the PM 3400 is thus a logical choice for such applications.

STAGE DELAY AND SWITCHING TIMES

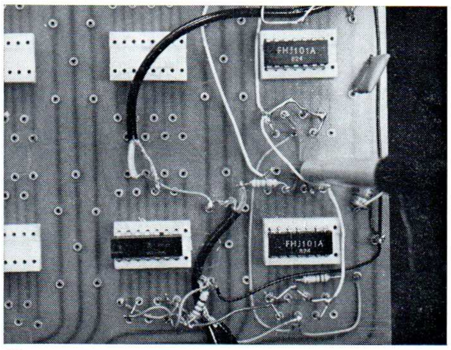
The stage delay of individual gates or cascades gates can easily be determined with the PM 3400. A suitable pulse driver is the Philips pulse generator PM 5770. A measuring circuit is shown in figure 12, while figure 13 shows the voltage waveforms at the points A and B in fig. 14.

Passive probes with 100-times attenuation are used to transmit the signal from the printed circuit board to the oscilloscope. In spite of the probe attenuation, the remaining signal (with an amplitude of approximately 30 mV) is sufficient to give a stable, internally triggered display.

Figure 12 shows the experimental set-up in our laboratory.

Rise and fall time can easily be measured on the large screen, thanks the dotted 10% and 90% lines on the internal graticule. The time scale of the display is 1 ns/cm. It is not necessary to correct the measurement for bandwidth limitations of the PM 3400 in such a case.

Pulses and groups of pulses can be surveyed or studied in detail. The photo shows an example of dual pulses. fig. 15 and 16.



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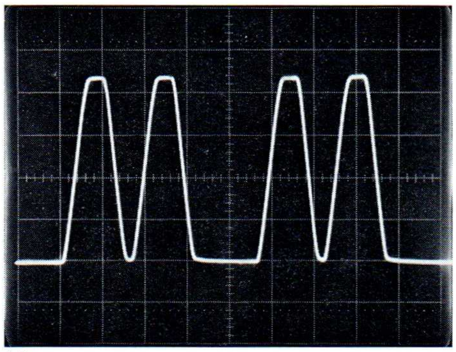

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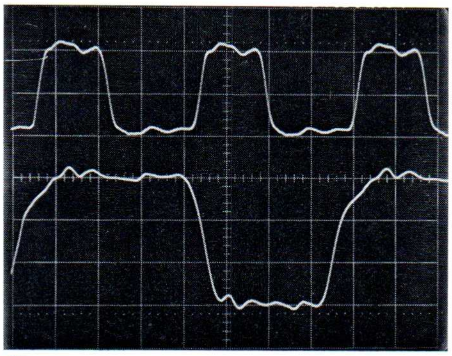

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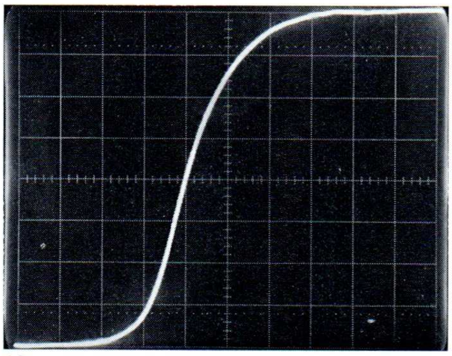

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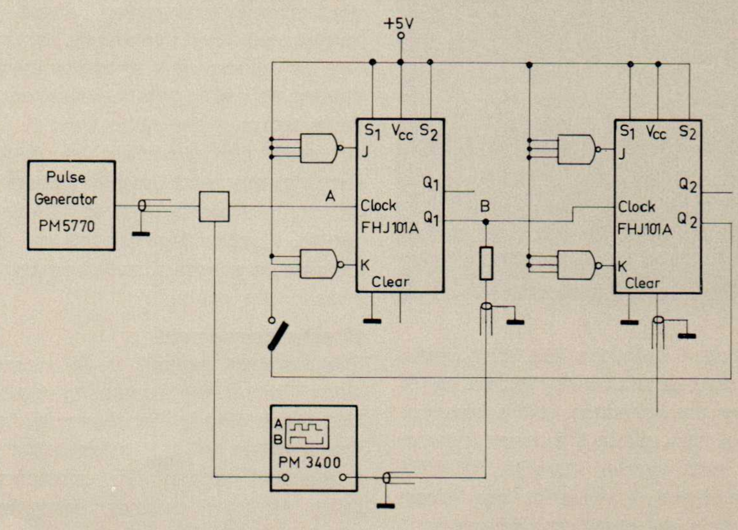

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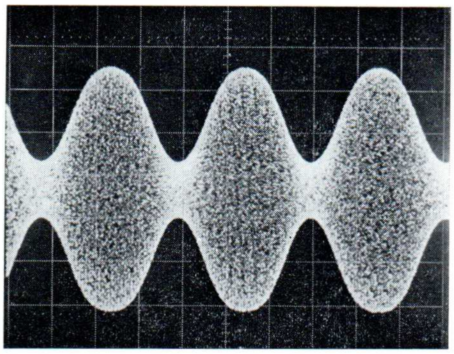
Display of amplitude modulation

Until now, very few engineers have actually seen a visual display of the modulated signal in their VHF and UHF equipment. Our new oscilloscope has been provided with circuits which make it easy to display both the carrier wave and the amplitude-modulated signal. Thanks to the wide bandwith of the PM 3400, the carrier wave is not attenuated by the oscilloscope, so reliable measurements can be made in this way. The oscillograms below illustrate two applications of this technique. The first shows a 200 MHz carrier wave modulated by a 1000 Hz sine wave, fig. 17.
The second shows a pulse-modulated 2 GHz carrier wave, together with the modulating wave form. fig. 18.
The PM 3400 can even be used to give a direct display of a sweep generator, i.e.



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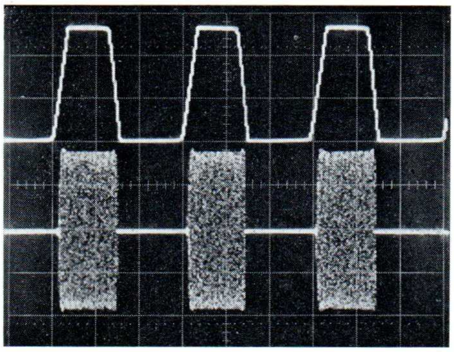

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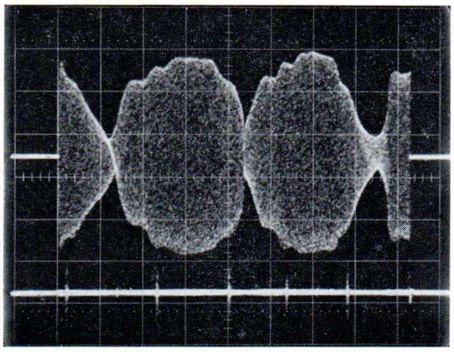

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without using a detector. The third photo fig. 19 represents such a display: the upper trace shows the response of the sweeper to a coaxial stub, while the lower trace is modulated with crystal markers, 50 MHz apart. The sweep is evidently non-linear, so the markers are absolutely necessary if frequency measurements are to be made on the displayed signals.

Accurate measurement of delay in coaxial cables

High-frequency signals, pulses as well as sine waves, have to be transported by means of transmission lines. Coaxial cables constitute one class of transmission lines, which can be used from DC up to some cut-off frequency which is determined by the geometry of the line. The velocity of propagation depends only on the constants μ and ε of the dielectric medium, as given by the expression:

$$v = \frac{1}{\sqrt{\mu\,\varepsilon}}$$

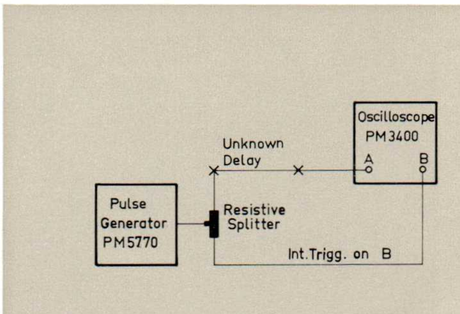
For air as the dielectric, we have:

$$\mu_0 = 4\,\pi\ \ 10^{-7}$$

$$\varepsilon_0 = \frac{1}{36\,\pi\ 10^{-9}}$$

$$v = \sqrt{9\ 10^{16}} = 3 \times 10^8 \text{ m/s}$$

which is the velocity of light.



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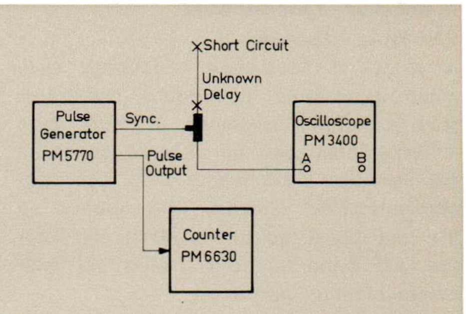

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The delay in a cable with air as insulation is thus

$$\frac{1}{v}\ \text{s/m} = \frac{1}{3 \times 10^8}\ \text{s/m}$$

$$= \frac{10^9}{3 \times 10^8}\ \text{ns/m} = 3.3\ \text{ns/m}$$

If a dielectric material is used instead of air, the propagation velocity will decrease. For instance, polyethylene, which is found in many commonly used cables (RG 174, RG 58) has a velocity factor of about 0.67. This means that the delay per metre increases to about 5 ns/m. Other materials, such as teflon, will have other velocity factors again. It is sometimes difficult to get reliable information about velocity factors and their tolerances. It may therefore be necessary to measure the delay in cables; this will give a check on the velocity factor at the same time.
We shall now describe two methods of carrying out such measurements. These descriptions are directly applicable to 50 Ω cables. If other impedances are involved, impedance adaptors must be used at both ends of the cable.

Direct measurement

The simplest method is to measure the delay directly with a sampling oscilloscope. The block diagram is shown in figure 20. The position of the pulse edge is first established without the unknown cable delay. After the unknown delay has been inserted in the circuit, the pulse edge is shifted by an amount which can be read off directly from the horizontal scale of the oscilloscope. The accuracy is determined by the following factors; (see also EMM Notes 1969/3, pp 38—41):

Error of time base $\pm$ 3%
Reading error $\pm$ 0.5 mm

It is good practice to use a low deflection coefficient (e.g. 5 mV/cm) so that the pulse edge becomes almost vertical.

NULL METHOD

A much higher accuracy can be reached by a null method: see fig. 21.
The pulse generator is set for minimum delay and pulse width and minimum rise and fall times.
The sync pulse is connected to the cable, as it has faster rise time than the main pulse.
The pulse from the generator travels along the cable and is reflected with reversal of polarity from the short-circuit end. By suitable adjustment of the REPETITION TIME of the pulse generator until T equals 2 T_D, one can annul the next pulse from the generator. The null signal can be detected with the aid of a samping oscilloscope. The counter, connected to the main output of the generator, measures the frequency (1/T) at which the null signal occurs. This frequency can be measured to a very high degree of accuracy (10^{-8}). The precise accuracy attainable in any given case depends mainly on how sharp and free from ambiguity the null detection is. The pulse is attenuated by the cable

losses, which means that the reflected pulse is smaller and has less high-frequency components. It is, however, not difficult to determine the delay to well within 1%. It is highly desirable always to use good connectors, and to connect them securely. The delay in the connectors themselves can be compensated for, if necessary.

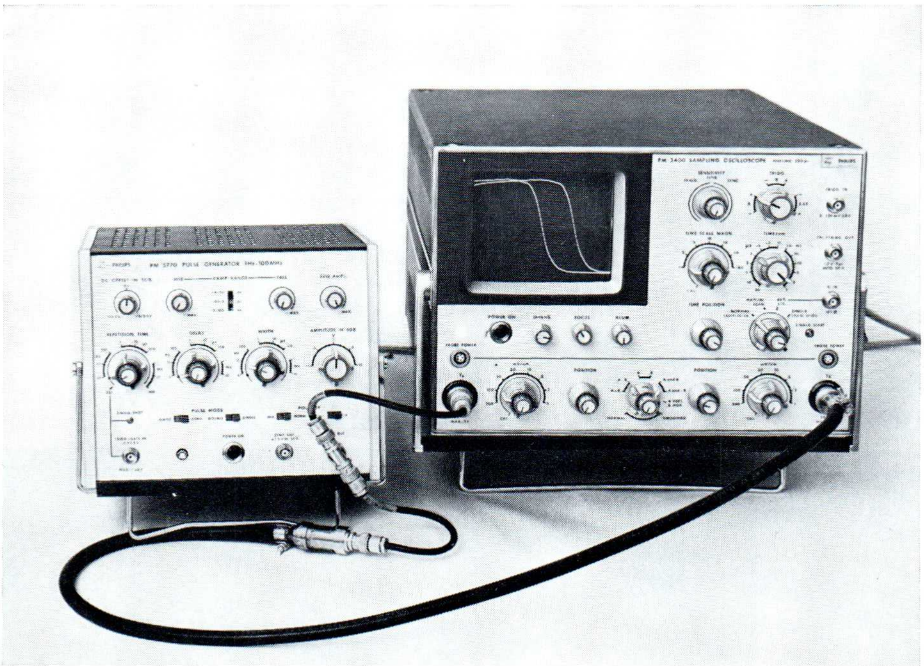
SMOOTHING

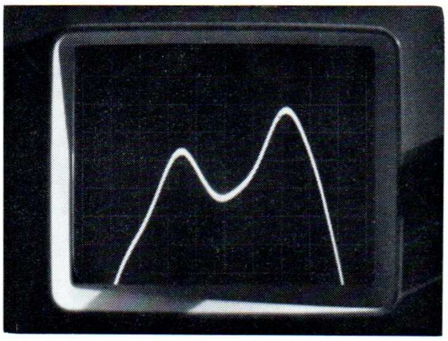
In normal amplifier techniques, the signal-to-noise ratio can be improved by decreasing the bandwidth. In a sampling oscilloscope noise suppression is possible without reduction of bandwidth.

In the position of the NORMAL SMOOTHED switch, the loop gain is reduced to approx. 0.3, which means that more than one sample is required before the final value is reached. Since noise has a random character in contrast to the signal to be measured, the noise averages out over a large number of samples. The signal-to-noise ratio is thus improved by approximately a factor of 3. It is interesting to note that the time jitter also is improved when smoothing is introduced.

If the samples of the input signal are taken with a high density then the amplitude change is very small between two successive samples. The smoothing hence and noise reduction, can therefore be introduced without affecting the signal shape. If, however, the signal is changing rapidly between two samples, which can occur if the sampling density is too low or if a step is viewed on a long time scale, then the step will appear as rounded.

It is therefore good practice to choose TIME/cm and SAMPLES/cm in such a way





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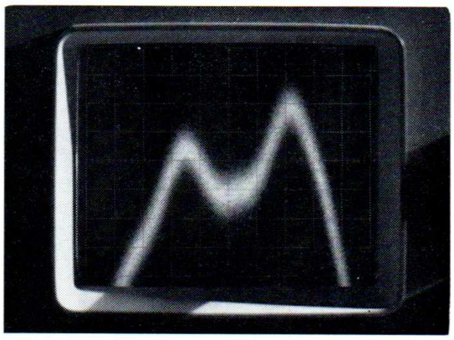

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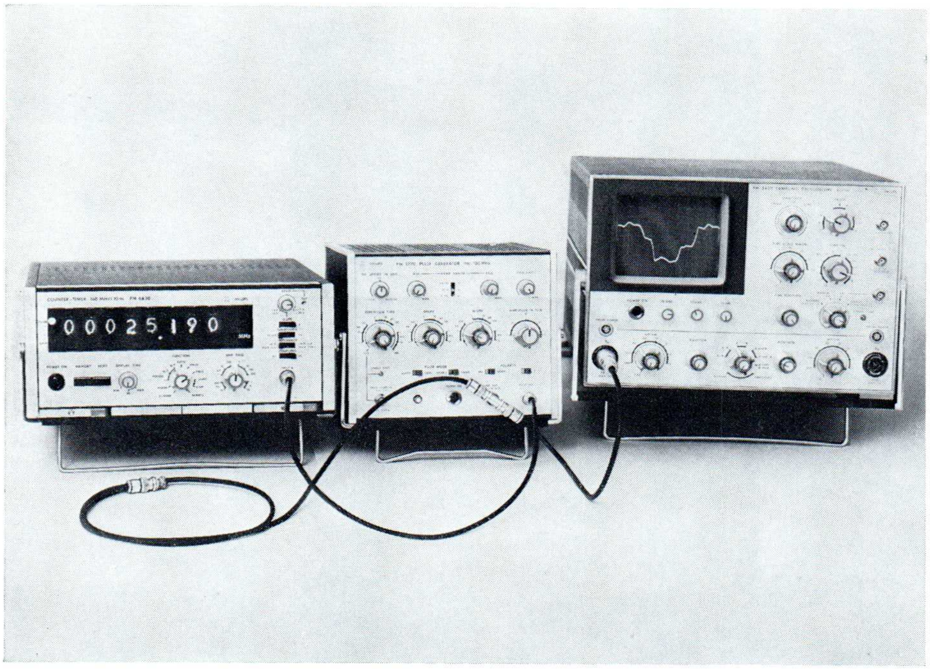
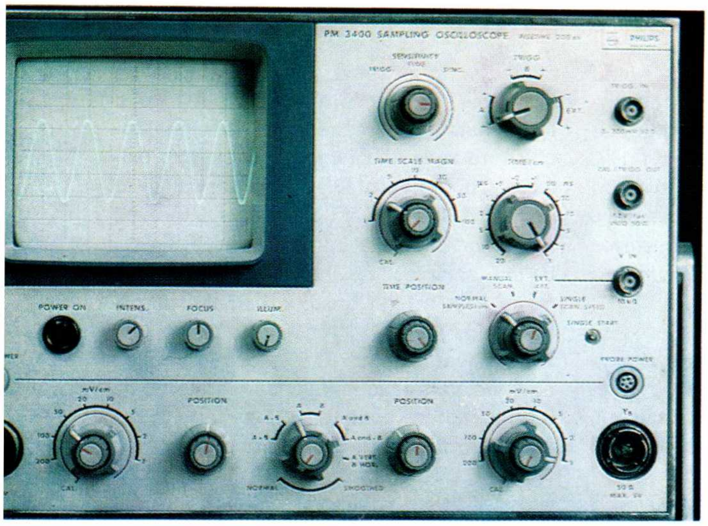


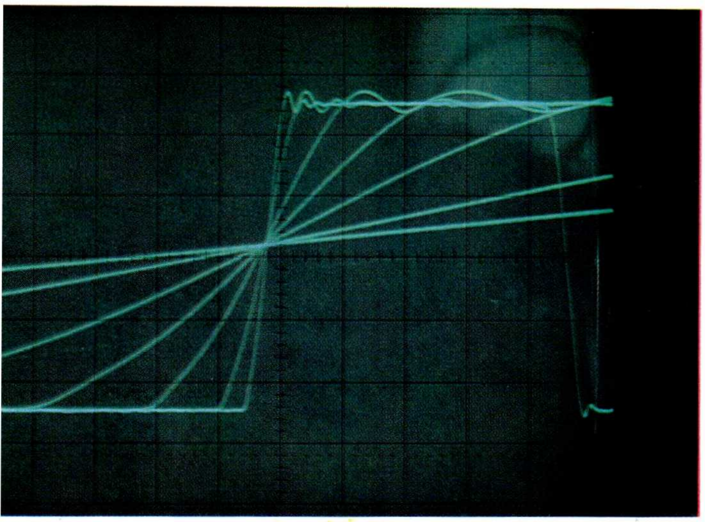
that amplitude changes between samples are small enough to have a negligible effect on the signal shape. This effect can simply be checked by switching between NORMAL and SMOOTHED. Used in the proper way, the smoothing of the noise can be very helpful for viewing of low level signals.

A special smoothing circuit is used in the PM 3400, eliminating the troublesome phenomenon of base line-shift on switching from NORMAL to SMOOTHED.

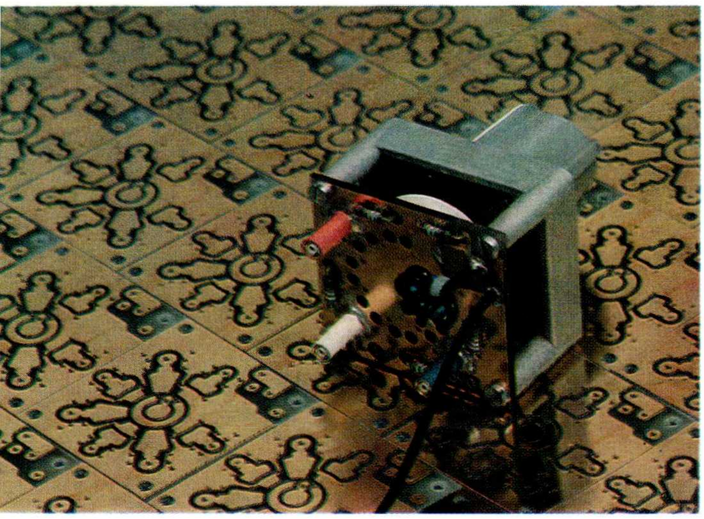
Fig. 22 shows an example of a trace which has been smoothed with the aid of the SMOOTHED control. The improvement compared with the unsmoothed trace (fig. 23) is striking.

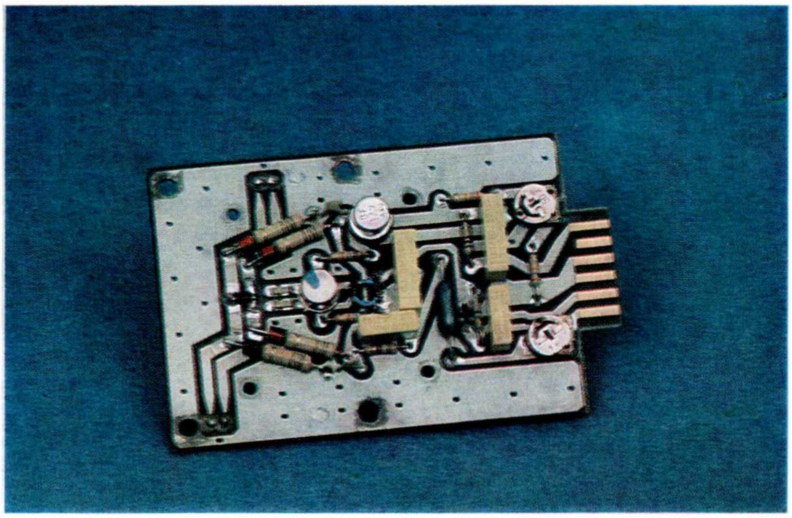
Some smoothing is automatically introduced in the most sensitive positions. The smoothing factor is 2.5 in the 2 mV/cm position and 5 in the 1 mV/cm position.

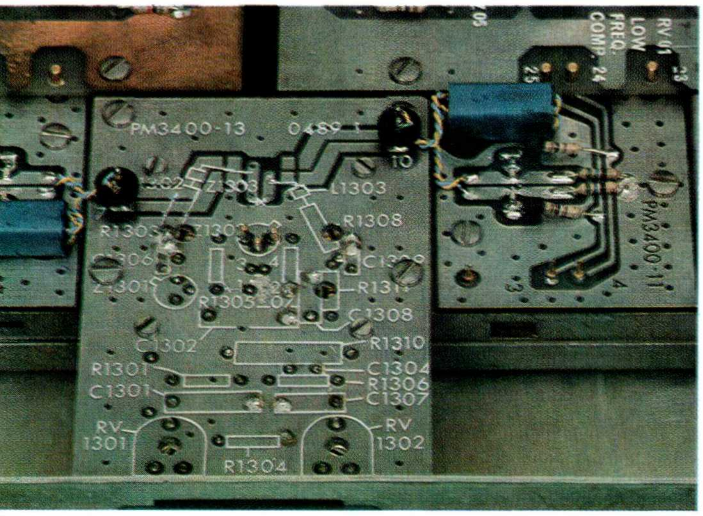


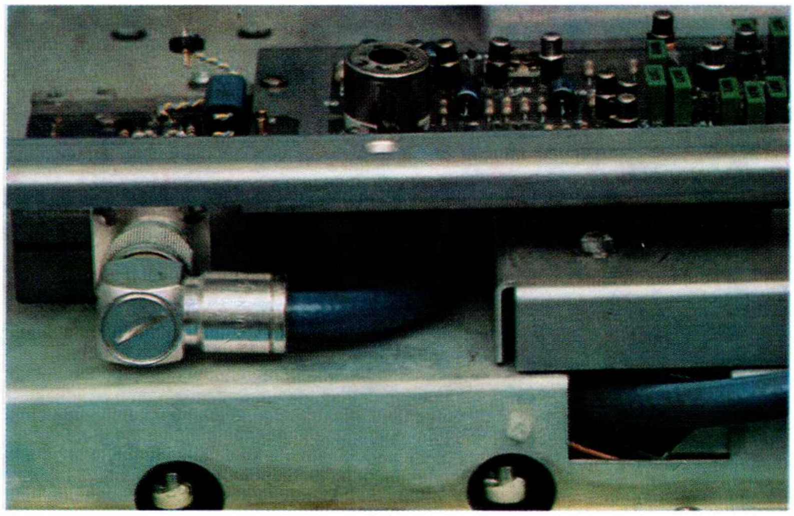


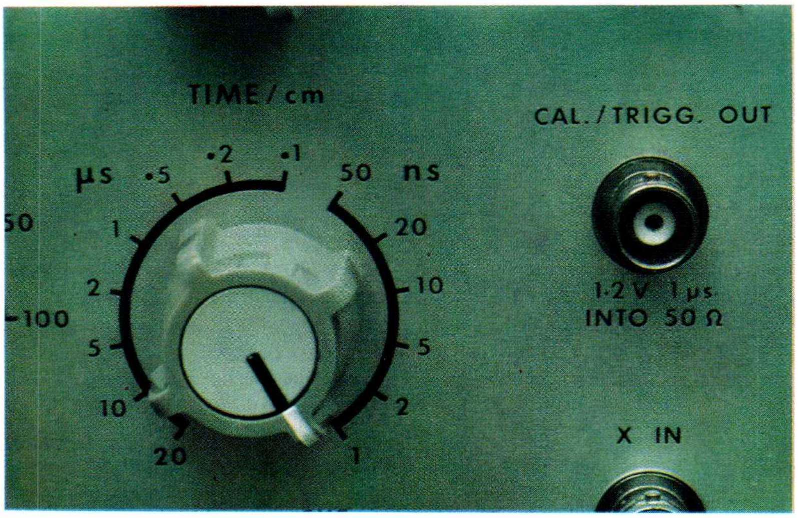
There is a very active photo club among the employees of Philips Industrielektronik (where the PM 3400 has been designed and made). A working group (the Night owls) within this photo club has specialized in making colour slides programmes using two projectors controlled by a tape recorder which also provides the sound.
Several "night owls" work in the department which developed the PM 3400, and they got the idea of making a programme about this new oscilloscope too.
The photos on these pages have been selected from some 70 colour slides which in the original form provide a 12-minute show.

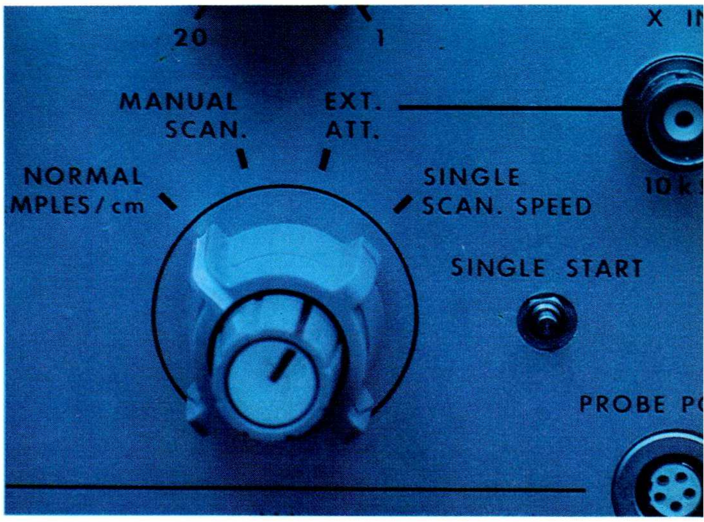


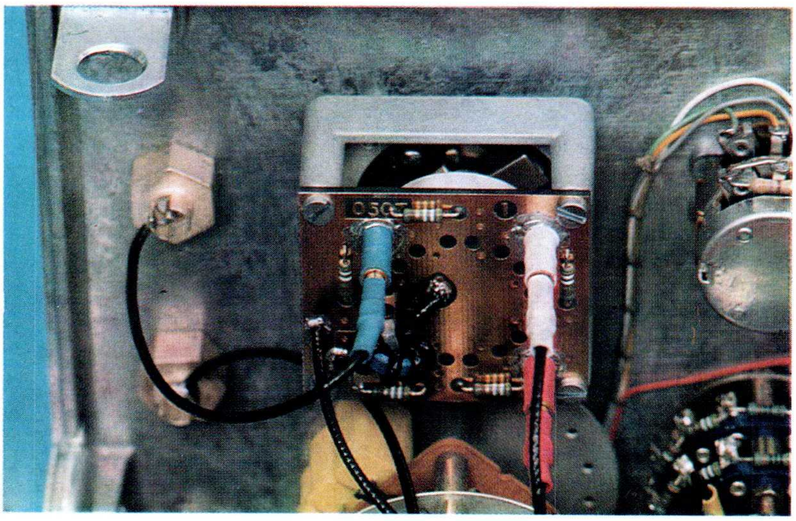


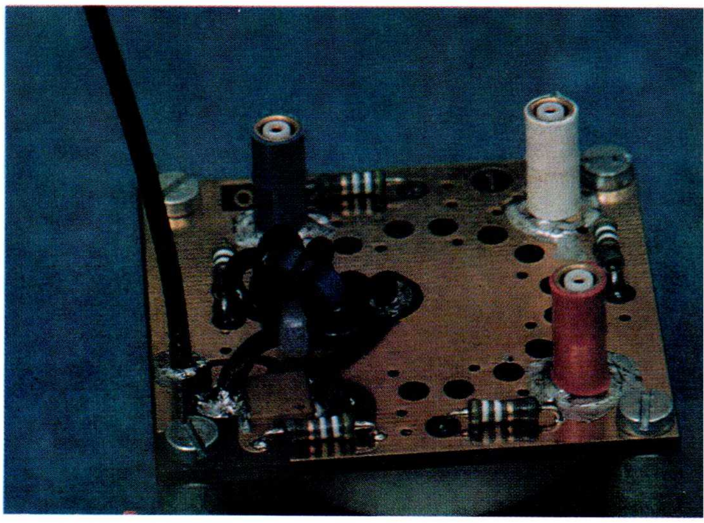


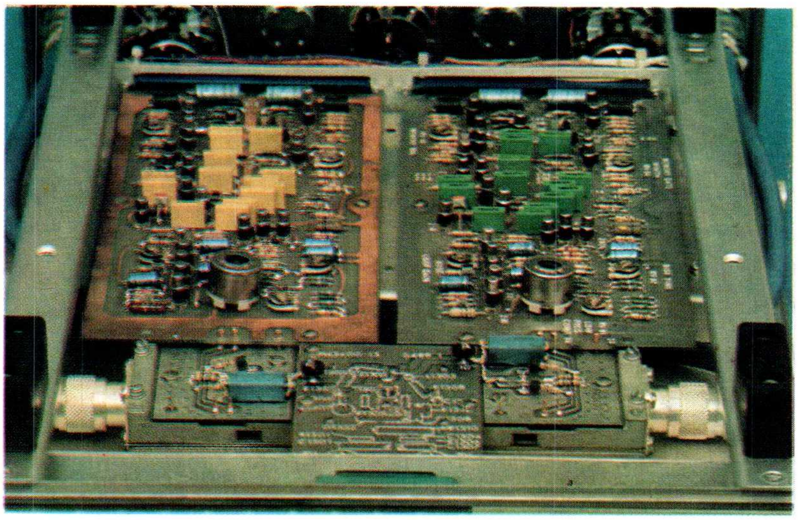


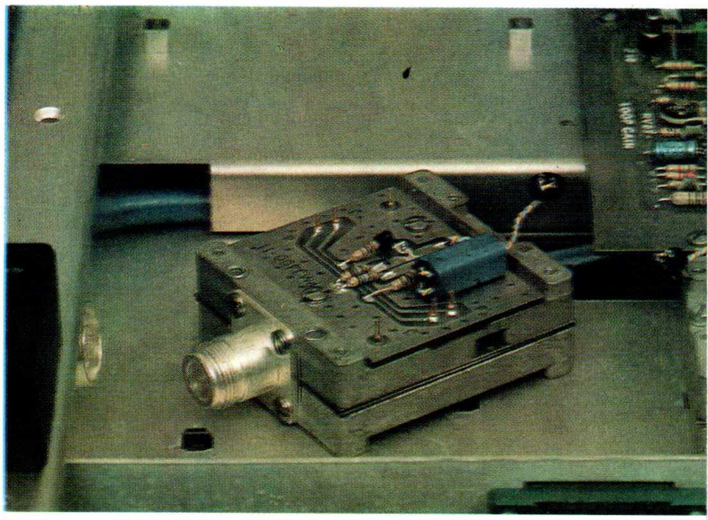

TIME / cm
CAL. / TRIGG. OUT
μs
ns
1·2 V 1 μs
INTO 50 Ω
X IN

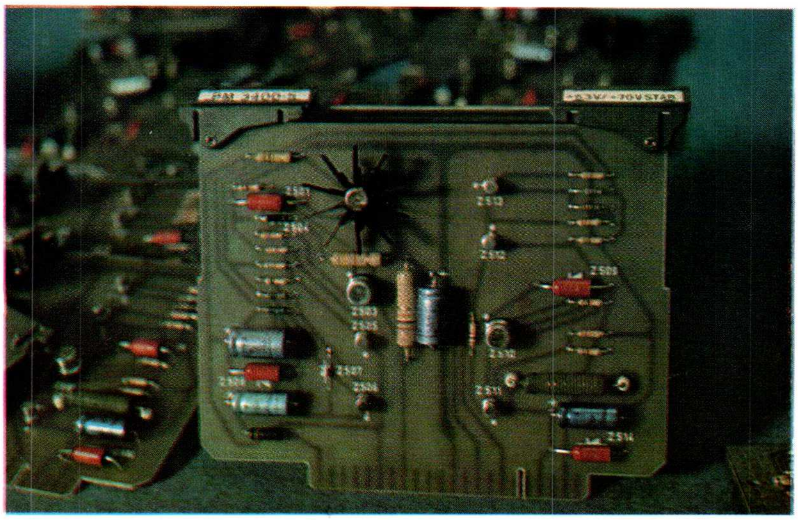

MANUAL
SCAN.
EXT.
ATT.
NORMAL
SINGLE
SCAN. SPEED
SINGLE START

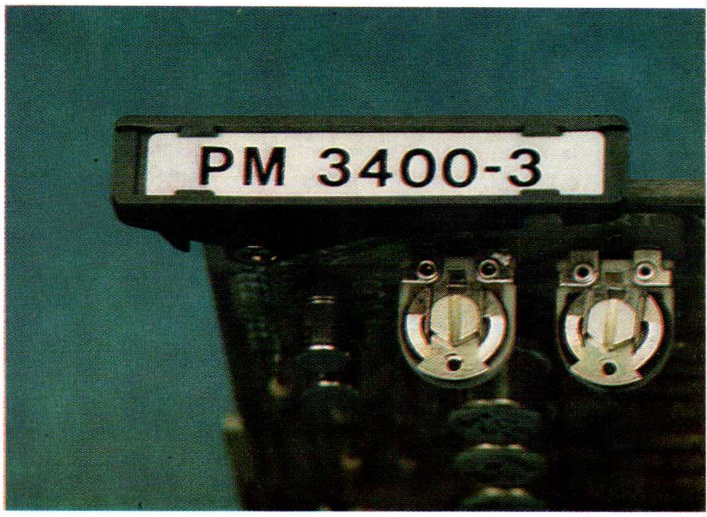











PM 3400-3

How to use the PM 3400 with recorders

The CRT-deflection of a sampling oscilloscope can run at any speed and is completely independent of the TIME/cm setting. This feature makes it possible to use an X-Y pen recorder (e.g. PM 8120) together with the PM 3400. It is interesting to note that the (slow) recorder works as a noise filter and gives clear pictures, even if the CRT display is quite noisy.

OUTPUT FACILITIES

The PM 3400 is provided with three connectors (A, B and Y) for vertical recorder output. The Y output, which is a novelty, also makes it possible to record the composite picture displayed in the A+B and A—B modes. When recording the mV/cm and TIME/cm controls should be set to CAL. The output is then always 0.5 V per cm of CRT display, and zero on the screen corresponds to zero volt at the output.

The sweep is internally generated and is available at the X-output connector. The signal is first reviewed on the CRT in the repetitive mode and the wave form displayed is given a suitable size and position on the screen. The total sweep time can be manually adjusted between 1 and 60 seconds, but should normally be set to the maximum value (with the knob turned all the way to the right). Recording is carried out in the SINGLE mode. To initiate recording, the button "SINGLE START" should be depressed. If this button is kept depressed, there will be no retracing of the X-deflection. The recorder pen should be lifted from the chart before the button is released.

WIRING

Schreened cables should be used, with BNC connectors at the oscilloscope end and banana plugs at the recorder end. Both instruments should be earthed via the mains cables.

Noise and jitter

NOISE

The accuracy of readings derived from an oscilloscope display is limited by noise and time jitter when measurements are made at the highest sensitivity or with the fastest time scales. The noise should theoretically be defined as a RMS value. However, voltmeters with a true RMS reading are rare; it is therefore important to find a simple and practical method of measuring noise with a reasonable accuracy. Furthermore, it is desirable to find a method that reflects the actual influence of noise in practical measurements. The "tangential noise" method meets these requirements.

MEASUREMENT OF "TANGENTIAL NOISE"

For an oscilloscope like PM 3400, this measurement can be carried out as follows.

1. Measure at 5 mV/cm (as there is automatic smoothing in the 1 mV/cm and 2 mV/cm settings).
2. Connect a square wave, e.g. from the PM 5770, to the input via a 100X attenuator.
3. Turn "SENSITIVITY" to the SYNC-side (fully clockwise). One will then see two horizontal noise bands.
4. Decrease the pulse amplitude until the dark band between the two noise bands just disappears.
5. Remove the 100X attenuator and measure the amplitude of the pulse displayed on the oscilloscope screen.

The "tangential noise" is then equal to 0.01 times the measured amplitude. The RMS value of the noise, which is the only value used in theoretical analyses, is estimated as half the tangential noise.

JITTER

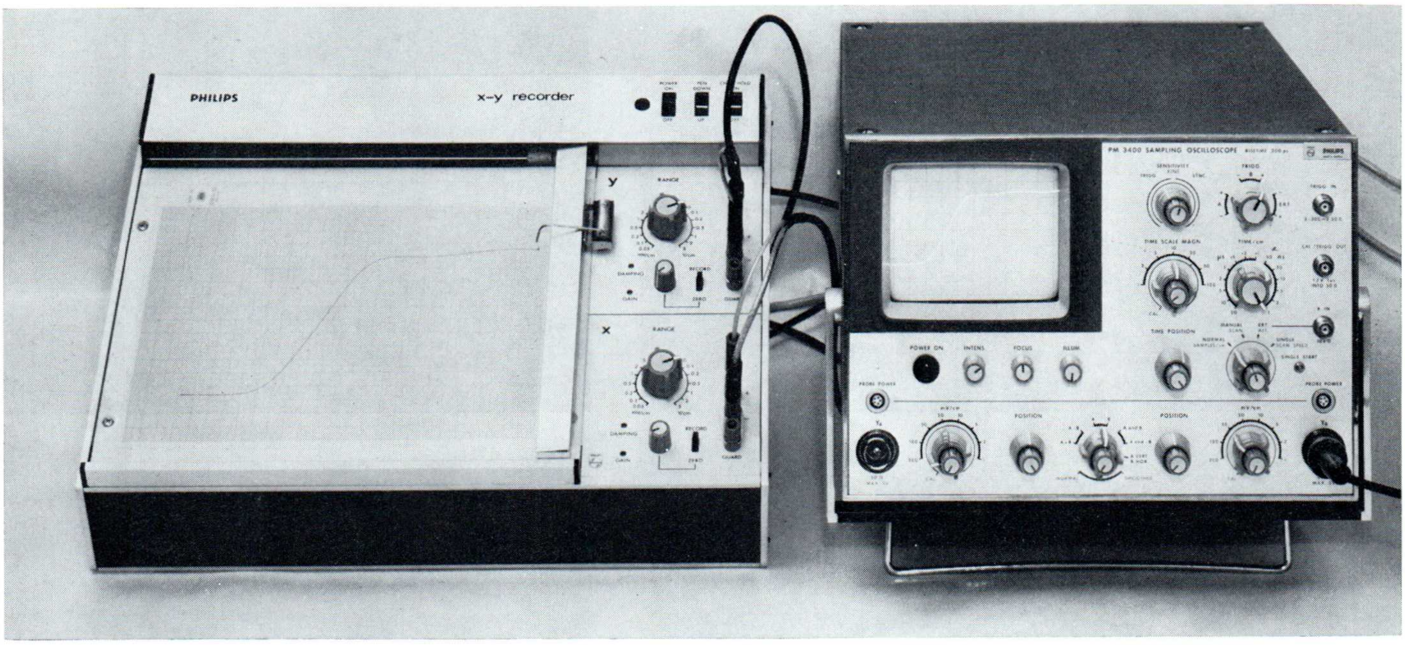
Jitter is defined as indesirable fluctuation of a pulse edge, displayed on an oscilloscope screen, measured along the time axis. The fluctuation is primarily caused by thermal noise (and possibly also by hum or other systematic disturbances), and can therefore be regarded as noise projected on the time axis. The difficulties in measuring jitter are even more pronounced than with amplitude noise, because jitter can only be measured from the CRT display.

Our new sampling oscilloscope, PM 3400, has a very good triggering system. Its quality can be described by stating the amplitude range within which a stable display can be produced on the screen. However, a more accurate description must also define the degree of stability and this is where the jitter comes in.

We have felt it necessary to improve the reproducibility of our jitter measurements, and have therefore devised a novel method for measuring time jitter, which resembles the tangential noise measurement described above.

"TANGENTIAL JITTER" MEASUREMENT

The first step is to connect the signal to the A channel. The "SENSITIVITY" control is adjusted for minimum jitter. The display is adjusted by means of the POSITION controls (fine) so that the edge to be measured is in the middle of the screen and crosses the zero line at an angle of 45°. Photo 24 shows such a display. A pulse generator (e.g. PM 5770) is connected to channel B. The frequency of the pulse generator must have no correlation with the signal frequency. The amplitude is set to a convenient value so that the distance between the two parallel lines displayed on the screen is approximately equal to the width of the apparent jitter. The display mode is then changed to "A+B", when an image like that of photo 25 will be displayed on the screen. By changing the pulse amplitude, we can bring the two curves together in the middle so that the dark line between them just disappears. The jitter, measured along the horizontal axis, is then equal to the pulse amplitude which can be expressed



as a time by measuring the width of the display (in cm) e.g. by switching to the display mode: A VERT., B HORIZ. and multiplying the reading by the time coefficient (ns/cm). See photo 26 where the pulse width can be seen to be 0.4 cm; since the time scale was 50 ps/cm in this case, the tangential jitter will be 0.4 x 50 = 20 ps. The method, described above can be used for checking the performance of an oscilloscope. It can, however, also be used for other applications, e.g. for measuring the jitter of a delay circuit.

Technical data

Mode of operation
Channel A only
Channel B only
Channel A and channel B
Channel A and inverted channel B
Channel A plus channel B
Channel A minus channel B
Channel A vertical and channel B horizontal

Displayed noise
(tangentially measured)
Less than 2 mV with NORMAL-SMOOTHED switch in NORMAL position and less than 0.8 mV in SMOOTHED position. Automatic smoothing in the 1 and 2 mV/cm ranges

Isolation between the channels
More than 60 dB up to 1 GHz

Input impedance
50 Ω. Input connectors: General Radio 874, locking recessed

Signal delay
Delay time for each channel: 30 ns
Visible delay: 7 — 10 ns
The difference in delay between the channels is less than 30 ps

Signal range
Small signals on top of DC levels up to ± 1.6 V can be displayed without distortion, at any sensitivity. +2 V or —2 V can be displayed at 200 mV/cm

Position
Coarse and vernier controls provide a vertical shift of ± 1.6 V

Maximum input voltage ± 5 V DC

Probe power
Connectors for active probes on both channels

Recorder output
X OUT. Output amplitude of 0.5 V/cm.
Source resistance 1 kΩ. BNC-connector.
Zero volt level corresponds to the left side of the screen.

TRIGGERING

Mode Triggered or synchronized.

Source Channel A, channel B or external source.

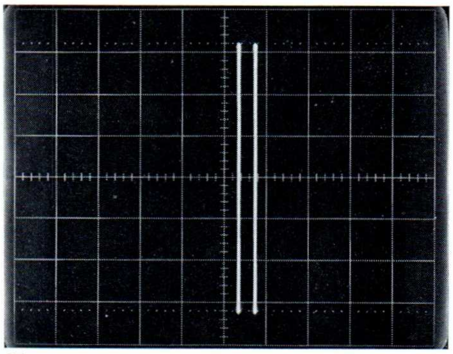
Slope + or —.

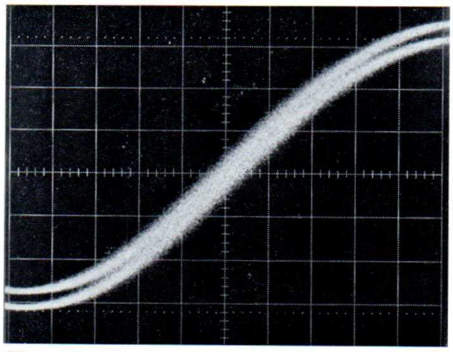
Trigg. capability
Internal 20 mV_{p-p} to 2 V_{p-p}.
External 3 mV_{p-p} to 300 mV_{p-p}.

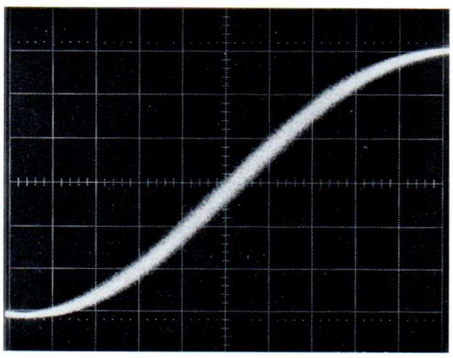
LF synchronization 10 Hz — 10 kHz by applying signal > + 1 V to X IN

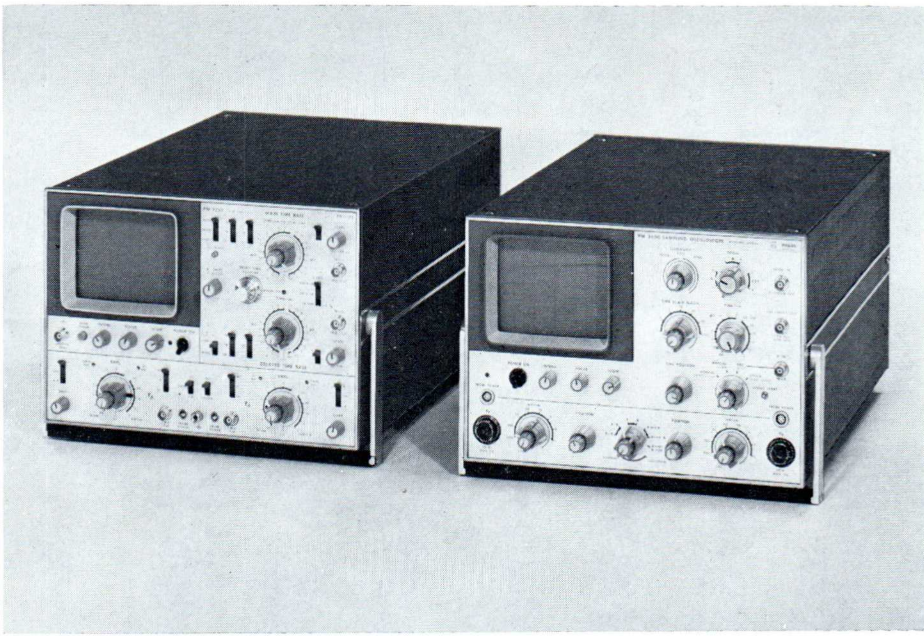
Time jitter
Less than 30 ps +0.2 % of unmagnified time/cm for pulses with ≤ 300 ps rise time and 10 mV on EXT. input or 100 mV in INT. mode.

Sine waves
Less than 30 ps + 0.2 % of unmagnified time/cm — or 1 % of period, whichever is greater — from 100 kHz to 1700 MHz with 10 mV_{rms} on EXT. input or 100 mV_{rms} in INT. mode.


24


25


26


Combining the measuring facilities of the 50 MHz real time oscilloscope PM3250 and PM3400 gives a versatile measuring capability from DC up to 1.7 GHz

Bandwidth
DC to 1.7 GHz

Rise time
200 ps ± 10%

Overshoot
Less than 3 % (with 200 ps pulse gen.)

Deflection coefficients
8 calibrated ranges from 1 mV/cm to 200 mV/cm in 1—2—5 sequence. A vernier provides uncalibrated, continuous control between the ranges and extends deflection coefficient to less than 0.4 mV/cm

Attenuator tolerance ± 3 %

Recorder outputs
Channel A, channel B and Y. Output amplitude 0.5 V/cm. Source resistance 1 kΩ
Zero volt level corresponds to centre of the screen

TIME AXIS

Time coefficients
14 calibrated ranges from 1 ns/cm to 20 μs/cm in 1—2—5 sequence.
Tolerance: ± 3 %

Time scale magnification
7 calibrated ranges from x1 to x100 in 1—2—5 sequence
A vernier provides uncalibrated, continuous control between the ranges. The intensity and the sample density remain constant when the display is magnified.
At all magnifier settings, the tolerance is within ± 5 %.
The centre of magnification is at midscreen (or at the left-hand side of the screen, depending on the position of an internal selector).

Time position
Coarse and vernier controls provide a time-positioning range equal to at least one unmagnified screen width.

X-deflection
— Repetitive from 5 to more than 1000 samples/cm, continuously variable.
— Manual scan.
— External scan
— Single scan 5 to 60 s per sweep.
One continuous control covers all these functions.

Trigger kick back
Less than 3 mV amplitude on the EXT. input connector.

Safe overload Maximum 3 V_{peak}.

Trigger output
Suitable as calibration voltage.
Pulse amplitude: 1.2 V ± 2 % into 50 Ω.
Pulse rise time: less than 4 ns.
Pulse width: 1 μs ± 2 %.

CRT

Type
D14 — 120 GR/37 with long persistance phosphor.

Graticule
Internal, with cm-divisions and 10%- and 90%-indications for measuring rise times.

Useful screen area 8 cm x 10 cm.

Graticule illumination Continuously variable.

Total acceleration voltage 10 kV.

POWER SUPPLY

Mains frequency 50 — 400 Hz.

Power consumption 80 VA.

TEMPERATURE RANGE

Operation within specification
0° to + 45°C

Operating —10° C to +55° C.

Storage —40° C to +70° C.

DIMENSIONS AND WEIGHT
Height: 22 cm
Width: 32 cm
Depth: 47 cm
Weight: 18 kg (40 lbs)

Applications of the new monochrome and colour test-pattern generator PM 5544

by J. Overzee

The PM 5544 test-pattern generator has been developed to supply TV test patterns at the following points:

- in transmitters, so that viewers and service personnel can assess the quality of the broadcast TV pictures;
- in studios for the checking of monitors and decoders;
- in TV factories, for research, development and production purposes.

It will be clear that different test patterns are required for the various applications. However, the composite test pattern provided by the PM 5544 fulfils all the various needs, and still manages to look quite attractive and not too cluttered-up. The object during the development of this generator was to arrive at a pattern which could be used to check and/or adjust a

TV set, monitor, decoder etc. without the aid of another measuring instrument, i.e. from visual observation of the screen. This object has been attained for the greater part of the checks or adjustments involved however in some cases the use of an oscilloscope will definitely give better accuracy.

Below we shall give a survey of the various checks and alignments which can be carried out with the aid of the pattern produced by the PM 5544, classified according to the circuitry involved, as follows:

deflection

- aspect ratio
- picture size
- scanning linearity
- convergence

synchronization

- sync separator check
- interlacing

luminance section

- low-frequency response
- transient response
- resolution and bandwidth

chrominance section

- delay-line circuit
- demodulator circuit
- matrix circuit
- bandwidth
- chrominance/luminance delay
- colour rendering
- burst-gating

additional features

The test pattern is shown in fig. on pag. 5. For the sake of clarity information about the various components is printed over the components in question.

Deflection

Aspect ratio

The circle should be quite round at the correct aspect ratio and linearity. Since the accuracy and stability of the generated circle are very high any deviation from the circular shape is due to an error in the deflection system. (It should be remembered that distortion of the circle may be due to non-linearity as well as to an incorrect aspect ratio).

Picture size

The top and bottom border castellations provide a check on overscan. The castellations at the left-hand and right-hand sides are wider than those at top and bottom. They will be cut away in case an aspect ratio of 4 : 5 is used instead of the standard 3 : 4 ratio.

Scanning linearity

The rectangles formed by the horizontal and vertical lines should be squares if correct linearity is realized. The circle should of course be round.

Convergence

Static convergence can easily be checked (and adjusted if necessary) with the aid of the horizontal and vertical lines in the middle of the circle. If desired, an additional (longer) vertical line can be switched in, indicating the exact centre of the complete pattern.

Dynamic convergence: the cross-hatch information around the outside of the circle is mainly intended for this purpose.

NOTES

— The background amplitude of the crossed lines can be varied between black and 80% white for ease of viewing and to get the best balance between white and black

— Since the circle is locked to the grid raster and the latter in its turn to the horizontal and vertical frequencies, a stable picture is obtained.

— The width of the vertical lines is chosen so that cross colour (i.e. interference from bl/wh information in the colour channel) is minimum.

— The same full-screen grid raster signal can be made separately available at a special socket.

Synchronization

Sync separator check

The right-hand black/white castellations give a check on the functioning of the sync separator. Any error here will cause the vertical lines to be displayed not as straight lines but as zigzags.

Interlacing

A special trick has been employed for checking of the interlacing. The reader will be aware that the horizontal lines of the grid raster are in fact made up of two lines, each from a different field. The horizontal line in the middle of the circle is built up in the same way, except that the scanning sequence is reversed. This means that bad interlacing ("pairing") or complete non interlace will make the widths of the two types of lines visibly different.

Luminace section

Low-frequency response

This can be checked by means of the black rectangles in the upper and lower parts of the circle; streaking at the right-hand side of these blocks indicates poor low-frequency response.

Transient response

The 250 kHz square-waves give a clear impression of the transient response, overshoot, undershoot and ringing are all reflected in the reproduction of the square-wave signals. In order to reduce quadrature distortion, the amplitude has been reduced to 75%.

Resolution and bandwidth

The definition lines correspond to frequencies from 0.8 to 4.8 MHz and have a sinusoidal form. The fall-off of the amplitude of these lines gives a clear indication of the bandwidth. On a normal TV set the 0.8 to 2.8 MHz lines should have full amplitude, whereas the 4.8 MHz lines will only have a small amplitude. The percentage drop can be measured with the aid of an oscilloscope.

Chrominance section

Checks on the various circuits of the chrominance part of the colour TV receiver are dealt with separately, for ease of understanding, see fig. on pag. 31.

Delay-line circuit

Here we can find **amplitude** or **phase errors,** i.e. either the amplitude or the phase of the direct and the delayed chrominance signals, or both, may differ.

Let us discuss first the check on the amplitude adjustment. This is made with the line-alternating ± (R-Y) and ± (B-Y) signals. If the alignment is wrong, successive lines in the line-alternating colour-difference signal section will differ in colour. These sections instead of being grey like the background will give a so-called "Venetian blinds" effect.

Phase errors between the delayed and the direct signals are detected in much the same way as the amplitude errors, but here the "Venetian blinds" appear mainly in the (R-Y) and (B-Y) sections (i.e. the non-alternating ones). For example phase errors may cause (R-Y) signals to appear in the (B-Y) section, thus giving a change of hue in alternate lines. Since the cyan and green blocks of the colour bar both contain considerable (R-Y) and (B-Y) components, a phase error also gives an easy recognizable "Venetian blinds" effect here.

Demodulator circuit

CHECK OF REFERENCE PHASE

The above mentioned section with alternating (R-Y) signal is used to check the (B-Y) synchronous detection.

Due to the PAL coding of this signal a non-alternating phase-switched (R-Y) signal arrives at the (B-Y) output of the delay-line circuit, and consequently at the (B-Y) synchronous demodulator. Only when the phase of the subcarrier signal fed to the synchronous demodulator is exactly orthogonal to the phase of the (R-Y)-modulated signal will no output signal be obtained. In any other situation, the section has a more or less visible colour.

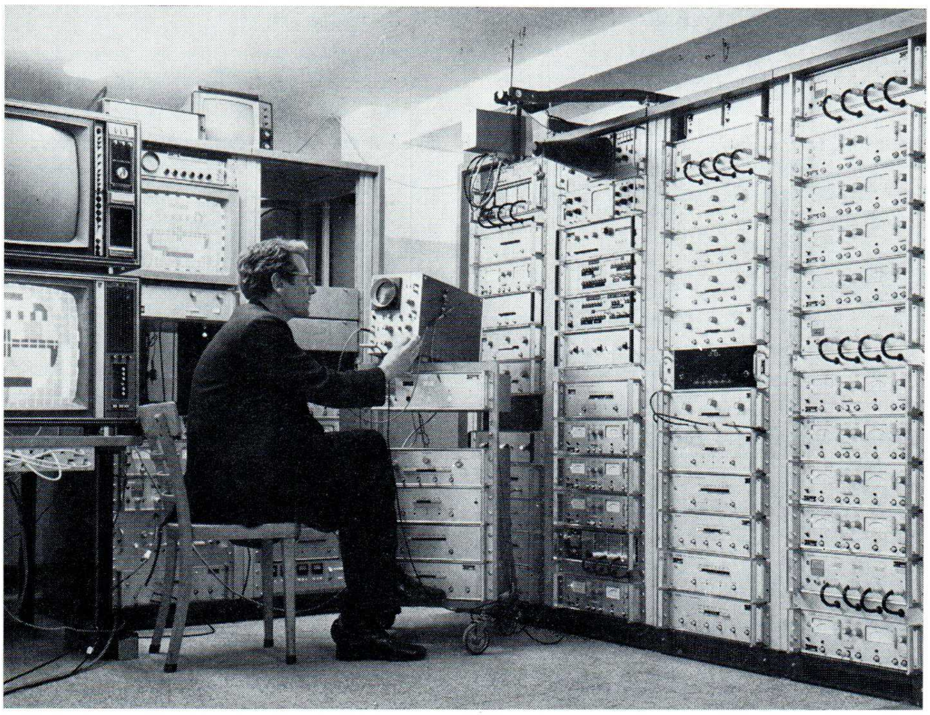
CHECK OF (R-Y) SYNCHRONOUS DEMODULATOR

The line alternating 180° phase-switched (B-Y) signal is used for a check on the (R-Y) demodulation. This (B-Y) signal appears at the (R-Y) output of the delay line and consequently at the (R-Y) demodulator. As in the previous sub-section, only when the phase angle between the subcarrier applied to the demodulator and this (B-Y) modulated subcarrier signal is 90° will the right-hand vertical ± (B-Y) bar remain colourless. It will be clear that in both the above cases, the demodulation can easily be adjusted from the screen, by comparing the colour of the alternating colour difference signal bars in question with the grey background next to them.

Matrix circuit
The colour bar of this test pattern is the standard 100% saturation 75% contrast type, while the adjacent 250 kHz square-wave section also has 75% white amplitude. If now e.g. the red and the green guns of the picture tube are switched off, only the blue blocks of the colour bar will be visible together with the blue portions of the 250 kHz square-wave section. The saturation control of the set should now be set so that the adjacent blue fields have equal intensity. If two other guns are switched off, the corresponding adjacent fields should have the same intensity; otherwise, a readjustment of matrix will be necessary.

Bandwidth
Since the subcarrier frequency is 4.43 MHz a certain "moiré" effect in the 3.8 MHz and 4.8 MHz definition lines is inevitable in the TV set or decoder.
Because this subcarrier frequency lies nearly half-way between 3.8 and 4.8 MHz, the amplitudes of this interference in the two definition lines sections should be almost equal if the bandwidth characteristic of the chrominance channel is symmetrical. Any asymmetry may easily be detected by comparing the amplitudes of the two interference patterns. A smaller amplitude in the 4.8 MHz section generally indicates an asymmetrical chrominance band pass characteristic.

Chrominance/luminance delay
A difference between the chrominance and luminance delays of the device to be checked can easily be demonstrated by means of the colour transient at the bottom of the circle. After a lot of experiments it turned out that a red square on a yellow background was the ideal combination to detect this phenomenon. Because the leading and the trailing edges of this red block correspond to parts of the vertical lines just beneath them, we can get an good impression of the difference between the chrominance and luminance timing.



Colour rendering
One of the purposes of the colour bar is to facilitate overall assessment of the picture quality and correct setting of the saturation. Although the assessment of colour is a subjective thing, a general impression can be obtained in this way.

Burst-gating
As can be seen from fig. on pag. 5, two of the far left-hand castellations contain a line-alternating (R-Y) signal.
If due to an incorrect burst gating this colour information is passed to the reference generator, a local colouring of the line-alterating (R-Y) and (B-Y) sections and a slight loss of saturation of the non-alternating colour difference signal will be the result.

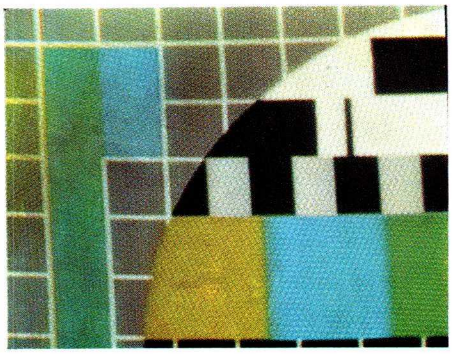
Additional features
Area with blacker-than-black level
The black background of the lower part of the central cross can be adjusted to be beneath black level. This feature can be used as a picture line-up information for adjustment of the contrast and brightness of TV monitors.

Identification signal
A signal from e.g. an alphanumeric generator can be blanked into the lower black poses. The appropriate signal is applied to a separate socket and is then automatically amplitude-controlled and position-gated. The polarity of the identification signal can be reversed internally.

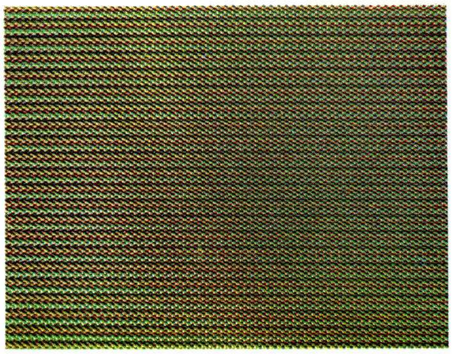
Replacement of information inside circle
The information within the circle can easily be replaced by an external colour picture from a camera or flying-spot scanner, thus allowing a fully electronic test pattern to be combined with a slide or camera picture.

Adaptation to different field blanking duration
On delivery, the instrument will be set for a field blanking period of 25 lines, but it can easily be adjusted to any field blanking length between 18 and 25 lines for use with older types of sync generators.

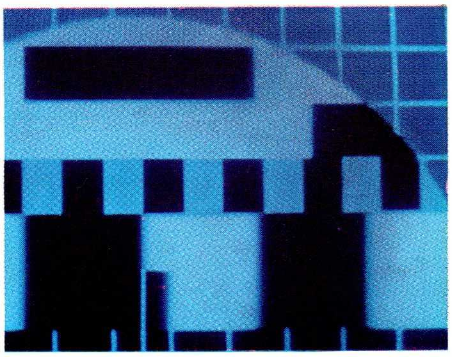
Subcarrier locking
The subcarrier of the colour TV systems has to meet certain standard requirements, one of which is that there should be a fixed phase and frequency relationship between the subcarrier and the line frequency signal.
As mentioned under "bandwidth" above, a slight moiré effect will be evident in the 3.8 and 4.8 MHz lines because of interference with the 4.43 MHz subcarrier signal. If the subcarrier locking is correct, the moiré effect will appear to be stationary; otherwise, the pattern will move.



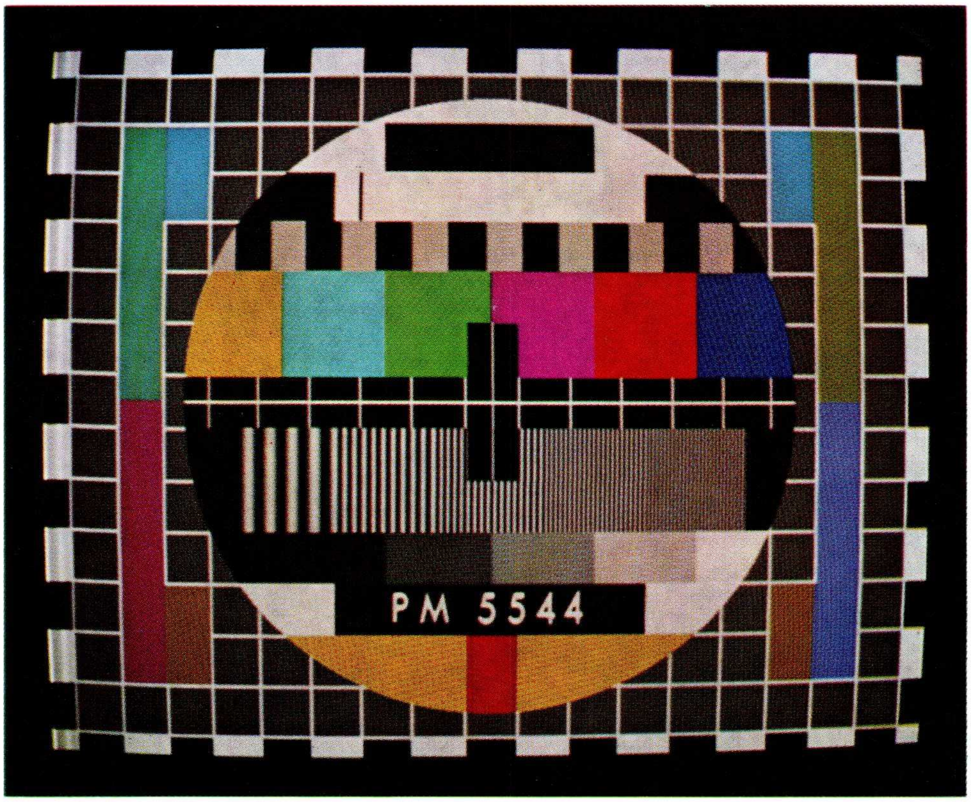
Wrong burst gate location
Note local colouring of line-alternating R-Y section

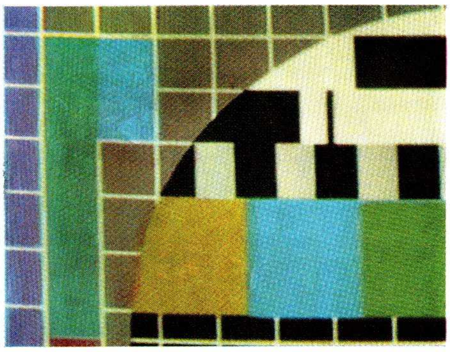


Venetian blinds due to incorrect phase of delay line circuit

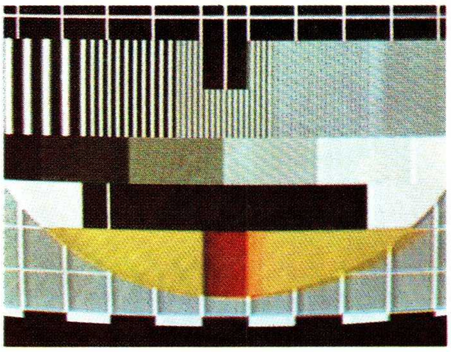


Matrix fault
Note different intensity of adjacent blue sections

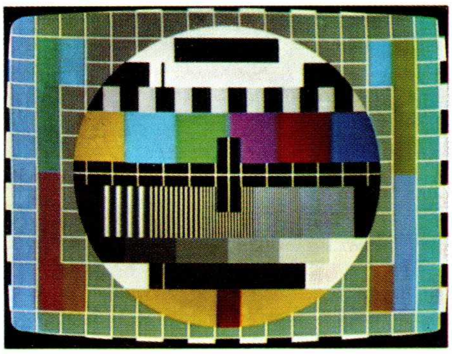




Detail of picture
(Wrong demodulator phase alignment)



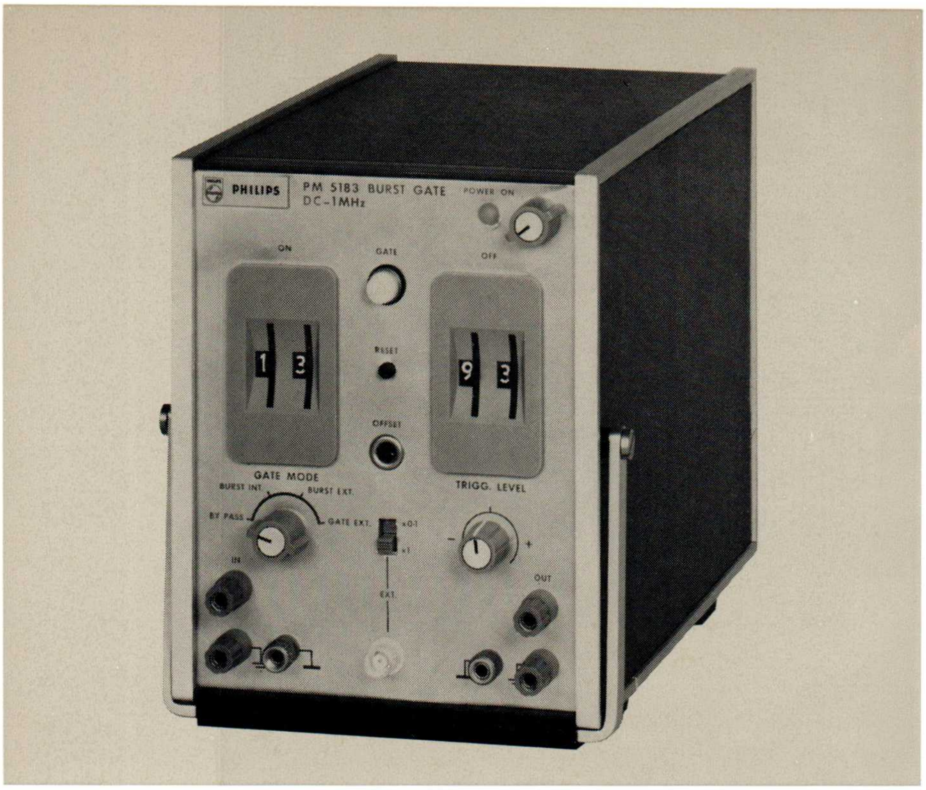
Chrominance/luminance delay inequality
Note smearing of red block



Wrong demodulator phase alignment
Note colouring of line-alternating R-Y and B-Y sections

Applications of a tone-burst gate

by H. J. Burema



A new instrument, the tone-burst gate PM 5183 has recently been added to our range of Low Frequency Equipment. This instrument adds several new techniques to those offered by the existing equipment, for applications in various fields of science and technology. A tone-burst gate can be considered as a switch activated by a preset counter which determines the number of periods of a signal to be passed and the number of periods to be blocked. The output thus consists of trains of periods of the original signal. The signal can be sinusoidal or have any other periodic waveform, but usually a sine wave is to be preferred.

The preset counter can be actuated either by the signal itself or by another signal. In the latter case the signal is not coherent, i.e. the different trains of periods do not start at the same point of the periods every time. Finally, the instrument can be used simply as a gate with the aid of a square-wave signal.

The applications of this instrument may be divided into five different groups.

Audio

1. A tone burst can be considered as something between a continuous sine wave and a pulse; this makes it very suitable for measurements on loudspeakers and amplifiers.

When a tone burst is produced by a loudspeaker, the signal can be picked up by a measuring microphone and the output of this microphone compared with the original tone bursts (fig. 1)

The difference between the two is the distortion, which can be detected during the off-time of the burst.*

* (See: V. J. Kaminsky: The response of loudspeakers to tone-bursts, Journal of the audio Eng. Soc., April 1965).

Other important characteristics of amplifiers which can be measured are the distortion under overload conditions (peak power) and the recovery time required by the amplifier after overload.

Sometimes the signal level between the bursts should not be zero but should have some arbitrary value. This can be accomplished by bypassing the burst gate with a resistor of several hundreds of ohms. This set-up has been recommended by a IEC committee for the testing of amplifiers.

Response time

2. Use of a tone burst is very convenient for measurement of the response characteristics of a VU meter (programme level meter). One very important characteristic of such a meter is the response time, for both raising and lowering the programme level.

For instance, if the response time of the VU meter is required to be 300 msec at 1 kHz this means that the meter should give a full-scale deflection when 300 periods of a 1 kHz signal are applied to it.

The test signal required here can easily be produced with the aid of two LF generators and the PM 5183 (fig. 2). The response time of the VU meter for increasing signal values can now be determined by adjusting the number of cycles with the PM 5183 until the meter reads exactly full scale. The response time signal for decreasing values of the signal can be determined by adjusting the blocking time. Use is made of a second tone-generator because more than 100 periods are needed to obtain the required burst length.

Response test of AC-meters are also important in broadcast and grammophone recording studio's. Colour figure on the page 34 shows the set-up of fig. 2 in use for the testing of peak-level indicators in an audio console.

Reflection measurements

3. Many applications are based on reflection measurements. A tone burst is sent into a system, and is detected after reflection. The time delay between the two signals, and the magnitude and phase relations, can give information about the system in question.

An obvious application is the study of room accoustics, but these measurements are also used in chemistry and medicine.**

One way of measuring the delay time and magnitude relation is to use a second tone burst to cancel out the reflected tone burst.

Oscillograms illustrating this technique are shown in fig. 3 and 4.

Other applications with the same set-up are: liquid level measurements, non-destructive testing of materials, flow measurements and so on.

** (See G. M. Glover et al.: "A magnetostrictive instrument for measuring the viscoelastic properties of liquids in the frequency range 20 - 1000 kHz", J. Sci. Instr. 1968 p. 383).

Biology

4. In biology and medicine, a signal is often used to stimulate nerves and muscles. There are many types of stimulating signals. The kind the PM 5183 can produce is perhaps especially useful for research work on auditory organs. In biology synthetic sounds which can be made with the aid of a PM 5183 are of interest for research on bats, dolphins etc.

The PM 5183 can only produce bursts of constant amplitude. Sometimes, however, a burst of increasing or decreasing amplitude is required. In this case the system described in issue 1968/4 of EMM Notes can be useful. To obtain a coherent signal, the PM 5183 can be used as a frequency divider.

Electronics

5. In the field of pure electronics the following applications are the most important:

a) A very obvious application is that as a frequency divider, e.g. to obtain an accurate frequency of an arbitrary value starting from a reference frequency, see fig. 5.

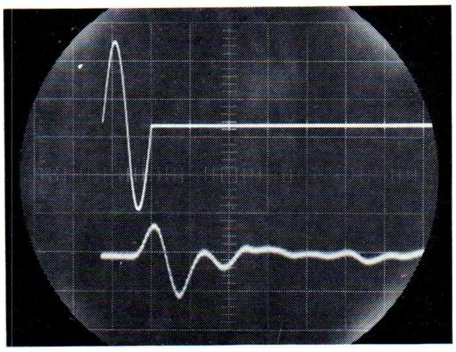
b) A tone burst can also be used to produce pulses of long duration. As the lowest frequency of a pulse generator is generally a few Hz this may be useful.

For instance, with a 1 Hz sinusoidal signal as an external burst signal, a pulse with a duration of up to 99 sec is available at the gate output, fig. 5 and 6.

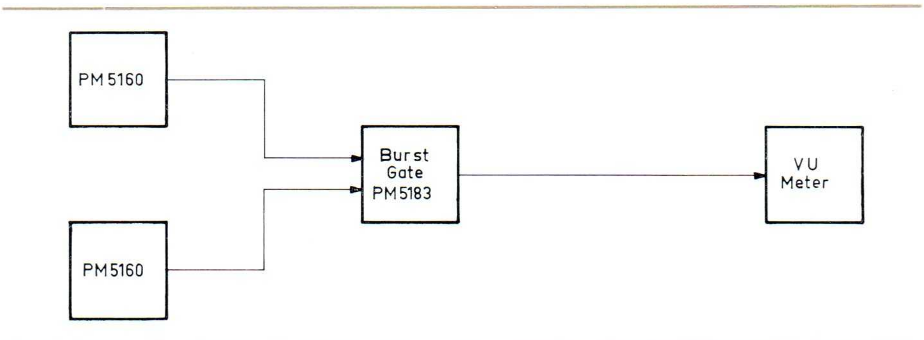
If desired the gate lamp can be used as a time indicator.

c) Use of a sine-squared pulse provides a new method of testing amplifiers, transmission systems etc.

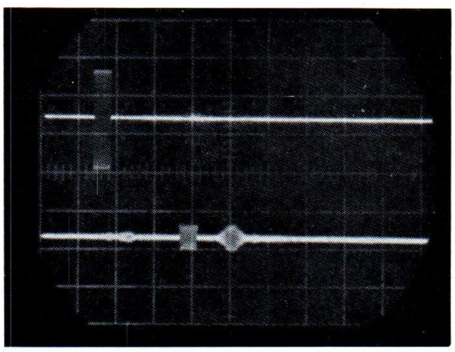
The frequency spectrum of a sine-squared



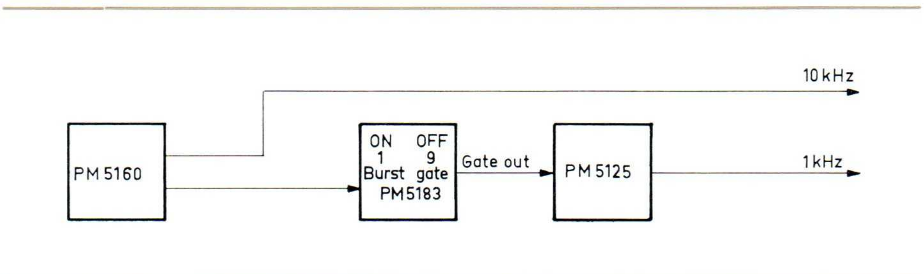
1. The output signal of the microphone compared with the original tone burst.



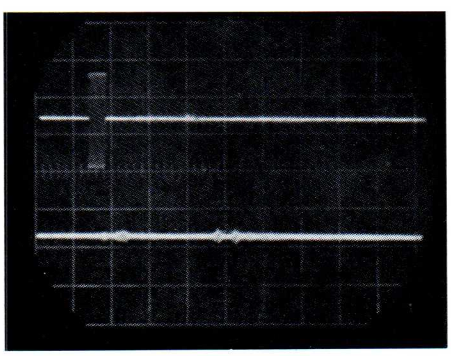
2. Block diagram for measurement of the response characteristics of a VU meter



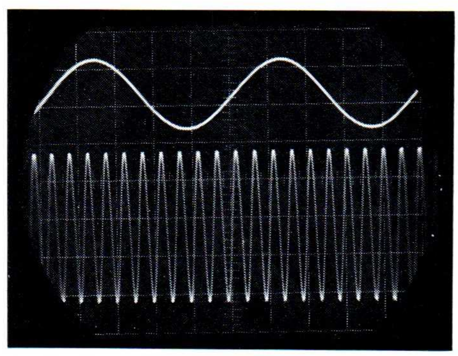
3. The various bursts involved in a reflection measurement displayed on a dual-trace oscilloscope. The reflected and cancellation bursts may be seen in the lower beam.



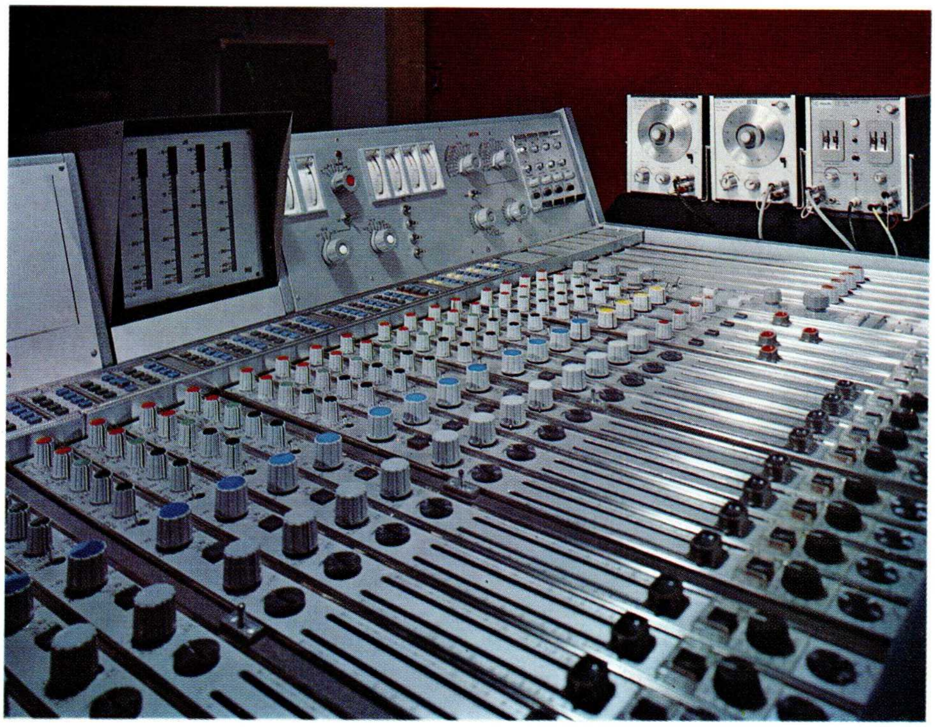
5. The PM 5183 can be used as a frequency divider. To obtain a sine wave, a PM 5125 can be synchronised with the gate pulse of the PM 5183



4. As fig. 3, but with the reflected burst cancelled out



6. The signals obtained with the circuit of fig. 5.



pulse contains no appreciable components above twice the fundamental. Below this frequency its spectrum closely resembles that of a square-wave pulse. Because of this lack of very high components which are of no importance for the transmission system under test, the evaluation of measuring results is much easier.
Sine-squared pulses can be obtained very simply with the aid of a function generator PM 5168 and the PM 5183. It seems likely that this type of signal will find much application in the future.***
d) A burst gate can also be used to produce high peak voltages. If the PM 5183 is used with a low duty cycle, the average power can be kept low while the energy of the burst (or single sine wave) may be high.

*** (A. Schaumberger: Vorbildliches Impulsverhalten Hifi May 1969).

Under these conditions, high voltage peaks can be obtained with the aid of suitable amplifiers.
One application of this type is the generation of mains transients. The input voltage to the PM 5183 is taken from the mains via a step-down transformer, and the output transformer of the amplifier is connected in series with the mains cable of instrument to be tested with mains transients.
Details of a circuit producing artificial mains transients are described in EMM Notes 1970/1.

Technical data

Frequency range: DC . . . 1 MHz

Signal input: 1 V_{rms}; max. permissible ± 15 V_t; 0.1 V_{rms} minimum

Input impedance: 600 Ω

Signal output: 1 V_{rms} into 600 Ω, open 2 V_{rms}

Output impedance: 600 Ω

Functions: Direct-gate continuously closed
Burst intern: internal control. The gate is driven by the signal to be switched
Burst extern: Internal preset counter which controls the gate is driven by an external signal
Gate extern: Internal preset counter is switched off. Gate is only operated by external pulse

ON-Mode (Gate closed)
Additional distortion: < 0.1 % up to 100 kHz
< 0.3 % up to 500 kHz
Insertion loss: ± 0.05 dB up to 100 kHz
± 0.15 dB up to 1 MHz
with respect to 1 V_{rms}
Pedestal output: can be nulled (screw driver control)
Hum and noise: > 74 dB with respect to 1 V_{rms}

OFF-Mode (Gate open)
Signal rejection (input voltage 1 V_{rms}):
> 70 dB up to 20 kHz
> 60 dB up to 100 kHz
> 46 dB up to 1 MHz

On/off timing
On 1 . . . 99 periods
Off 1 . . . 99 periods
Phase: coherent
Trigger phase: see timing input
Hum and noise: 74 dB with respect to 1 V_{rms}

Switching transients < 50 mV_{pp}
Duration: 100 ns

Timing input
Trigger phase: adjustable over approx. 150 ° for sinusoidal signals and 175 ° for triangular signals
Trigger level: 1 V_{rms} and 10 V_{rms} for sinusoidal signals 2.8 V_{pp} and 28 V_{pp} for triangular signals

Gate extern
Input: as timing input

Gate out
Output voltage:
in the On-mode 1.4 V into 600 Ω
in the Off-mode 0 V
Rise time: approx 80 ns
Short circuit proof

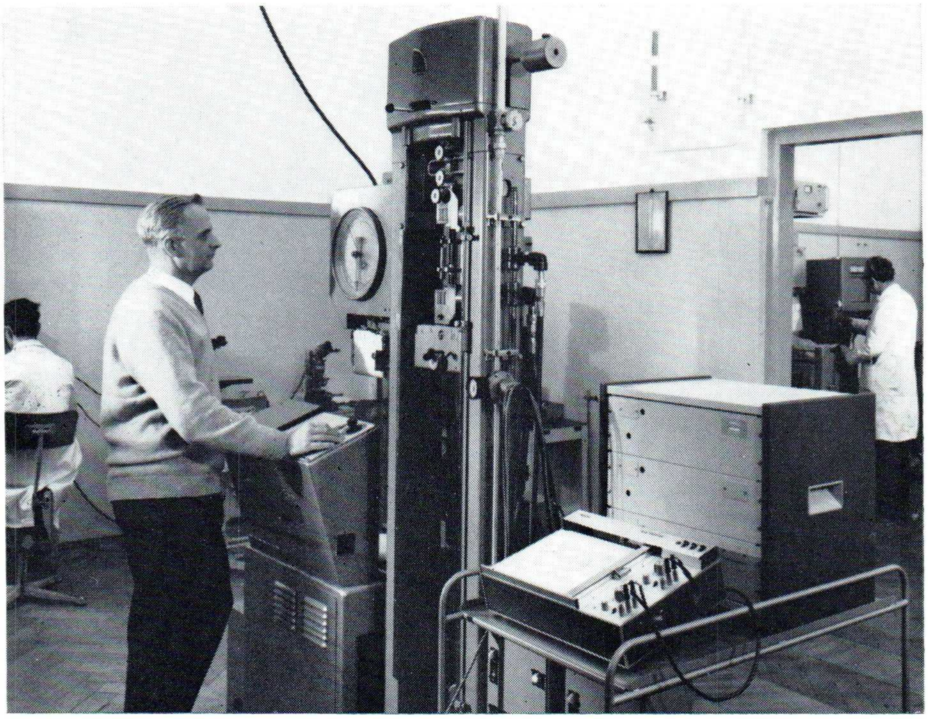
Reset
Manual: push-button
Electrical: on rear panel BNC connector
Sensitivity: > + 2V
Max. signal: + 6 V
Rise time: < 500 ns
Ambient temperature: 10 ° . . . 45 °C

Power supply
115, 230 V ± 15 %; 50 . . . 100 Hz; 15 W

Dimensions and weight
Height : 19 cm
Width : 16 cm
Depth : 27 cm
Weight : approx. 3.2 kg

A new universal extensometer

by N. G. J. Nühn, Philips Metallurgical Laboratory



Summary

A universal extensometer which has been developed in Philips' Metallurgical Laboratory for the automatic recording of the strain in tensile tests, has the possibility to clamp any gauge length* desired of a tensile specimen. This instrument permits rapid, accurate and reproducible determination of the mechanical properties of the test material. The elongation of the test piece produced during the tensile test is converted into an electrical signal with the aid of an inductive displacement transducer, which is interchangeable so that both low and high strains can be measured. If this extensometer is used in combination with a load cell, on which the load is measured with the aid of a similar transducer, the load-elongation diagram can be continuously recorded up to fracture on an appropriate X-Y recorder.

* Gauge length:
Prescribed part of the test piece on which elongation is measured.

Introduction

The tensile test is the simplest and most widely used test method for determining the mechanical properties of materials. A test piece is subjected to tensile stress, and the elongation found is plotted as a function of the load in what is known as the load-elongation diagram.

Fig. 1 shows a typical stress-strain diagram, with indication of the various properties which can be determined from the tensile test.

Most tensile testing machines are provided with a device which allows the load-elongation diagram to be recorded during the test itself. The elongation recorded generally corresponds to the displacement of the two clamping jaws with respect to one another or the displacement of the cross head of the testing machine. This means that the recorded extension includes not only the increase in length of the test bar itself, but also that of the parts outside the bar.

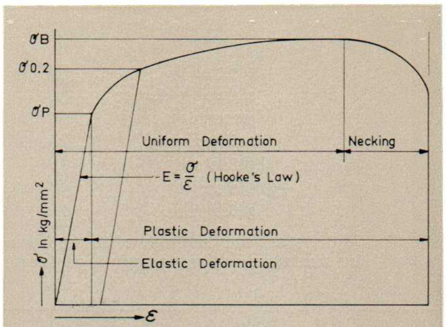
This extra extension may be made up of e.g.:

- the play of the clamping heads
- displacement of the hardened clamping inserts with respect to the body of the clamping heads
- displacements connected with the recording of the load and the elongation.

Since this extra elongation is generally also proportional to the load, the linear part of the load elongation diagram will be less steep than it should really be.

The load is generally recorded via a system of levers, and after calibration the values occurring in the diagram correspond to the real loads in the system.

A load-elongation diagram determined in this way will be adequate in practice for the determination of the 0.2 proofstress, the tensile strength and the total strain after fracture.



P = load in kg

O = original cross-sectional area of the gauge length in mm²

$\triangle L$ = increase in length, in mm

L_0 = the gauge length of the elongation tensile specimen in mm

E = modulus of elasticity in kg/mm²

σ = P/O = stress in kg/mm²

ε = $\triangle L/L_0$ = strain

σ_B = P_{max}/O = tensile strength

σ_p = proportional limit, the highest stress at which Hooke's law still applies

$\sigma_{0.2}$ = 0.2 proof-stress, the stress at which a non-proportional elongation of 0.2 % of the original gauge length occurs

1. A typical stress-strain diagram

If however we want to study the modulus of elasticity, (Young's modulus), elastic strain, hysteresis, relaxation and creep phenomena in the material in question, the method of measurement described above will no longer be adequate.

The results of the tensile test are often used as criteria on the basis of which predictions are made. It will be clear that if really comparable data are desired for this purpose, the tensile test will have to be made more accurate.

Recognition of this necessity led us among other things to measure the elongation of the test bar directly on the bar itself with the aid of extensometers which are clamped on to the bar.

The different types of extensometers

Commercial extensometers can be divided into three different groups, depending on the way in which the displacement is measured.

MECHANICAL EXTENSOMETERS

In these extensometers, the change in length is generally indicated with the aid of a dial gauge. The accuracy of this length measurement is closely related to the accuracy with which the dial gauge can be read. The load-elongation diagram is here determined in the form of individual points giving the elongation at various loads. This type of meter is quite heavy, and if the weight is not properly balanced an extra (bending) stress can be produced in the material. This may lead to very considerable errors in the measurement, especially for relatively thin test bars.

ELECTRICAL EXTENSOMETERS

Here the variations in the length to be measured are determined with inductive displacement transducers or with strain gauges.

The operation of the inductive transducer is based on the changes in the inductance of two coils produced by movement of a ferromagnetic core (the measuring pin). In strain gauges, changes in length lead to a proportional change in resistance. The voltage differences occurring in both systems can be amplified, allowing the displacements to be measured to be magnified several thousand times.

Extensometers of this type are used in particular for the determination of the modulus (Young's modulus) of elasticity, the elastic limit or proof stress and small changes of length under varying load. They are also used for the study of creep and hysteresis phenomena.

OPTICAL EXTENSOMETERS

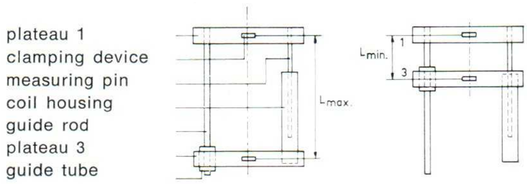
The best known meter of this type is Marten's mirror apparatus. The elongation of the test bar is measured here from the rotation of a mirror clamped to the test bar. With the aid of a telescope, a fixed scale is observed via this mirror, and changes in the reading on this scale are recorded.

These simple aids allow the displacement to be magnified up to 1000 times, but the method is rather complicated in execution and is not suitable for direct recording.

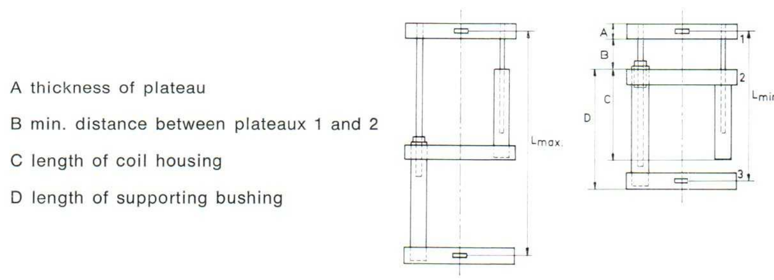
However, the firm of Instron has introduced a new optical extensometer on to the market, in which two fixed reflection points applied to the test bar are followed by two optical servo-systems. The accuracy of adjustment is ± 0.25 mm.

Optical extensometers are used for the testing of materials (plastics, metal foils and thin wires) which would be affected too greatly by the extra stresses introduced by fixing an extensometer on them. However, the costs of the complicated equipment involved makes them unsuitable for general application.

Extensometers of types 1 and 2 above share the characteristics that each fixed meter has only the possibility to clamp one gauge length, and that there is an upper limit to the displacement which can be followed. In most cases, this effect is related to an angular displacement in the measuring system, which only allows a limited stroke. This means that extensometers of this type in many cases cannot be used for recording of the whole load-elongation diagram.



2. The two extreme settings of the coil housing, for maximum and minimum gauge length, with two plateaux



3. The two extreme settings of the coil housing for maximum and minimum gauge, with three plateaux

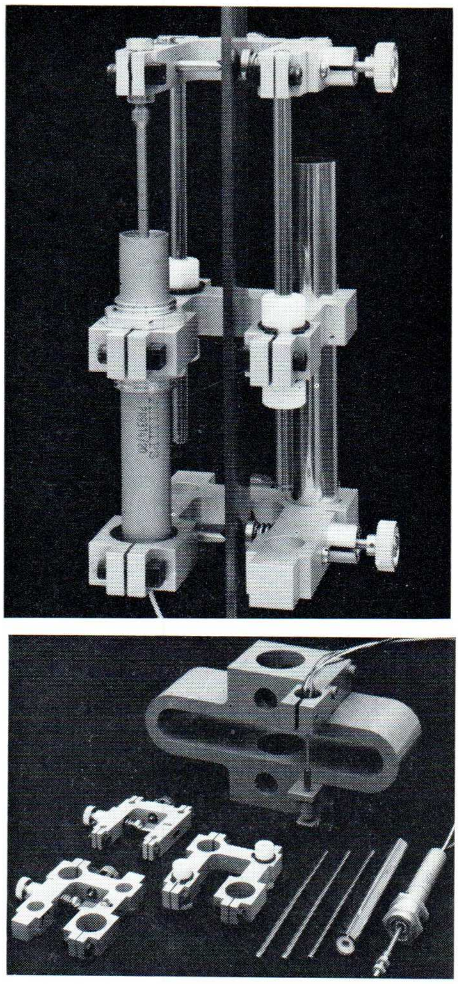
The new extensometer

An extensometer has been developed in Philips' Metallurgical Laboratories which is of universal application, because the above-mentioned difficulties have been taken into account in its design. The operating principle is based on the measurement of elongations with the aid of an inductive displacement transducer. A metal cage, which contains the transducer, allows the gauge length to be varied and makes it possible for the changes in length to be followed until fracture of the specimen occurs.

Further, this cage ensures good alignment and counters tilting of the clamping device on the tensile test specimen.

The cage is built up of two plateaux (1 and 3 in fig. 2) provided with knife-edges and spring-loaded supports for the clamping of round or rectangular test bars. The lower plateau (3) has three guide tubes for three steel rods fixed to the upper plateau. Thanks to this system, plateau 1 can move smoothly with respect to plateau 3. The measuring pin of the inductive transducer is clamped in plateau 1, and the housing with the coil system in plateau 3. The gauge length can be adjusted by varying the point at which the coil housing is clamped.

The displacement transducers and the guide pins are interchangeable, allowing



4. Extensometer in combination with a pull ring

measurements to be made in a number of different strain ranges.

In order to give the cage the required stiffness with long test bars, a third plateau (2 in fig. 3) is introduced. This extra plateau also serves as a guide for the steel rods and for the clamping of the coil housing.

Plateau 2 is rigidly connected to plateau 3 by means off a bushing, and plateau 1 can moved with respect to 2 and 3. In this case, the gauge length to be measured can be varied by changing the clamping point of the coil housing and that of the supporting bushing between 2 and 3. The supporting bushing is also used as counter weight of the transducer, so that the extensometer is properly balanced.

As we have already mentioned, the gauge length of the test bar which can be clamped into this universal extensometer depends on the length of the transducer, of the guide rods and of the supporting bushing. The stroke of the displacement transducer determines the range of elongations which can be followed.

An impression of the possibilities of this extensometer when used with 3 of Philips' diplacement transducers is given by the data of Table I, for both of the two extreme positions of the plateaux with clamping system shown in fig. 2 and 3.

Only one side of the measuring length of the transducers is used (since the measuring pin is at the middle of the coil housing in the zero setting). It follows that the maximum strain which can be measured by the transducer is (E/L_{min}) x 100%. The values of this maximum strain for the three Philips' transducers are given in Table II.

Since the sensitivity of the transducers decreases as the measuring range increases, it is advisable in all cases to use that transducer for which the maximum mechanical displacement is closest to the expected elongation of the test piece.

Under these conditions, the reproducibility of the extensometer is within ± ½%, and when it is used in combination with the Philips signal converter PR 9309 and the X-Y recorder PM 8120 the elongations recorded can be magnified up to 2000 times.

The weight of the extensometer without displacement transducer and supporting bushing is:

with two plateaux at least 200 gram;

with three plateaux at least 275 gram.

It can be applied to test bars of diameter from 2 to 15 mm, and rectangular ones of cross-section from 1 x 30 mm to 15 x 30 mm.

It is intended to use this extensometer in combination with a pull ring (see Fig. 4) which is used for electronic measurement of the load; the elastic deformation of this pull ring, which depends on the load on it, is measured by an inductive transducer similar to that fitted in the cage. The signals from these two transducers are fed via an amplifier to the X-Y recorder, e.g. PM 8120, see fig. 5.

Table I

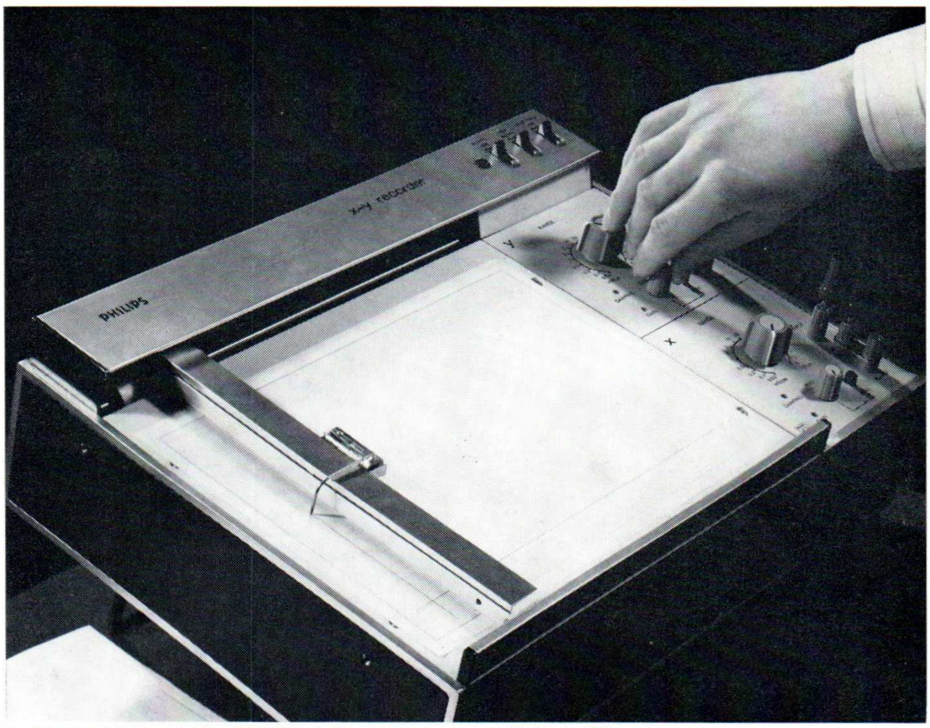
Philips inductive displacement transducer	Dimensions in mm					2 plateaux gauge length		3 plateaux gauge length	
	A	B	C	E	D	L_{min} A+B	L_{max} B+C	L_{min} B+D	L_{max} —A+B+C+D
PR 9314/05	12	5	56	5	100	17	61	105	149
PR 9314/10	12	5	70	10	100	17	75	105	163
PR 9314/20	12	5	97	20	100	17	102	105	190

E: measuring length of transducer

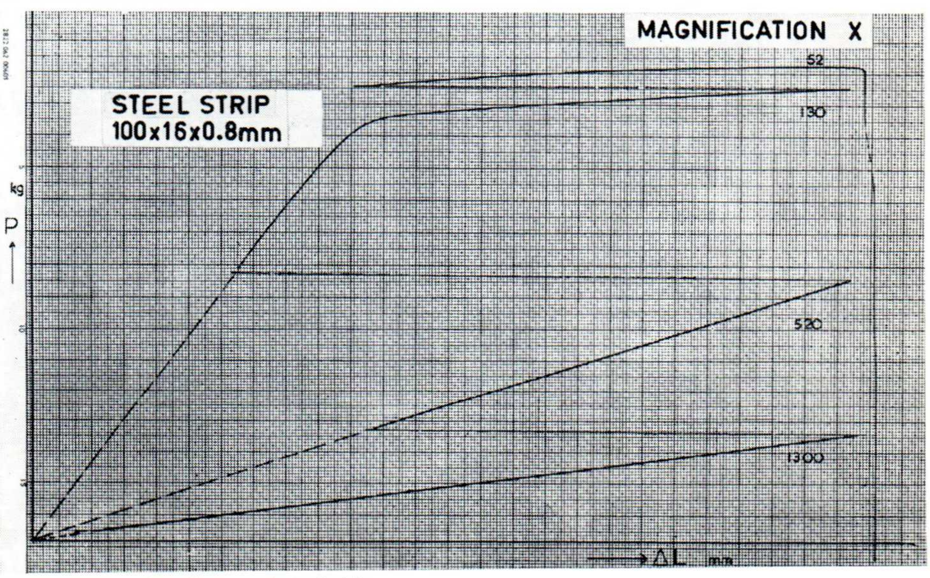
Table II

	PR 9314/05	PR 9314/10	PR 9314/20
2 plateaux	29.4 %	58.8 %	117.6 %
3 plateaux	4.8 %	9.6 %	19.2 %

This extensometer combined with this load cell offers a simple means of electronic recording of load-elongation diagrams on many types of mechanical and hydraulic tensile testing machines. If a possible shift in the zero setting is taken into account, the load-elongation diagram can be recorded up to fracture by switching successively to wider measuring ranges. Fig. 6 shows a diagram of a steel strip obtained with the equipment in this way.



5. Flat bad X-Y recorder PM 8120; 0.05 mV/cm max. sensitivity; 0.25% accuracy



6. Load-elongation diagram of steel strip

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