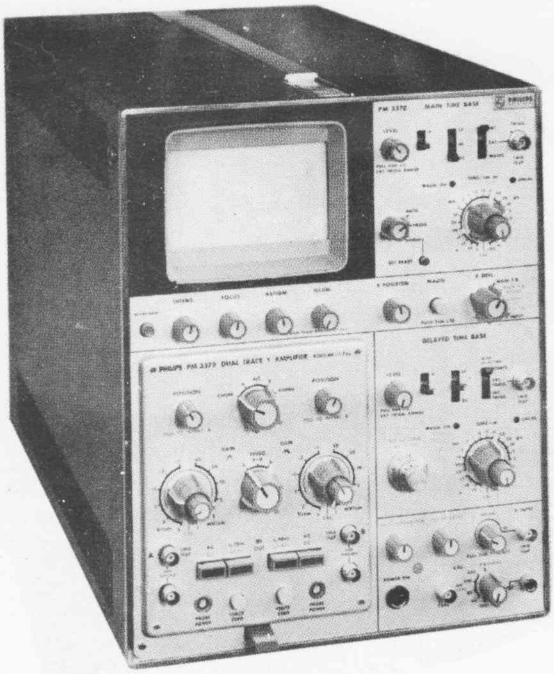

PHILIPS

PM 3370 LABORATORY PLUG-IN OSCILLOSCOPE

9444 033 70011

OPERATING MANUAL

9499 440 05811

1/670/01

IMPORTANT

In correspondence concerning this apparatus, please quote the type number and the serial number as given on the type plate at the rear of the apparatus.

N.V. PHILIPS' GLOEILAMPENFABRIEKEN - EINDHOVEN - THE NETHERLANDS - 1970

PHILIPS

SERVICE

Electron optics / Nuclear and electrochemical equipment / X-Ray analysis / Cryogenic equipment / Test and measuring equipment / Process instrumentation / Industrial Data Processing Systems / Weighing / Welding / Numerical Control / Textile equipment

industrial equipment division

PHILIPS

17-9-1970 GENERAL Cd 667

TEST AND MEASURING INSTRUMENTS

RE: TEST INSTRUMENTS FOR OSCILLOSCOPES

The importance of using appropriate test and calibrating instruments for pre-sale testing and servicing of equipment is now generally recognised. After careful study, in co-operation with development and quality-control specialists, we compiled a recommanded list especially for oscilloscopes. Depending on the local needs and availabilities, we advise the National Service Organizations to consider investing in the following test instruments.

A. REAL-TIME OSCILLOSCOPES

a. Calibrating deflection factors and sweep speeds

b. Checking the square-wave response of probes and attenuators

For a) and b) use Oscilloscope Calibrator, type 156, by G & E Bradley Ltd, Electrical House, Neasden Lane, London NW10, England.

c. Checking bandwidth[x)]

For the new procedure, applicable to PM 3200, PM 3210, PM 3220/21, PM 3230, PM 3231, PM 3250 and future oscilloscopes or units up to 100 MHz bandwidth, a constant amplitude generator, a 50 Ω cable and a 50 Ω termination pad, ordering code PM 9585 (i.e. type XE 101 96) are required.
The advised generator is Tektronix type 191.
In general, an oscilloscope may be rejected when the sum of the tolerances of the oscilloscope under test and the measuring instrument are exceeded.

d. Checking rise times[x)]

For this check we recommend square-wave generator Tektronix type 284. As under c) the generator should be connected via a 50 Ω cable, terminated by a 50 Ω pad. The rise time of the generator should be taken into account and preferably be checked with a sampling oscilloscope, e.g. PHILIPS PM 3400.

e. Checking pulse response (overshoot, ringing etc.)*)

The generator mentioned under d), should be connected via a 50 Ω cable and a General Radio power divider, type 874-TPD, terminated at the oscilloscope input by a 50 Ω termination pad, General Radio type 874-WM.
A sampling oscilloscope e.g. PM 3400 must also be connected to the power divider in order to check the pulse form to which the display on the oscilloscope under test should be referred.

f. Checking trigger functions

PHILIPS Sine-wave Generator type PM 5125 (or PM 5160) is recommended for this check.

g. To check the PM 3370 main frame, use the PHILIPS Test Unit PM 3363

B. SAMPLING OSCILLOSCOPES

a. Checking the triggering and the time-base circuit*)

For the checking of these circuits we recommend the use of Tektronix Pulse Generator type 284, PHILIPS Digital Multimeter PM 2421, PHILIPS Timer/Counter PM 6630, a 10 dB attenuator e.g. General Radio 874G10, a 50 Ω cable and a 50 Ω termination pad e.g. PM 9585.

b. Checking mixer and deflection amplifier

For these checks we recommend the use of PHILIPS Digital Multimeter PM 2421 and a 50 Ω e.g. 4822 320 10012.

c. Checking the stabilized supply voltages and the low-voltage rectifier

The recommended instrument for this check is the PHILIPS Digital Multimeter PM 2421 which should be connected to the circuits under test via a screened cable.

d. Checking the sampling amplifier*)

For this check we recommend the use of Tektronix Pulse Generator type 284, two 6 dB attenuators e.g. General Radio 874G6, one 20 dB attenuator e.g. General Radio 874G20 and a 50 Ω cable with a length of <30 cm e.g. 4822 320 10009.
For the tangential noise measurents we recommend PHILIPS Pulse Generator type PM 5770, together with a 100x attenuator and a 50 Ω cable e.g. 4822 320 10012.

e. Checking and adjusting after replacement of the sampling gate*)

The recommended instrument is the Tektronix Pulse Generator type 284 with two 50 Ω cables of equal length and with a propagation delay of less than 2 ns, e.g. 4822 320 10009, a 50 Ω cable e.g. 4822 320 10012 and a BNC T piece e.g. Amphenol UG-274U.

C. SURVEY OF THE RECOMMENDED INSTRUMENTS

Oscilloscope Calibrator	G&E BRADLEY type 156 192
Constant-amplitude generator	TEKTRONIX type 191
Square-wave generator	TEKTRONIX type 284
Sampling oscilloscope	PHILIPS type PM 3400
Sine-wave generator	PHILIPS type PM 5125 or PM 5160
Digital multimeter	PHILIPS type PM 2421
Test unit	PHILIPS type PM 3363
Counter/Timer	PHILIPS type PM 6630
Square-wave generator	PHILIPS type PM 5770
Termination pad	PHILIPS type PM 9585
Termination pad	GENERAL RADIO type 874-WM
Power divider	GENERAL RADIO type 874-TPD
6 dB attenuator	GENERAL RADIO type 874G6
10 dB attenuator	GENERAL RADIO type 874G10
20 dB attenuator	GENERAL RADIO type 874G20
50 Ω cable 20 cm	PHILIPS code 4822 320 10009
50 Ω cable 60 cm	PHILIPS code 4822 320 10012
BNC T piece	AMPHENOL type UG-274U
BNC-GR adapter	GENERAL RADIO type 874-QB7A

x) BNC and General Radio plugs can be coupled via General Radio Adapters type 874-QB7A

PHILIPS

N.V. PHILIPS' GLOEILAMPENFABRIEKEN. EINDHOVEN - NEDERLAND

Tel. Adr.: PHILIPS EINDHOVEN

Circular letter to the T&M Service Manager
Confidential

From dept. - Du dépt. - Von Abt.
Service P.I.T.
BH/FS/9729.

Re. - Conc. - Betr. Tel. Eindhoven 60000 - Ext. - App. Date - Datum

H.F. oscilloscope PM 3370 and
Y plug-in unit PM 3372.

4-3-1971.

The current input (input I) of all PM 3370 main frames with serial numbers from D772, has been modified in order to obtain optimum pulse response.
A series network (90.9 Ω, 1.2 pF, 90.9 Ω) has been connected between the input terminals of unit 12. Consequently, all Y plug-in units PM 3372 from serial number D670 have been adjusted before leaving the factory, to suit the requirements of the modified PM 3370.
When such a PM 3372 with a serial number from D670 is used with a pre-modification PM 3370 main frame (i.e. a main frame with a serial number prior to D772), an overshoot of approximately 8 % on the pulse will be observed. For this reason, we are currently supplying all PM 3372/01 and -/02 units complete with a package containing two 90.9 Ω resistors (ordering number 5322 116 50799) and one 1.2 pF capacitor (ordering number 5322 122 30102) together with the enclosed service information sheet Cd 690 which recommends the PM 3370 modification.
Those PM 3372 units with serial numbers prior to D670 will give an 8 % undershoot (rounding off) during the first 6 ns of the pulse when used in conjunction with a modified PM 3370 main frame. In this case, we recommend a h.f. readjustment or the return of the PM 3372 to Eindhoven for this readjustment.

The readjustment will be done free of charge, provided that the units concerned are returned before December 31, 1971. Each readjusted unit returned by us will bear a sticker which states that the readjustment has been made.
For fixed combinations of unmodified main frames and PM 3372 units with serial numbers prior to D670 the above mentioned modification and h.f. readjustment are not necessary.

Test unit PM 3363

The test units supplied have also been adjusted to meet the requirements of the modified PM 3370.
If a PM 3363 unit is used to check input I of a PM 3370 main frame which has not been modified, we recommend that the main frame in question is temporarily modified for the duration of the check.

Note

Returns can only be accepted if the goods are returned without charge to us, and provided that they have been allocated a reference number which may be obtained from Mr. Potter, PIT Service, Eindhoven.

p.o.N.V. PHILIPS'GLOEILAMPENFABRIEKEN.

B. Huijbers.

Enclosure : Cd 690.

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industrial equipment division

1-3-1971 | PM 3372/0. 9499 033 720.1 | Cd 690

In the main frames PM 3370 with serial numbers from D772 onwards, a modification has been incorporated in the current input (input I) which is used for h.f. units.
Your unit PM 3372 (and all units PM 3372 with serial numbers from D670 onwards) has been adjusted in a modified frame PM 3370.
If your main frame carries a serial number below D772, the enclosed network (2x90.9 Ω and 1.2 pF) should be fitted on to the input terminals of unit 12 of your main frame (Fig. 1).
This will result in an optimum pulse response and obviates further recalibration or h.f. readjustment of your PM 3370.

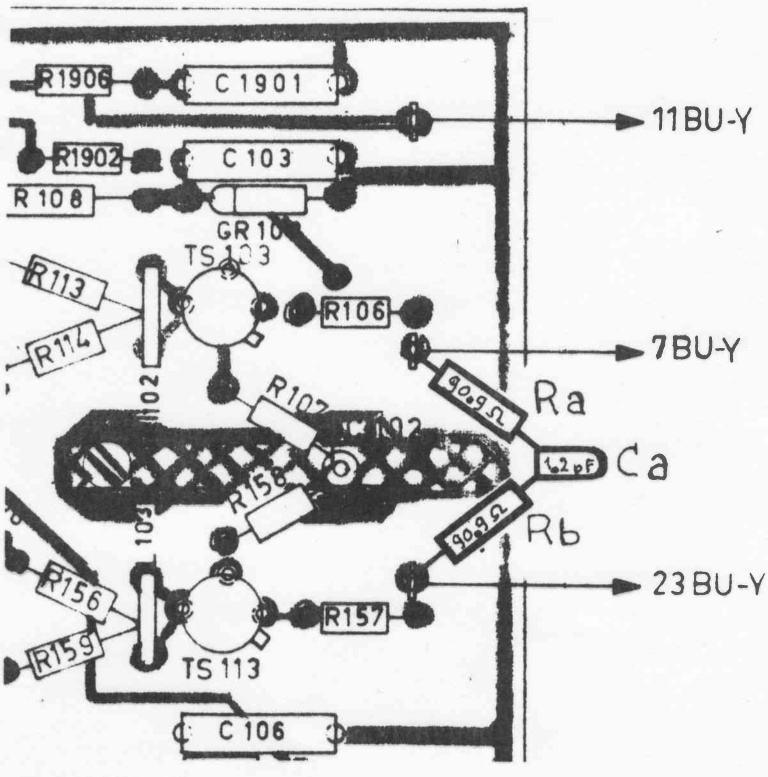

Fig. 1. Part of the printed circuit board at the rear of the Y plug-in compartment.

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Contents

List of illustrations

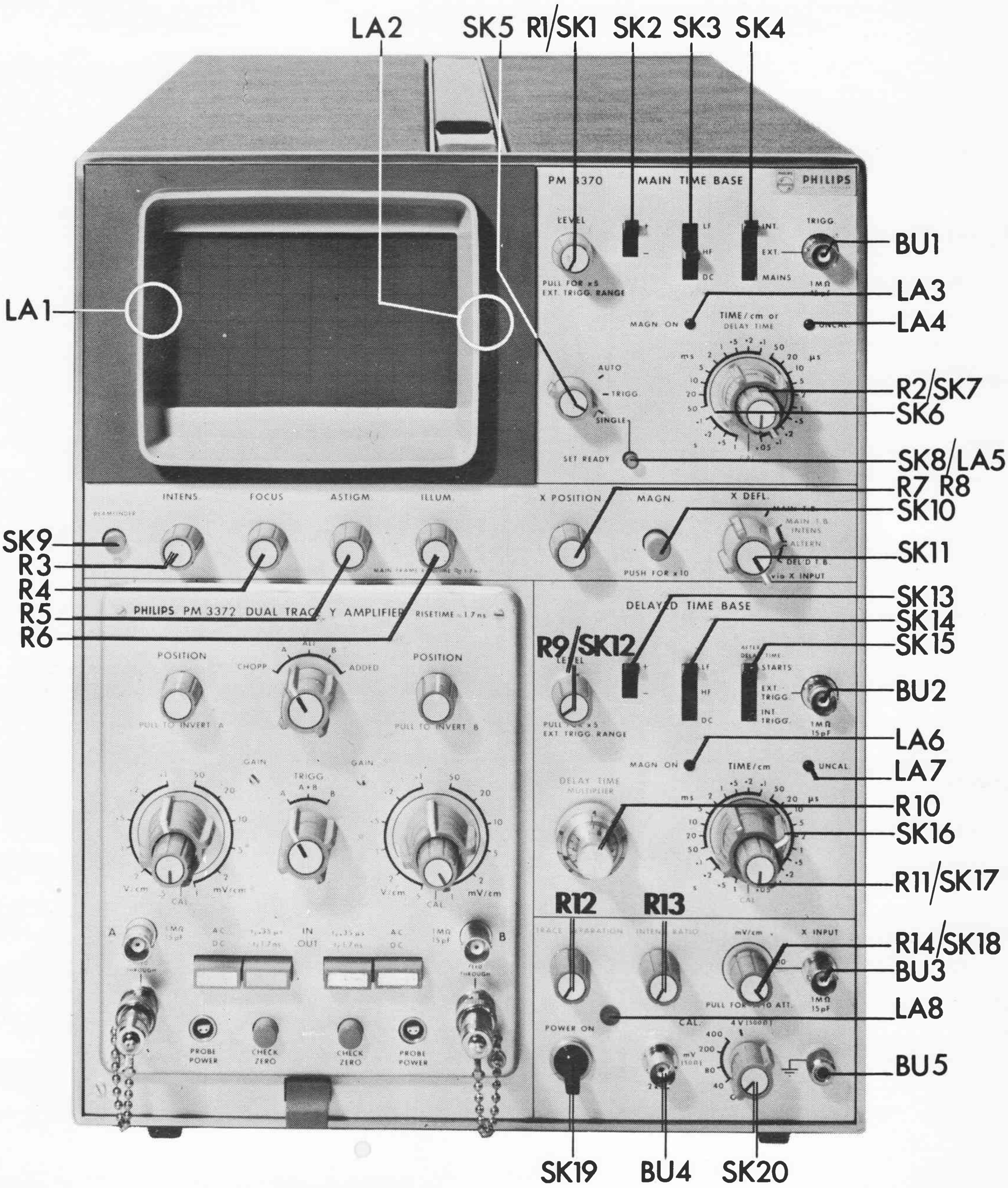


Fig. 1. General View

GENERAL INFORMATION

This section of the instruction manual deals with introductory material and basic information of interest to both operating and servicing personnel.
It includes specifications of physical and electrical data and a description of the operating principles of the instrument to block diagram level.

The three chapters found in this section are:

I. *Introduction*

The PM 3370 oscilloscope, shown in Fig. 1, is a general-purpose instrument designed for a wide range of laboratory applications. This versatility is achieved by a series of modular plug-in units each covering one or more aspects of the applications field.

All Y plug-in units of the PM 33 . . series can be accommodated with the exception of the LF unit PM 3351. Choise of a plug-in unit, for example, permits the display of multi-trace signals, up to four, either separately or in combination. A dual-trace unit, the PM 3372, provides for a deflection coefficient of 1 mV/cm and a bandwidth of 150 MHz.

A signal delay line permits the leading edges of fast signals to be displayed. Detailed observation of complex signals on an expanded time-base is facilitated by means of a built-in delayed time-base generator. For ease of operation, the delayed time-base generator controls are arranged in conformity with those of the main time-base generator. Each time-base has its own trigger unit.
Further attention has been paid to the ergonomic layout of other front-panel controls: the colour matching of controls that are located in separate groups but have interdependent functions also facilitates operation of the oscilloscope.
The PM 3370 incorporates a rectangular, flat-faced cathode ray tube with an illuminated internal graticule with obviates measuring errors due to parrallax.
The use of silicon transistors throughout the oscilloscope results in a high degree of reliability.
Provision is made for mains operation over the range 110 V to 245 V by means of a series of primary connections on the mains transformer.

II. *Specification*

Properties expressed in numerical values with stated tolerances are guaranteed for nominal mains voltages.

Numerical values without tolerances serve as a guide and represent the characteristics of an average instrument.

A. ELECTRICAL

1. C.R.T. CIRCUIT

C.R.T.

Type	D13–451 GH/45, rectangular with internal graticule.
Effective screen area	6 cm × 10 cm
Phosphor	medium long (P31)
Total accelerator voltage	15 kV
Unblanking	d.c. coupled
Graticule	internal with continuous control of illumination.
External Z Modulation	5 V peak-to-peak signal required at 500 Hz to 50 MHz for visible intensity modulation.
Beamfinder	push-button for reducing deflection sensitivity for locating the trace on the screen.

2. Y CHANNEL

Final Amplifier

Type	d.c. amplifier
Delay	by internal delay line (delay 80 ns), effective delay >20 ns.
Rise-time	input I: 1.7 ns (equivalent bandwith 210 MHz) input II: 5 ns (equivalent bandwith 70 MHz) Plug-in units PM 3332, PM 3334, PM 3342, PM 3344 and PM 3379 automatically use input II.

Y Output

Coupling	a.c. coupled, f_{3dB} low 1 kHz
Volts out	1 V/cm deflection of the trace; 9 V maximum.
Resistance out	200 Ω
If Y Output terminated with 50 Ω	
Volts out	200 mV/cm deflection of the trace; 1.8 V maximum.
Bandwidth	100 kHz to 50 MHz

Plug-in Unit — See the relevant specification of the plug-in unit in use.

Calibration Unit

Voltage	for R_i = 50 Ω: 40 mV, 80 mV, 200 mV, 400 mV peak-to-peak for R_i = 500 Ω: 4 V peak-to-peak
Tolerance	± 1%
Frequency	2 kHz square wave voltage

Current	8 mA peak-to-peak maximum
Tolerance	± 1%
Frequency	2 kHz square wave current

3. X CHANNEL

Deflection Modes	– Main time-base – Main time-base intensified – Delayed time-base – Alternate between main time-base intensified and delayed time-base – External

Main Time-base

Sweep speeds	50 ns/cm to 1 s/cm (1, 2, 5 sequence) in 23 calibrated steps. Continuous control between steps (uncalibrated) Tolerance ± 3% (± 5% in 1 s/cm position)
Magnification	10 × (± 2%) with maximum magnification the fastest sweep speed is 5 ns/cm
Mode	automatic (AUTO) triggered (TRIGG.) single shot (SINGLE)
Triggering Source	internal (INT.) external (EXT.) internal at mains frequency (MAINS)
Slope	+ or –
Coupling	(LF) 3 Hz to 1 MHz (HF) 2 kHz to full bandwidth (DC) 0 to full bandwidth
Sensitivity	with external triggering; 200 mV (LF and HF coupling) 400 mV (DC coupling) With internal triggering see the specification of the Y plug-in unit in use.
Input Impedance of Trigger Input	1 MΩ, 15 pF
Level	Internal: continuously adjustable over 6 cm External: continuously adjustable over 3 V peak-to-peak for medium frequencies (range can be magnified 5 ×)

Main Time-base Intensified	In this position, the portion of the main time-base which coincides with the delayed sweep is intensified. The intensity ratio is adjustable by means of the INTENS. RATIO control.

Delayed Time-base

Sweep speeds	50 ns/cm to 1 s/cm (1, 2, 5 sequence) in 23 calibrated steps. Continuous control between steps (uncalibrated). Tolerance ± 3% (± 5% in 1 s/ cm position)
Magnification	10 × (± 2%) With maximum magnification the fastest sweep speed is 5 ns/cm
Mode	Selected by AFTER DELAY TIME switch; STARTS immediately after delay time, EXT. TRIGG. after delay time, INT. TRIGG. after delay time.

Slope Coupling Sensitivity Input impedance Level	as detailed for main time-base
Delay	adjustable up to 10 seconds. Incremental multiplier linearity, typically 0.2%.
Jitter	<0.005% of the final value of the range
Alternate between Main Time-base Intensified and Delayed Time-base	In the ALTERNATE position, the main time-base intensified and the delayed time-base are displayed alternately. The vertical separation (TRACE SEPARATION) and intensity ratio are continuously adjustable.

External Deflection

Amplifier	d.c. amplifier
Input	asymmetrical; BNC connector
Impedance	1 MΩ; 15 pf
Deflection coefficient	10 mV/cm and 100 mV/cm switchable continuously adjustable 1 : 10 (not callibrated)
Bandwidth	0 to 1 MHz
Undistorted deflection	10 cm maximum

4. OUTPUT SIGNALS

Gate of main time-base and delayed time-base	0 V to 2 V; R_i = 1 kΩ V; maximum output current is 2 mA
Sweep of main time-base and delayed time-base	0 V to 8 V; R_i = 5 kΩ; maximum output current is 1.6 mA
Delayed trigger pulse	2 V; R_i = 1 kΩ; maximum output current is 2 mA
Calibration voltage	As detailed in Calibration Unit specification in Section 2.
Y Output	see Section 2.

5. POWER SUPPLY

Voltage	adjustable for 110 V, 125 V, 145 V, 200 V, 220 V and 245 V at 46 Hz to 60 Hz. Effect of ± 10% variations, negligible.
Power consumption	180 W maximum.

B.. PHYSICAL

Height: 37 cm
Width: 28.5 cm
Depth: 56 cm (overall)
Weight: 25 kg

Plug-in units available:

PM 3332 – 50 MHz vertical amplifier (500 μV/cm)
PM 3334 – 60 MHz vertical amplifier (10 mV/cm)
PM 3342 – 50 MHz dual-trace vertical amplifier (10 mV/cm)
PM 3344 – 50 MHz four-trace vertical amplifier (10 mV/cm)
PM 3363 – Test unit
PH 3372 – 150 MHz dual-trace vertical amplifier (1 mV/cm)
PM 3379 – Spectrum analyser unit

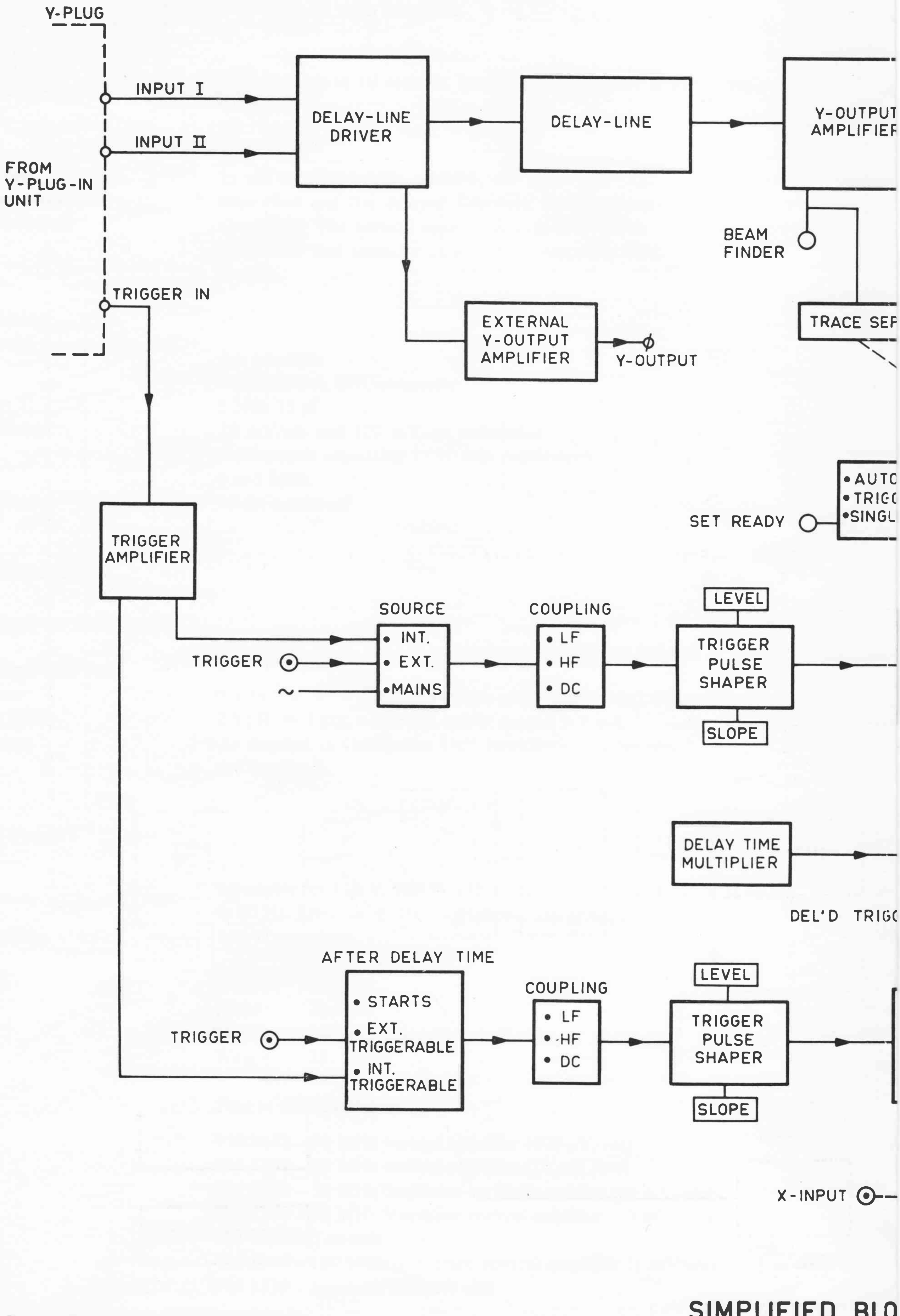
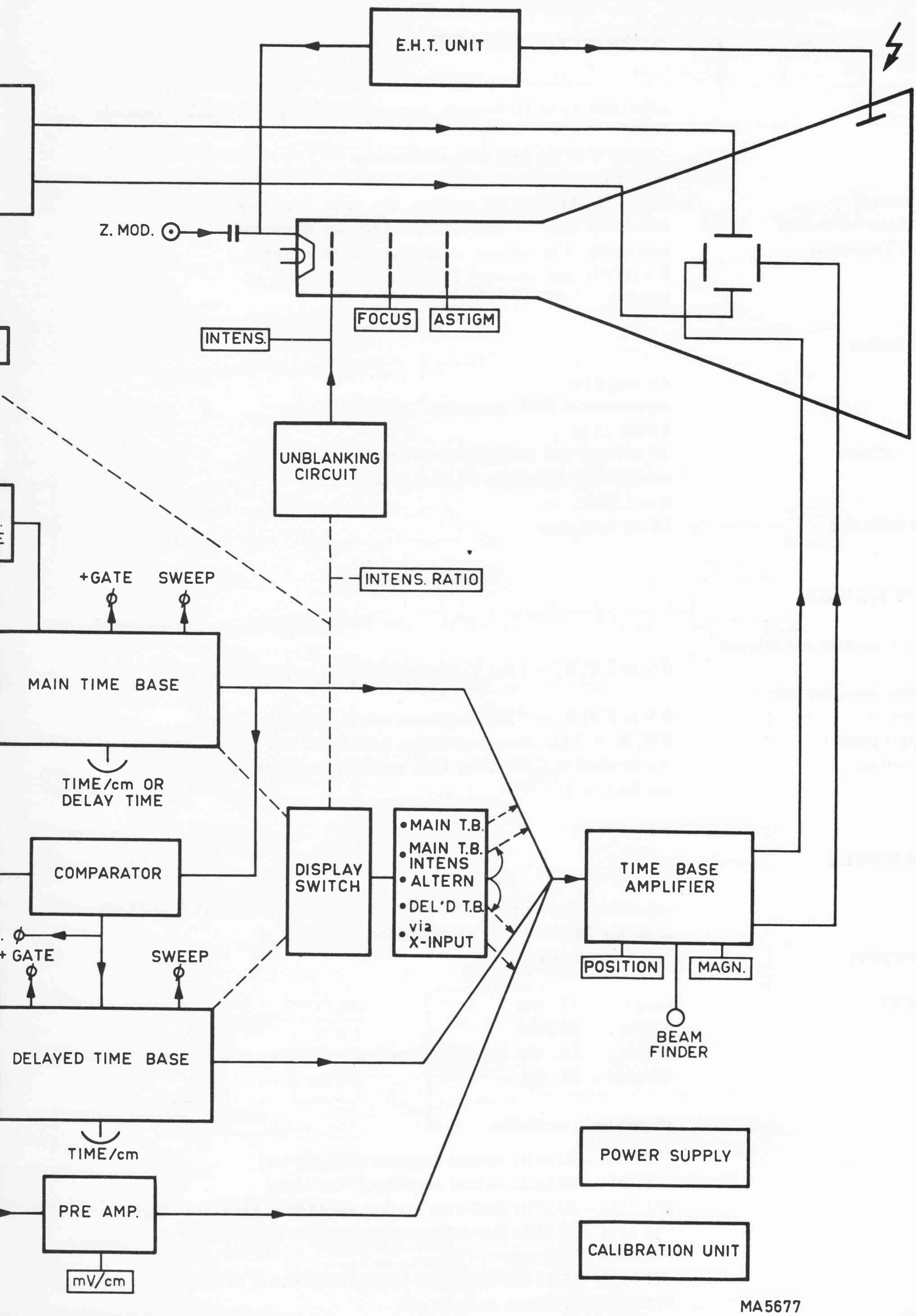


Fig. 2. PM 3370 – Block Diagram



CK DIAGRAM PM3370

III. *Principles of operation*

A simplified block diagram of the PM 3370 oscilloscope is shown in Fig. 2. The functions of the various blocks can best be understood by considering first of all the Y signal and trigger paths and secondly the time-base circuits.

A. Y SIGNAL PATH

The Y deflection signal, derived from the Y plug-in unit, is applied symmetrically to the delay-line driver.

Delay-line Driver

The delay-line driver has two inputs, a current input (input I) and a voltage input (input II). The requisite input is selected automatically on the insertion of a plug-in unit. The units already available for the 60 MHz plug-in oscilloscope PM 3330, i.e., units PM 3332, PM 3334, PM 3342 and PM 3344,use the voltage input (input II).

Rise-time

The rise-time for the current input is 1.7 ns. For example, when using the dual-trace plug-in unit PM 3372:

Total rise-time $= \sqrt{1.7^2 + 1.7^2} = 2.4$ ns approx.
The rise-time for the voltage input is 5 ns. When using one of the units mentioned above:

Total rise-time $= \sqrt{t_{r_{unit}}^2 + 5^2}$ nanoseconds

The delay-line driver provides two outputs, one for the delay line and the other to feed an external Y amplifier.

External Y Output Amplifier

This amplifies one of the outputs from the delay-line driver to provide an a.c. coupled Y output, available at a socket on the rear of the instrument, e.g., for triggering purposes when signals, not related in time, are displayed using a multi-trace unit in the ALTERN. mode.

Delay Line

The delay line, fed from an output of the delay-line driver, consists of two standard 75-ohm coaxial cables, each 18 m long, giving approximately 80 ns delay. This standard cable has both ends terminated to minimize reflections.

Y Output Amplifier

The signal from the delay line is amplified in the Y output amplifier stage before being passed to the segmented Y deflection plates of the cathode ray tube.

B. TRIGGER PATH

The trigger signal from the Y plug-in unit is fed to the trigger amplifier. The output of the trigger amplifier is passed to the trigger circuits of the main time-base and the delayed time-base.

Source Selector

The main time-base trigger circuit accepts this signal when the three-position source selector switch is in the INT position. The EXT TRIGG position permits the time-base to be triggered by an external signal applied at the EXT TRIGG socket. In the MAINS position a signal derived from the mains transformer provides the triggering facility.

Coupling Selector

The three-position coupling selector switch permits the frequency range of the trigger amplifiers to be reduced to remove interfering frequency components (hum or noise) from the trigger signal. In the LF position the range is from 3 Hz to 1 MHz, in the HF position the range is from 2 kHz to the upper limit of the bandwidth and in the DC position the range covers the whole bandwidth (0 to upper limit).

Trigger Pulse Shaper

In the trigger pulse shaper circuit a d.c. voltage is added to the trigger pulse, adjustable by the LEVEL potentiometer, to shift the trigger point. The control knob has a "pull-push" action which in the "pull" position increases the external trigger range by a factor of 5.
The trigger signal can be reversed in polarity by means of the SLOPE switch (+ –) to permit triggering by the positive-going or negative-going edge of the trigger signal.

Main Time-base Operating Modes

The trigger pulse shaper converts the trigger signal into sharp positive and negative pulses. The negative pulses are used to trigger the time-base generator, while the positive pulses are used in the automatic free-run circuit. The saw-tooth voltage from the main time-base generator is fed to the time-base amplifier in the MAIN T.B. and MAIN T.B. INTENS. positions of the X DEFL. switch.

Three modes of operation of the main time-base are determined by the three-position switch AUTO/TRIGG/SINGLE.

In the AUTO mode, the automatic free-run circuit is operative when triggering pulses are absent. Thus a trace, though not necessarily a stationary one, is always displayed even though the trigger controls may not be correctly adjusted. In this way, correct adjustment of the oscilloscope trace is greatly facilitated. However, when trigger pulses are present the circuit reverts to the normal triggered mode. If trigger pulses disappear, the time-base free-runs after a lapse of 0.5 seconds. In the TRIGG. mode, a display is present only when suitable trigger pulses are available.

In the SINGLE mode, events that occur only once can be observed and photographed if necessary. It is often desirable to ensure that only one saw-tooth is generated, even though other trigger pulses might follow the phenomenon of interest. In this mode, after the trigger pulse has initiated the main time-base to produce a saw-tooth voltage, the circuit is unaffected by further trigger pulses until it is either switched to the TRIGG. mode or reset for the next event by operating the SET READY push-button.

C. DELAYED TIME-BASE PRINCIPLES

The saw-tooth voltage derived from the main time-base generator is passed to a comparator where it is compared with an accurately adjustable d.c. voltage. The comparator output voltage is then pulse shaped by a reset multivibrator to provide the required delayed pulse. As indicated in the relevant waveforms of Fig. 3., the pulse shaper output voltage drops to its original value at the end of the forward sweep of the main saw-tooth voltage.

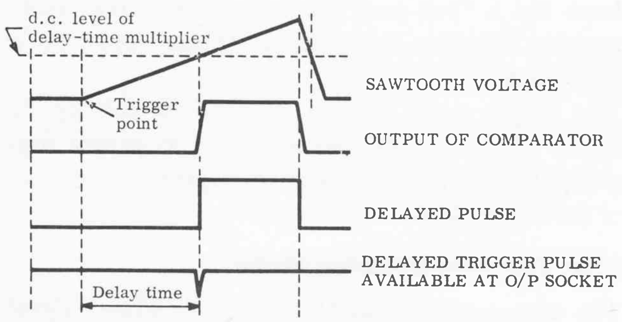


Fig. 3. Derivation of Delayed Pulse

The delayed pulse is fed to the delayed time-base generator which then initiates a saw-tooth voltage and an unblanking pulse, both of which are fed to the c.r.t. The time relationship between these waveforms is shown in Fig. 4.

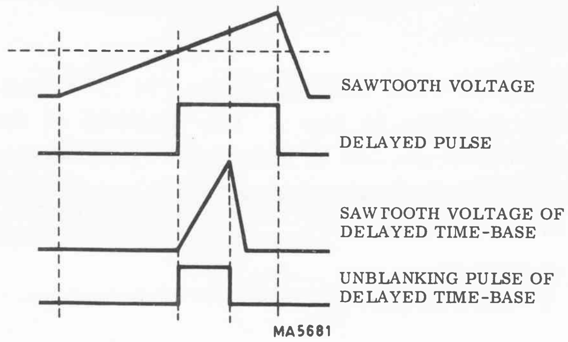


Fig. 4. Delayed Time-Base Waveforms

With the AFTER DELAY TIME switch in the START position, the delayed time-base starts immediately on receipt of a pulse from the reset multivibrator.

Gated Operation of the Delayed Time-Base

With the AFTER DELAY TIME switch in the INT. TRIGG. or EXT. TRIGG. position, the delayed trigger pulse prepares the time-base for the normal triggered mode of operation. The next trigger pulse from the internal trigger unit or from an external source (dependent on switch setting) arriving after the set delay time actuates the delayed time-base, which is then locked to this trigger signal. The waveforms of Fig. 5. illustrate this gating procedure. The total delay is now the sum of the set delay time (i.e., the product of the values indicated by the DELAY TIME and DELAY TIME MULTIPLIER controls) and the extra delay indicated in Fig. 5.

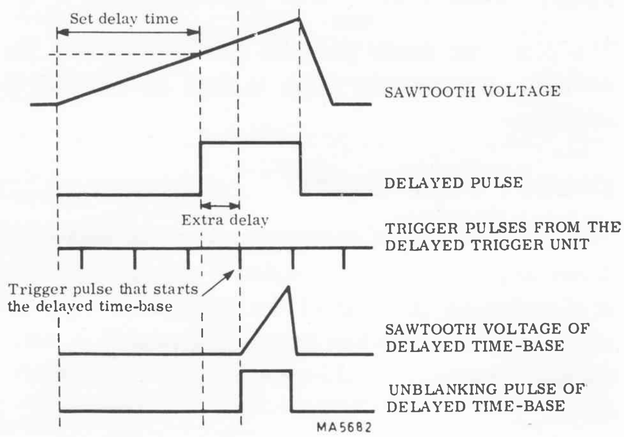


Fig. 5. Gating Waveforms of Delayed Time-Base

The remainder of the trigger circuit for the delayed time-base generator is identical to that for the main time-base generator.

D. DISPLAY MODES

A choise of five different modes of display is possible by means of the X DEFL. selector switch.

MAIN T.B.

When the X DEFL. switch is set to MAIN T.B., a saw-tooth voltage derived from the main time-base generator is fed via the time-base amplifier to the horizontal deflection plates of the cathode ray tube. In addition, the gating pulse from the main time-base is applied to the control grid (Wehnelt cylinder) of the c.r.t. via the unblanking circuit in order to intensify the trace during the sweep.

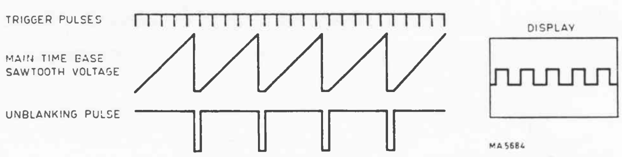


Fig. 6. Main Time-Base Display

MAIN T.B. INTENS.

When the X DEFL. switch is set to MAIN T.B. INTENS. the saw-tooth voltage derived from the main time-base generator is again fed to the c.r.t. via the time-base amplifier. However, in this position of the X DEFL. switch, the gating pulses from the main time-base and the delayed time-base are combined and applied to the control grid of the c.r.t. During the operation of the delayed time-base generator the trace undergoes extra intensification. The start of the intensified portion can be shifted by means of a ten-turn potentiometer, the DELAY TIME MULTIPLIER. The brightness of the non-intensified portion of the trace can be adjusted by means of the control INTENS. RATIO.

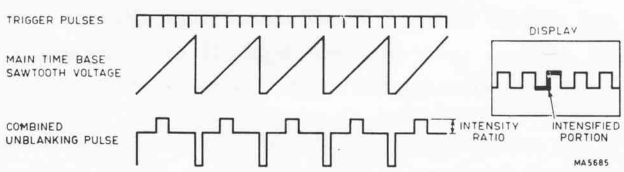


Fig. 7. Main Time-Base Intensified Display

DEL'D T.B.

When the X DEFL. switch is set to DEL'D T.B. the saw-tooth voltage from the delayed time-base generator is fed to the deflection plates of the c.r.t. and the gating pulse from the delayed time-base is fed to the control grid of the c.r.t. As a result, the intensified portion of the display, produced by the previous setting, is now expanded to fill the entire screen.

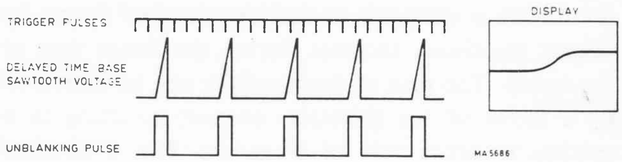


Fig. 8. Delayed Time-Base Display

ALTERN.

When the X DEFL. switch is set to ALTERN. an electronic switch enables the display of Fig. 7 and the display of Fig. 8 to be alternately traced on the screen. The two displays can be separated by varying the voltage applied to the vertical amplifier, derived from the driving circuits of the electronic switch. This separation is symmetrically variable by means of the TRACE SEPARATION control.

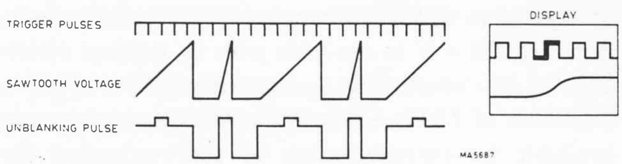


Fig. 9. Alternate Time-Base Display

VIA X INPUT

When the X DEFL. switch is set to VIA X INPUT, this permits an external voltage to be applied to the X pre-amplifier to provide horizontal deflection via the time-base amplifier. The deflection coefficient is 10 mV/cm with a bandwidth from d.c. to 1 MHz. A 1-to-10 continuous gain control, incorporated in the X pre-amplifier, provides for a deflection range from 10 mV/cm to 100 mV/cm. The deflection coefficient may be increased by a factor of ten by means of a pull switch integral with the gain control. This provides for a total range from 10 mV/cm to 1 V/cm.

This facility can be used for XY applications, where phase relationships between the X and Y deflections above 50 kHz are not important. This limit is imposed because of the presence of the delay line in the Y amplifier.

E. MISCELLANEOUS CIRCUITS

Time-Base Amplifier

The main function of this amplifier is to amplify the saw-tooth voltages produced by the time-base generators. In order to improve linearity and accuracy, the circuit is designed so that the currents drawn by output transistors increase during the linear part of the sweep. The gain of the amplifier can be increased by a factor of ten (MAGN. control) resulting in a maximum sweep rate of 5 ns/cm. For a detailed description of this circuit see Chap. 6.

Unblanking Circuit

The unblanking pulses from the two time-base generators are fed, via the unblanking circuit, to the Wehnelt cylinder of the c.r.t. The d.c. coupling of this circuit is realised by means of a modulator and a d.c. restorer. For a detailed description of this circuit see Chap. 6.

Calibration Unit

This unit supplies the voltages for the calibration of the deflection coefficient and for probe adjustments. Voltages of 400 mV, 200 mV, 80 mV and 40 mV are available with an internal resistance of 50 ohms. A voltage of 4 V is available with an internal resistance of 500 ohms. The square wave delivered has a frequency of 2 kHz. Calibration currents can be made available for current probes by short-circuiting the output terminal. A detailed description is given in Chap. 6.

Power Supplies

The power supplies, which are electronically stabilised, are protected against overloads and short-circuits. Automatic reset facilities are provided. For a detailed description of these circuits see Chap. 6.

E.H.T. Power Supply

The e.h.t. voltage is obtained by transforming and rectifying the output voltage of a 40 kHz push-pull oscillator. This power supply delivers:

- +13,000 V with respect to earth, for post-deflection acceleration. The rectifying circuit comprises a voltage tripler.
- –2,000 V with respect to earth, (stabilised) the cathode potential of the cathode ray tube.

This power supply is also protected against overloads and short-circuits. For a detailed description of the power supply see Chap. 6.

Beamfinder

To facilitate rapid location of an image, the oscilloscope is fitted with a beamfinder.
When the BEAMFINDER push-button is pressed, the amplification factors of the X and the Y amplifiers are reduced so that the electron beam deflection is confined to the display area of the c.r.t. It is then a simple matter to centre the image by means of the position controls.

F. DETAILED OPERATION OF THE TIME-BASE GENERATORS

This section gives a more detailed description of the functional operation of the time-base generators with the aid of the block diagram. Fig. 10. Details of the individual units is given in the Circuit Description, Chapter 6.

Main Time-Base

The timing of the main time-base is controlled by the sweep gating multivibrators (SGM). The input signal to the SGM is the sum of three signals:

- the negative trigger pulses,
- the hold-off pulse,
- a d.c. voltage from the AUTO circuit.

When the SGM is triggered by the trigger pulse, a voltage step is applied to the integrator which results in a voltage, increasing linearly with time, at the output of the integrator; the forward sweep voltage. This voltage is also passed via the hold-off circuit to the hold-off multivibrator, a Schmitt trigger. At a predetermined level, the hold-off multivibrator switches, to produce a hold-off pulse, the leading edge of which resets the SGM to its original state. This causes the integrator output voltage to fall exponentially to its original value, relatively quickly: the flyback time period. The hold-off pulse, of longer duration than this period, keeps the SGM insensitive to further trigger pulses until the flyback is complete. The output voltage of the hold-off circuit then decreases by an amount such that the hold-off multivibrator is reset, thus allowing the SGM to be triggered again.

If the mode switch is in the AUTO position, positive trigger pulses from the pulse shaper produce a positive voltage at the AUTO circuit output. As a positive voltage does not affect the normal functioning of the time-base generator, as described above, normal triggered operation is obtained. However, when trigger pulses cease to arrive at the AUTO circuit, its output voltage decreases. At a certain moment, the SGM input voltage becomes so low that the saw-tooth generator commences to free run.

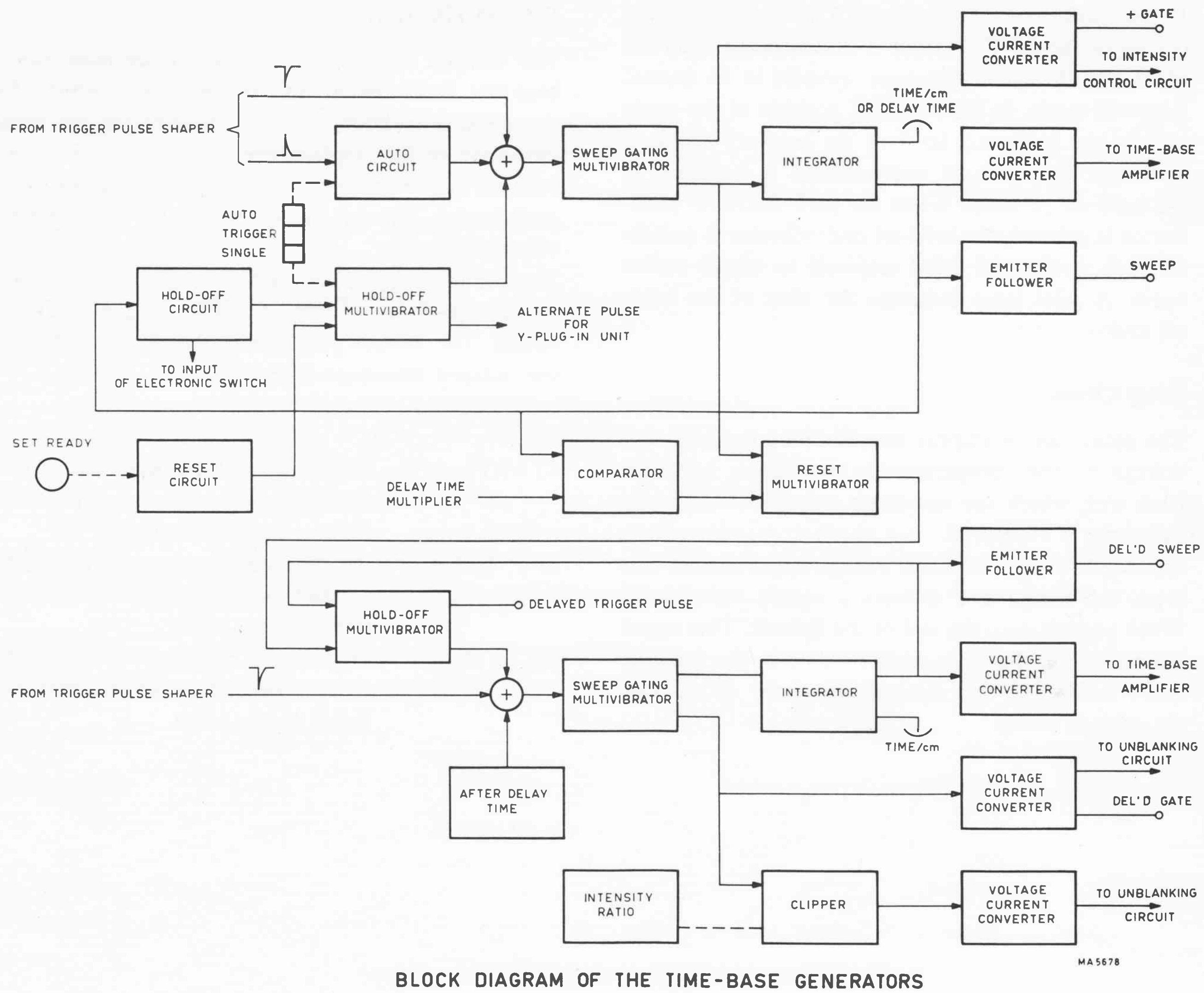


Fig. 10. Time-Base Generators – Block Diagram

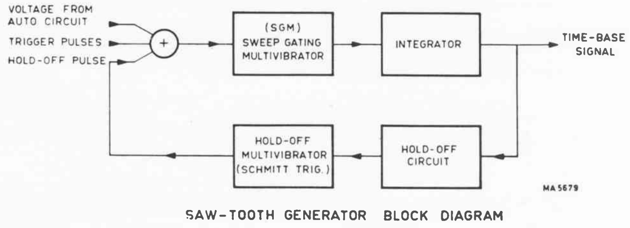


Fig. 11. Saw-tooth Generator – Block Diagram

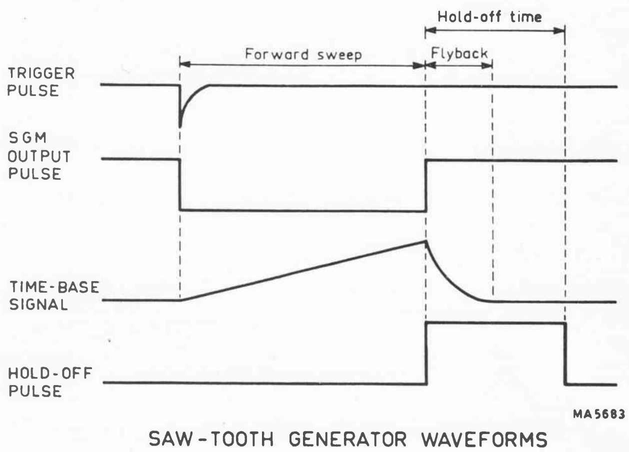


Fig. 12. Saw-tooth Generator Waveforms

If the mode switch is in the TRIGG. position, the output of the AUTO circuit is disconnected from the SGM and the main time-base operates in its normal triggered mode. In the SINGLE position of the mode switch, the input d.c. level of the hold-off circuit is such that the hold-off multivibrator is switched to the hold-off position. When the SET READY push-button is pressed, the hold-off multivibrator is switched back so that the SGM responds to trigger pulses again. A pilot lamp indicates the state of the hold-off multivibrator.

Delay Circuit

The delay time multiplier supplies an adjustable d.c. voltage to the comparator to provide a reference level with which the saw-tooth voltage of the main time-base is compared.
Immediately the saw-tooth voltage approximates this level, the comparator delivers a square wave signal which persists until the end of the flyback. This signal is applied via the reset multivibrator to the hold-off multivibrator of the delayed time-base to activate the delayed sweep.

Delayed Time-Base

The delayed time-base is similar to the main time-base but lacks the AUTO and hold-off circuits. Its operation is identical to that described for the main time-base in the single-sweep mode except that the hold-off circuit is not operated by the SET READY push-button but by pulses from the reset multivibrator.
The d.c. level applied to the SGM input is determined by the position of the AFTER DELAY TIME switch. The various positions of this switch influence the delayed time-base as follows:

STARTS – the delayed time-base starts immediately on receipt of a pulse from the reset multivibrator;

INT. TRIGG. – the delayed time-base is set ready to start on receipt of the next internal trigger pulse;

EXT. TRIGG. – the delayed time-base is set ready to start on receipt of the next external trigger pulse.

DIRECTIONS FOR USE

This section of the instruction manual is essentially of interest to operating personnel. It deals with the information necessary for installing and operating the equipment correctly, outlines its capabilities, reviews basic measuring principles and suggests techniques for obtaining the best results in various applications.

IV. *Installation*

The PM 3370 oscilloscope is despatched complete with the following accessories which are stowed, for transit, in the packing space above the instrument. These items are:

1. a mains lead with connector,
2. a shorting link for calibrating current probes,
3. a viewing hood,
4. a green filter,
5. an instruction manual,
6. a BNC - 4 mm adaptor,
7. a BNC-BNC cable.

On receipt, remove these accessories and the instrument from the carton and examine them to ascertain whether any damage has been sustained in transit.
Remove each of the side covers by means of the two quick-release fasteners located near the top corners. Check that all printed circuit cards are fully inserted and visually inspect the interior. Replace the side covers by first inserting the lower edges in the appropriate recesses at the base of the instrument.

A. MAINS ADJUSTMENTS & FUSES

Before switching on, the instrument should be adjusted to the local mains voltage by means of the voltage adaptor on the rear panel. Provision is made for selecting 110 V, 125 V, 145 V, 200 V, 220 V and 245 V. The voltage selected is displayed through an aperture in the cover plate.

The fuse-holder on the rear panel normally carries a 2.5 A mains fuse but if the instrument is to be connected to a mains voltage of less than 200 V, the 5 A fuse supplied should be fitted. The 5A fuse is mounted on top of the screening partition over the Y plug-in compartment.

A thermal cut-out is incorporated as an integral part of the mains transformer to prevent excessive overheating in the event of a prolonged short circuit.

B. EARTHING

In the interests of safety, the instrument should be earthed via one of the earth terminals (⏚) on the front or rear panel, or via the mains flex if this has a plug with an earth connection.

NOTE: Double-earthing must be avoided as this may cause hum on the trace.

C. PLUG-IN UNITS

The instrument normally operates only if one of the Y plug-in units, listed in the specification, has been inserted. A push-button, situated below the aperture for the plug-in unit, provides for the release of a unit from the multi-way socket of the main frame to aid extraction.

D. SWITCHING ON

The instrument is switched on by means of the POWER ON switch. The white pilot lamp, adjacent to the switch, illuminates to indicate this condition when the mains are connected and the POWER ON switch is in the "up" position.
Under normal laboratory conditions, a warm-up period of about fifteen minutes is generally sufficient before accurate measurements are taken. If the oscilloscope has been subjected to abnormally low temperatures or to extreme humidity, the warm-up period should be extended accordingly.

WARNING:

This instrument generates high voltage and should not be operated with the side panels removed. The mains plug should be removed before attempting any maintenance work, and any relevant high voltage points discharged.

V. *Operating instructions*

Before switching on, ensure that the oscilloscope has been correctly installed in accordance with Chapter IV, INSTALLATION, and that the precautions outlined have been observed.

A. CONTROLS (refer to fig. 1)

Main Time-base Generator

INT/EXT/MAINS (SK4)	trigger source, three-position switch: INT: trigger signal derived from Y plug-in unit. EXT: trigger signal derived from a voltage applied to the TRIGG. BNC socket. (BU1) MAINS: trigger signal at mains frequency derived internally from mains transformer.
LF/HF/DC (SK3)	trigger coupling, three-position switch: LF: via a band-pass filter for frequencies from 3 Hz to 1 MHz. HF: via a high-pass filter for frequencies above 2 kHz. DC: direct coupling for triggering on a slowly varying voltage, or for full bandwidth working.
+/– (SK2)	slope control, two-position switch: provides for triggering on the positive-going or the negative-going slope of the signal.
LEVEL (R1/SK1)	continuously adjustable control to select the level at which the main time-base triggers. Incorporates a pull switch for ×5 increase of external trigger range.
AUTO/TRIGG/SINGLE (SK5)	time-base mode, three-position switch: AUTO: the time-base is free-running in the absence of trigger signals. TRIGG: the time-base is triggered normally. SINGLE: the time-base sweeps only once.
SET READY (SK8)	reset push-button for the SINGLE position of the time-base mode switch.
TIME/cm or DELAY TIME (SK6)	time coefficient control of main time-base, 23-way switch.
CAL (TIME/cm) (R2/SK7)	continuously variable control of time coefficient of main time-base. In the CAL. position the time coefficient is calibrated.

Delayed Time-base Generator

AFTER DELAY TIME (SK15)	three-position mode switch: STARTS: sweep starts immediately after delay time. EXT. TRIGG: can be triggered from external source (BU2) after delay time. INT. TRIGG: can be triggered from internal source after delay time.
LF/HF/DC (SK14)	trigger coupling, three-position switch: LF: via a band-pass filter for frequencies from 3 Hz to 1 MHz. HF: via a high-pass filter for frequencies above 2 kHz. DC: direct coupling for triggering on a slowly varying voltage, or for full bandwidth working.

+/– (SK13)	slope control, two-position switch: provides for triggering on the positive-going or the negative-going slope of the signal.
LEVEL (R9/SK12)	continuously adjustable control to select the level at which the delayed time-base triggers. Incorporates a pull switch for × 5 increase of external trigger range.
TIME/cm (SK16)	time coefficient control of delayed time-base, 23-way switch.
CAL (TIME/cm) (R11/SK17)	continuously variable control of time coefficient of delayed time-base. In the CAL. position the time coefficient is calibrated.
DELAY TIME MULTIPLIER (R10)	ten-turn helipot control of delay time used in combination with the DELAY TIME controls of the main time-base.

Horizontal Amplifier Controls

X POSITION (R7/R8)	continuously variable control giving coarse and fine (vernier) horizontal positioning of the display.
MAGN (SK10)	push-button control for × 10 magnification of horizontal deflection.
X DEFL (SK11)	time-base selector, five-position switch: MAIN TB: horizontal deflection is achieved by main time-base. MAIN TB INTENS.: horizontal deflection is achieved by the main time-base, the part of the trace coinciding with the delayed sweep being intensified. The intensity ratio is adjustable (see Miscellaneous Controls). ALTERN.: horizontal deflection is achieved by the main time-base intensified and the delayed time-base alternately. Vertical trace separation and intensity ratio are adjustable (see Miscellaneous Controls). DEL'D TB: horizontal deflection is achieved by delayed time-base. via X INPUT: horizontal deflection is achieved by an external source via X INPUT socket (BU3). Deflection coefficient is adjustable (see Miscellaneous Controls).

Miscellaneous Controls

TRACE SEPARATION (R12)	continuously variable control providing vertical trace separation.
INTENS. RATIO (R13)	continuously variable control for adjusting the intensity ratio in the MAIN TB INTENS. and ALTERN. positions of the X DEFL. switch.
mV/cm (X INPUT) (R14/SK18)	continuously variable control for X deflection from external source (BU 3) with integral × 10 pull switch attenuator.
CAL. (SK20)	six-position switch for selecting calibrated 2 kHz square-waves of various amplitudes for calibration purposes, which are available at BU4.
POWER ON (SK19)	toggle switch for the mains supply to the oscilloscope.

Cathode Ray Tube Controls

BEAMFINDER (SK9)	push-button to enable a trace to be readily located on the screen by reducing the deflection coefficients.
INTENS. (R3)	variable control of trace brightness.
FOCUS (R4)	variable control of electron beam focusing.
ASTIGM. (R5)	variable control of trace astigmatism.
ILLUM. (R6)	variable control of graticule illumination.

B. OPERATION & APPLICATIONS

An oscilloscope designed for a wide range of applications is, inevitably, a complex instrument. As modern instruments offer more and more facilities, so the task of operating them increases in complexity. The PM 3370, although of logical design and built for ease of operation, may present some problems to the occasional operator confronted with such a large number of controls. However, an understanding of the techniques for making basic measurements together with a recognition of the less obvious triggering problems and their solution, should help to dispel any apprehension on the part of the user.

Preliminary Adjustment of Y Amplifier

Observe the preliminary setting-up instructions for the particular Y plug-in unit fitted. Assuming that a PM 3372 Dual-Trace Y Amplifier is fitted, the preset GAIN controls can be adjusted as follows. As the circuits are identical, only the procedure for channel A has been described.

- With the oscilloscope correctly installed as outlined in the previous chapter, connect the CAL socket to the A input socket by means of a coaxial link.
- Select channel A on the display switch and DC on the AC/DC push-button.
- Set the mV/cm switch to 50 and ensure that the potentiometer is in the CAL position.
- Set the calibration output switch (CAL) to the 200 mV position and check that the vertical deflection is exactly 4 cm (2 cm when the second A input is terminated in 50 Ω).
- Adjust the preset GAIN control to achieve this, if necessary.

This procedure should be repeated for the B channel (and the C and D channels when a four-trace unit is fitted).

VOLTAGE MEASUREMENTS

Display the waveform as large as possible when making voltage measurements in order to obtain maximum accuracy. For all voltage measurements, the V/cm potentiometer on the Y plug-in unit must be in the CAL position, otherwise the deflection coefficients are not calibrated.

When using a ×10 probe, observe that the displayed amplitude must be multiplied by a factor of 10. Ensure that the probe is adjusted for good step response, and, in the interests of accuracy, that the Y GAIN preset is re-adjusted before use.

Peak-to-Peak Voltage Measurements

To measure the peak-to-peak voltage value of the a.c. component of a waveform, connect the signal to one of the Y input sockets and adjust the Y plug-in unit controls in accordance with the operating instructions to display as large a trace as possible. Then proceed as follows:

1. set the TIME/cm switch to display a few cycles of the waveform as illustrated; (fig. 13)
2. adjust the Y POSITION control so that the lower peaks of the waveform coincide with the nearest horizontal graticule line;
3. adjust the X POSITION control so that one of the upper peaks coincides with the centre vertical graticule line;
4. measure the vertical distance between the peaks of the signal;
5. multiply this measured distance by the voltage setting of the Y amplitude switch and by the attenuation factor of the probe, if any.

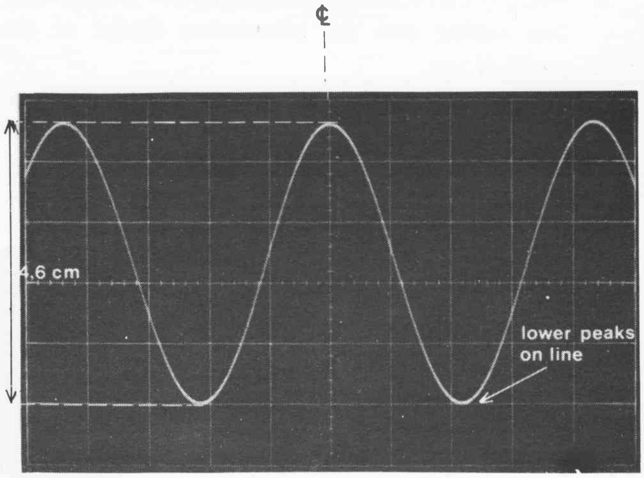


Fig. 13. Measuring Peak-to – Peak Voltages

Example 1.
Assume that the Y amplitude switch is set to 2 mV/cm and a 10 : 1 attenuator probe is used. The measured vertical distance is 4.6 cm.

Using the formula:

$$\text{Volts}_{p\text{-}p} = \begin{pmatrix}\text{Vertical}\\ \text{distance}\end{pmatrix} \times \begin{pmatrix}\text{Y ampl.}\\ \text{setting}\end{pmatrix} \times \begin{pmatrix}\text{probe}\\ \text{atten.}\end{pmatrix}$$

$$= 4.6 \times 2 \times 10$$

$$= 92 \text{ mV}$$

If the waveform is a pure sine wave the r.m.s. voltage is $\frac{V_{p\text{-}p}}{2\sqrt{2}} = 32.5$ mV

Instantaneous Voltage Measurements

To measure the instantaneous value of a waveform, connect the signal to one of the Y input sockets and adjust the Y plug-in unit controls in accordance with the operating instructions, to display as large a trace as possible. Then proceed as follows:

1. set the Y input to zero (CHEK ZERO push-button) and adjust Y POSITION control so that the zero reference line coincides with the nearest horizontal graticule line;

   NOTE: The Y POSITION control must not be moved after this reference line has been established;

2. release the CHECK ZERO push-button and select DC;
3. rotate the X POSITION control so that the point to be measured lies on the vertical centre-line;
4. measure the vertical distance between this point and the zero reference line; if the point lies above the reference line, the voltage is positive, if it lies below the line, the voltage is negative;
5. multiply the measured distance by the Y amplification setting and the attenuation factor of the probe, if any.

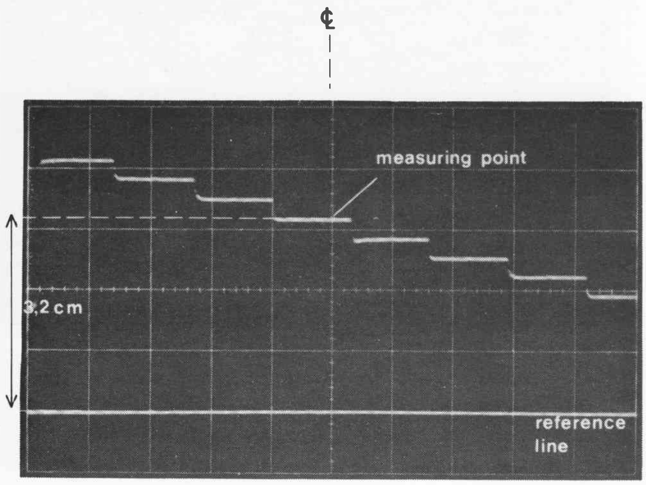


Fig. 14. Measuring Instantaneous Voltages

Example 2

Assume that the Y amplitude switch is set to 0.5 V/cm and that a 10 : 1 attenuator probe is used. The measured vertical distance is 3.2 cm. (Fig. 14)

Using the formula:

$$\text{Instantaneous Voltage} = \begin{pmatrix}\text{Vertical}\\ \text{distance}\end{pmatrix} \times \begin{pmatrix}\text{Y ampl.}\\ \text{setting}\end{pmatrix} \times \begin{pmatrix}\text{probe}\\ \text{attenuation}\\ \text{factor}\end{pmatrix}$$

$$= 3.2 \times 0.5 \times 10$$

= 16 Volts, of positive polarity.

NOTE: To measure a voltage level with respect to another voltage rather than with earth, apply the reference voltage to the input socket and the Y POSITION control so that the trace coincides with a horizontal graticule line, which can now be used as the reference line. This replaces the zero reference procedure described in step 1.

TIME AND FREQUENCY MEASUREMENTS

For all time and frequency measurements, the TIME/cm potentiometer must be in the CAL position, otherwise the deflection coefficients are not calibrated.

To reduce reading error, time and frequency measurements can be made by using the delayed sweep time-base.

Time Measurements

To measure the time interval between two points of a waveform, connect the signal to one of the Y input sockets and adjust the Y plug-in unit controls in accordance with the operating instructions, to display as large a trace as possible. Then proceed as follows:

1. set the TIME/cm switch so that the horizontal distance between the time measuring points is as large as possible;
2. rotate the X POSITION control so that one of the measuring points coincides with its nearest vertical graticule line;
3. rotate the Y POSITION control to bring the other point to the horizontal centre-line;
4. measure the horizontal distance between the two time measurement points;
5. multiply the measured distance by the TIME/cm setting. (If magnification is used, divide this product by 10.)

Example 3.

Assume that the TIME/cm setting is 0.1 ms and the magnifier is on. The measured distance is 7.5 cm. Applying the formula:

$$\text{Time interval} = \frac{\text{horizontal distance} \times \text{TIME/cm setting}}{\text{magnification}}$$

$$= \frac{7.5 \times 0.1\ \text{ms}}{10}$$

$$= 0.075\ \text{ms} = 75\ \mu\text{s}$$

Hence, the frequency, which is the reciprocal of the time duration of one cycle, can be easily calculated, viz.

$$\text{frequency} = \frac{1}{75 \times 10^{-6}} \approx 13\ \text{kHz}$$

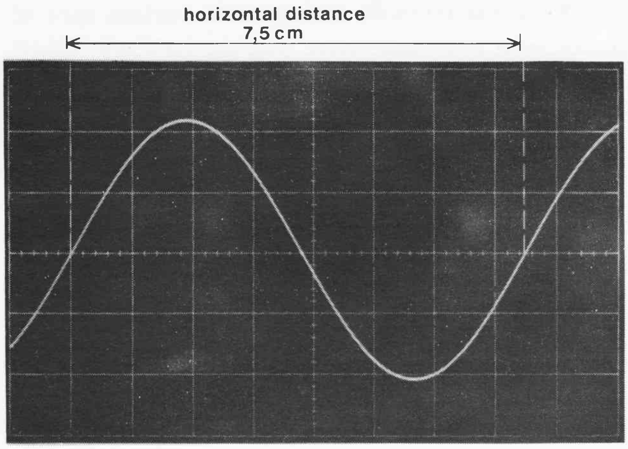


Fig. 15. Measuring Time Intervals

Rise-time Measurements

Rise-time is defined as the time required by the leading edge of a signal to rise from 10 % to 90 % of the amplitude, as shown in Fig. 16.

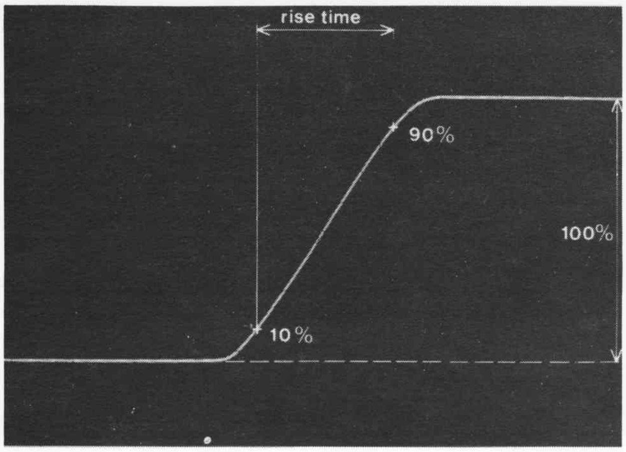


Fig. 16. Definition of Rise-Time

When the oscilloscope rise-time is comparable with the signal under test, the actual rise-time should be calculated as follows:

Actual $t_r = \sqrt{(\text{measured } t_s)^2 - (\text{oscilloscope } t_r)^2}$

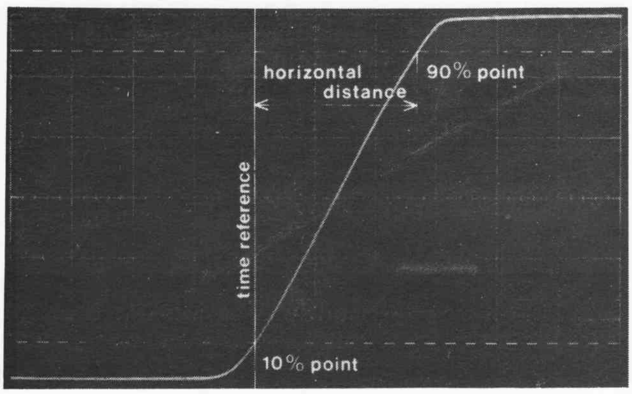


Fig. 17. Measuring Rise-Time

To measure the rise-time of a signal, connect the signal to one of the Y input sockets and adjust the Y plug-in controls in accordance with the operating instructions to display as large a trace as possible. Then proceed as follows:

1. set the TIME/cm switch of the main time-base to display the total voltage step on the screen;
2. adjust the Y amplitude so that the vertical deflection is exactly six centimetres.
   The 10 % and 90 % points now coincide with the dotted lines of the graticule.
3. adjust the X POSITION control so that the 10 % coincides with the nearest vertical graticule line; this line is now the time reference line, and no further adjustment of the X POSITION control should be made;
4. measure the horizontal distance between the time reference line (coincident with the 10 % point) and the point of intersection of the signal and the horizontal 90 % line.
5. The rise-time is given by the product of the horizontal distance in centimetres and the TIME/cm setting. If magnification is used, this product must be divided by 10.

Example 4. (see fig. 17)
Assume that the TIME/setting is 200 ns and no magnification is used. Assume a total oscilloscope rise-time of 0.35μs is obtained with the PM 3372 set accordingly.

measured rise-time

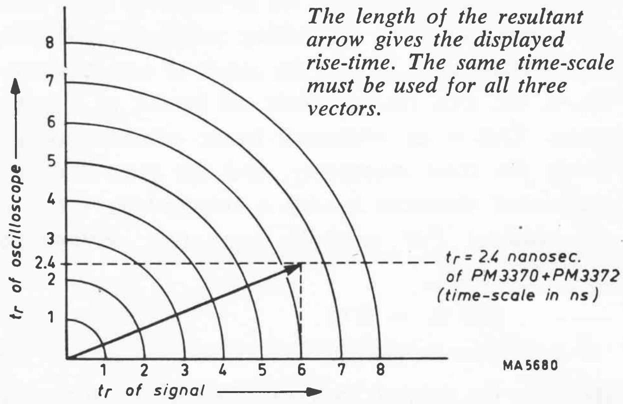
$$= \frac{\text{TIME/cm setting} \times \text{Horizontal distance}}{\text{Magnification}}$$

$$= \frac{200 \text{ ns} \times 2.7}{1} = 540 \text{ ns}$$

Substituting in the formula:
actual rise-time

$$= \sqrt{\text{measured rise-time}^2 - \text{oscilloscope rise-time}^2}$$

$$= \sqrt{0.54^2 - 0.35^2} = 0.41\ \mu s$$



Oscilloscope Rise-Time versus Signal Rise-Time.

Accurate Time Measurements using the Delayed Time-base

The delayed sweep is invaluable for making accurate time measurements.
The advantages of using the delayed time-base method can best be understood if we consider the factors that contribute towards measurement errors when using an oscilloscope.
These are:
a. the inaccuracy of the time-base,
b. the reading error.

The inaccuracy of the time-base is generally specified for the middle 8 divisions of the deflection (due to slight non-linearities at the extremes of the scan) a tolerance of approximately 3 % being common for professional equipment. This is often regarded as the measuring error of the oscilloscope, the reading error generally being neglected. However, this latter error can have considerable influence on the accuracy of the measurement. The factors that influence the reading error are:
- line thickness,
- the angle between the signal and the horizontal graticule line at the point where the reading is made,
- parallax.

Line thickness is dependent on the focussing and astigmatism of the c.r.t. spot and upon its intensity. For optimum line thickness, the intensity should not be too high.

The angle between the signal and the horizontal graticule line at the point of reading should be as large as possible to obtain a clearly defined cross-over point. It is therefore advisable to work with the biggest possible display and, if possible, to take the reading at the steepest part of the trace.

With the PM 3370, the reading error due to parallax is eliminated as the c.r.t. has an internal graticule.
The value of the reading error which results from taking measurements may be as much as 0.05 of a centimetre for each measuring point. As all time measurements are in fact the result of two measurements, the total reading error can be 0.1 of a centimetre. This is an additional factor contributing towards the total inaccuracy, and for measurements over small distances it adds a considerable error to the reading. For example, over two centimetres

$$\frac{0.1}{2} \times 100\,\% = 5\,\%.$$

By using the delayed sweep method of measurement it is possible to considerably reduce the influence of the reading error.

The following methods illustrate the various uses of the delayed time-base. Note that the DELAY TIME MULTIPLIER potentiometer introduces a slight inaccuracy due to its non-linearity which is 0.1 % maximum.

COMPARISON OF METHODS

The attendant advantages of measuring time differences by means of the delayed time-base can be shown by considering a specific example and applying the various methods of measurement at our disposal.

Example 5.
Assume a signal as illustrated in Fig. 18, where it is required to measure the time difference between the points t_1, t_2, t_3, t_4.

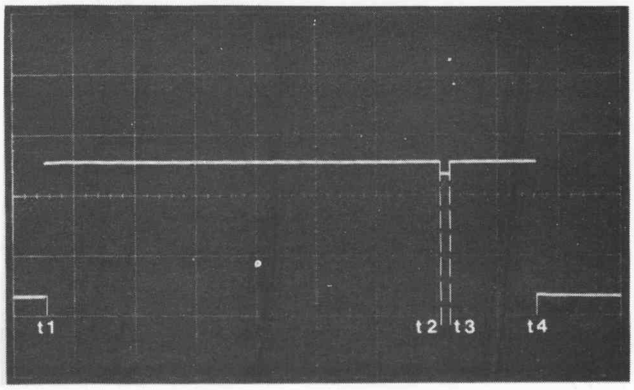


Fig. 18. Time Measurements

Method A.
Measuring the time difference by means of the main time-base.

Assume that the TIME/cm setting of the main time-base is 10 μs/cm and that the horizontal distance t_1 and t_4 is 8.2 cm. The measured time difference between them is therefore 8.2 × 10 μs = 82 μs. The measured distance $t_2 - t_3$ is 0.2 cm which represents 2 μs. The measured distance $t_3 - t_4$ is 1.4 cm which represents 14 μs. Therefore, the reading errors for the respective times are:

$$t_1 - t_4 = 2 \times \frac{0.05}{8.2} \times 100\,\% = \pm\, 1.2\,\%$$

$$t_2 - t_3 = 2 \times \frac{0.05}{0.2} \times 100\,\% = \pm\, 50\,\%$$

$$t_3 - t_4 = 2 \times \frac{0.05}{1.4} \times 100\,\% = \pm\, 7\,\%$$

As the error of the time-base may be as much as 3 %, this must be taken into account when calculating the total error.

Note: The figure for the time-base error can be checked by displaying an accurately known frequency.

It will be observed that the accuracy is rapidly degraded as the distance on the time axis decreases. For distances less than 1 cm, the ×10 MAGN. can be used. In the example for t_2-t_3, the distance is expanded to 1.7 cm, which gives 1.7 μs.

The reading error is $2 \times \frac{0.05}{1.7} \times 100\ \% = 6\ \%$

Therefore the max. total error could be
$3\ \% + 2\ \% + 6\ \% = 11\ \%$
The 2 % error factor is due to the use of the ×10 magnifier.
By using this method, the accuracy is improved by a factor of 5.

Method B.
Measuring the time difference by means of the delayed time-base.

With the X DEFL switch set to MAIN TB INTENS, the DELAY TIME MULTIPLIER potentiometer may be adjusted in conjunction with the TIME/cm switch of the delayed time-base to give an intensified display of that portion of the trace which embraces $t_2 - t_3$.
By switching the X DEFL switch to DEL'D TB an expanded image, as shown in Fig. 19, is obtained.

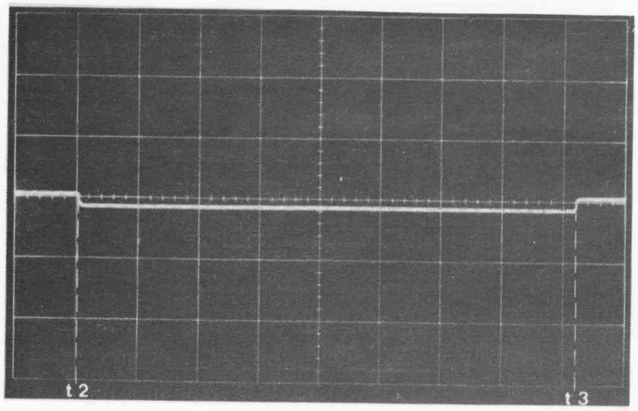


Fig. 19. Time Measurements using Delayed Time-Base

Assume that the TIME/cm setting of the delayed time-base is 0.2 μs/cm. The measured distance between t_2 and t_3 is now 8.2 cm and $t_2 - t_3$ is 1.64 μs.

The read-off error expressed as a percentage is now:

$$2 \times \frac{0.05}{8.2} \times 100\ \% = 1.2\ \%$$

The total measuring error is thus $3 + 1.2 = 4.2\ \%$. When t_3-t_4 is measured by the same method, the largest distance on the time axis will be a setting of 2 μs/cm for the delay time-base. The distance is 6.8 cm, therefore, the time is 13.6 μs, and this reading error is 1.5 % giving a total error of $1.5\ \% + 3\ \% = 4.5\ \%$.

Method C.
Measuring the time difference by means of the delayed time-base and the DELAY TIME MULTIPLIER.

Obtain an expanded display as in the previous method, then rotate the TIME/cm switch of the delayed time-base to 100 ns/cm so that the trace is expanded by a factor 100. Locate t_2 on the screen and align it with the vertical centre-line of the graticule by means of the DELAY TIME MULTIPLIER dial. Note the dial reading.

Then rotate the dial until t_3 coicides with the vertical centre-line and note the new dial reading.
If these readings are, for example, 7.08 and 6.92, then the dial distance between the two measuring points has been expanded to 1.6 cm and the time difference is 16×100 ns = 1.6 μs.
The total measuring error using this method, is the sum of the maximum main time-base error and the error due to the non-linearity of the DELAY TIME MULTIPLIER potentiometer (0.2 %) together with the read-off error.
The read-off error is now the sum of the error caused by shifting both measuring points to the vertical centre-line; i.e., a maximum of $2 \times \frac{0.05}{1.6} \times 100\ \% = 6.3\ \%$.

Thus the maximum total error $= 3\ \% + 0.2\ \% + 0.63\ \% + 6.3\ \% \approx 10\ \%$.
Measuring t_3-t_4 in the same manner will give dial readings of 7.08 and 8.445 so the difference is 1.365. Thus the distance between the two measuring points has now been expanded to 136.5 cm, the time difference being 136.5×100 ns = 13.65 μs.

The reading error on the display is

$$\frac{0.1}{1.365} \times 100\ \% = 0.07\ \%$$

the dial read-off error is $\frac{0.01}{1.365} \times 100\ \% = 0.7\ \%$

therefore, the total error $= 3\ \% + 0.2\ \% + 0.07\ \% + 0.7\ \% \approx 4\ \%$.

Measuring $t_1 - t_4$ with method C will give a dial reading difference of 8.21. The time is therefore 82.1 μs and the expanded distance is 821 cm. The reading error of the display is $\frac{0.1}{821} \times 100\ \% = 0.012\ \%$ which can be neglected. The dial reading error is $\frac{0.01}{8.21} \times 100\ \% = 0.12\ \%$ which makes the total error $3\ \% + 0.2\ \% + 0.12\ \% \approx 3.3\ \%$.

Conclusions

Interval	METHOD A		METHOD B	METHOD C
	× 1 MAGN.	× 1 MAGN.		
$t_1 - t_4$	82μs ± 4.3%	–	–	82μs ± 3.3%
$t_2 - t_3$	2μs ± 53 %	1.7μs ± 11%	1.6μs ± 4.2%	1.6μs ± 10 %
$t_3 - t_4$	14μs ± 10 %	–	13.6μs ± 4.5%	13.65μs ± 4 %

It will be seen from the table of results that Method B is best when very small distances on the main time-base axis are to be measured. However, when these distances are greater than about 1 cm, the read-off error of the DELAY TIME MULTIPLIER becomes negligible and Method C is to be preferred.

TIME RATIO MEASUREMENTS

The delay time multiplier offers the facility for the accurate determination of time ratios. Any significant errors incurred are due only to the incremental non-linearity of the ten-turn potentiometer, and to the reading error which can be kept small by using the delayed time-base.
This is illustrated by reference to the following example. (fig. 20)

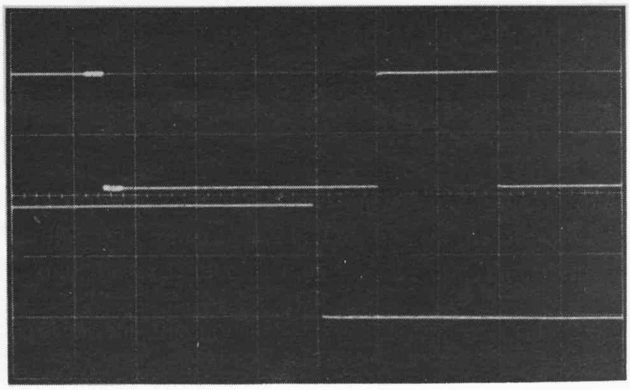


Fig. 20. Time Ratio Measurements

The upper trace shows the pulse displayed by the main time-base at the 20 μs/cm setting. The lower trace represents the intensified portion of the upper trace as displayed in the ALTERN. position of the X DEFL. switch.

The purpose of the measurement is to find the mark/space ratio of the signal. For suitable expansion of the leading and trailing edges, the delayed time-base TIME/cm switch was set to 1 μs/cm.
The negative-going leading edge was dialled to the centre vertical graticule line, as illustrated, and the dial setting of the DELAY TIME MULTIPLIER noted; this was 1.770. Then the next positive-going edge was dialled to the vertical centre-line, the setting being 6.265. Similarly, the final negative-going edge was dialled and a reading of 8.21 obtained.
Thus the negative-going portion of the trace gave a measured reading of:
$6.265 - 1.77 = 4.495$.
The positive-going portion of the trace gave a measured reading of:
$8.21 - 6.265 = 1.945$.
Therefore, the mark/space ratio is:

$$\frac{1.945}{4.495} = 0.433.$$

The accuracy of the positive-going portion is determined by the reading error and the incremental non-linearity of the dial potentiometer.
As the main time-base is expanded by a factor of 20, the pulse length is $20 \times 1.945 = 38.9$ cm.
Therefore,

$$\text{reading error} = \frac{2 \times 0.05 \times 100\ \%}{38.9} = 0.26\ \%$$

$$\text{dial reading error} = \frac{2 \times 0.005 \times 100\ \%}{1.945} \approx 0.5\ \%$$

potentiometer non-linearity = 0.2 %.

Total accuracy for the positive-going portion is therefore:
$0.26\ \% + 0.5\ \% + 0,2\ \% = 0.96\ \%$.

For the negative-going portion:

$$\text{reading error} = \frac{2 \times 0.05 \times 100\ \%}{89.9} = 0.11\ \%$$

$$\text{dial reading error} = \frac{2 \times 0.005 \times 100\ \%}{4.495} = 0.23\ \%$$

potentiometer non-linearity = 0.2 %.
Total accuracy for the negative-going portion is therefore:
0.11 % + 0.23 % + 0.2 % = 0.54 %.
The total ratio error is therefore:
0.96 % + 0.54 % = 1.4 %.
The resultant measurement gives a ratio of 0.433 ± 1.4 %; i.e. within 0.427 and 0.439.

Display Switching

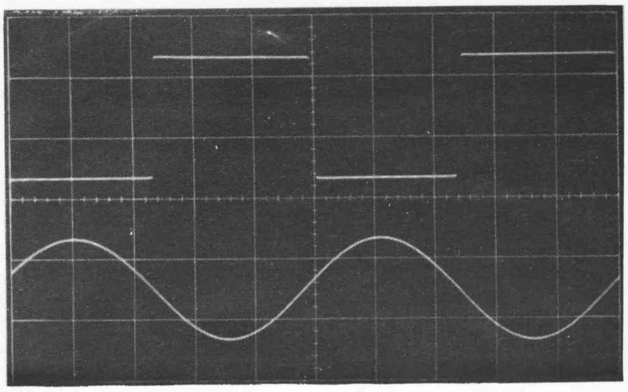
The PM 3370 is equipped with display switching, a new feature for the Philips range of oscilloscope. This now offers the instrument user a simultaneous display of the signal on the two time scales provided by the main time-base and by the delayed time-base.
Detailed examination of a certain portion of the main time-base display is enabled by expanding the time interval of interest by means of the delayed time-base. Expansion is achieved by selecting a correspondingly faster sweep for the delayed time-base TIME/cm control, and positioning the time interval by the DELAY TIME MULTIPLIER potentiometer.

The part of the signal under detailed observation by the delayed time-base appears as an intensified portion of the main time-base display. This not only facilitates the location of the required detail during dialling but also serves as a visual indication of which portion of the overall trace is being examined. (See Fig. 20.) Thus the operator can immediately correlate the detail with the overall signal, which may be extremely complex, without the necessity of switching between MAIN T.B. and DEL'D T.B. as required with most other instruments.
This feature is extremely useful when the aspects of the detail being observed are changes caused by the variation of some other signal displayed simultaneously by the main time-base.

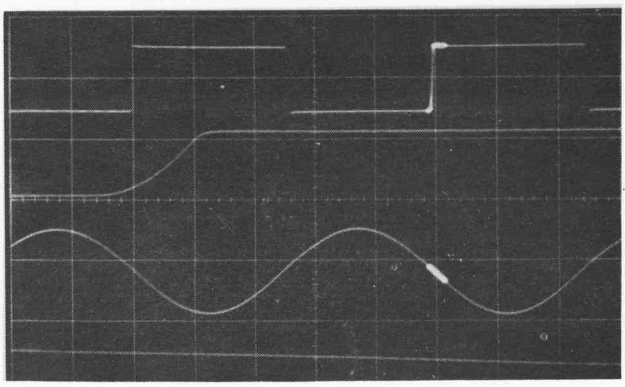
An example of this is shown in Fig. 21 where a sine wave of variable amplitude is fed into an overdriven amplifier which functions as a squarer. The amplitude of the square wave output, unlike the rise-time, is independent of the input voltage. To examine the relationship between rise-time and input voltage, the following procedure may be employed.

- Using a multi-trace plug-in in the ALTERN. mode display the output voltage as the upper trace and the input voltage as the lower trace, as shown in Fig. 21a.
- Set the X DEFL. switch to ALTERN. and adjust the delayed time-base controls for a suitable display of the leading edge of the square wave (Fig. 21b).
- Adjust the Y deflection and POSITION controls of the plug-in unit and the TRACE SEPARATION control of the main instrument to remove the extreme traces of Fig. 21b for clarity.

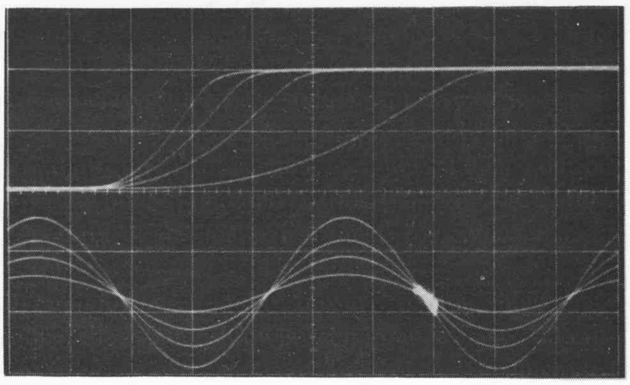
By employing a multi-exposure photographic technique, the relationship between input voltage and output rise-time can be effectively displayed as illustrated in Fig. 21c.



a. Output signal (upper trace) of a squarer, driven by a sinusoïdal input (lower trace).



b. Showing the leading edge (second trace) of the square wave.



c. Multi-exposure photograph showing the rise-time varying with input amplitude.

Fig. 21. Effective Use of Display Switching

PHASE MEASUREMENTS

To measure the phase difference between two sinusoidal signals of the same frequency, use the following method.
Connect one signal to one of the Y input sockets and the other signal to the other Y input socket of the PM 3372, using probes or coaxial cables **with equal time delays.** Display the traces using the AUTO mode of the main time-base with the Y select switch at CHOPP. (suitable for low frequencies) or ALT ERN. (suitable for high frequencies). If the signals are of opposite polarity then pull one of the Y POSITION controls to invert the lagging signal. Note that the total phase difference must be subtracted from 180° in this event. With a stable display of maximum amplitude. adjust the Y POSITION controls for symmetry about the horizontal centre-line.

Having set up the display, proceed as follows:

1. set the TIME/cm switch and potentiometer so that one cycle of the first signal occupies exactly 9 cm horizontally; i.e., each cm represents 360°/9 = 40°;

2. measure the horizontal distance between the two corresponding points on the waveforms, and multiply this by 40° to obtain the phase difference. If one of Y POSITION controls is inverted, subtract the result from 180°.

NOTE: For small phase differences (less than 40°) use the ×10 MAGN. push-button and divide the result by 10. The phase scale is now 4°/cm, therefore, the measured distance in centimetres should be multiplied by four to obtain the desired phase difference measurement.

Small phase differences can also be measured by means of the delayed time-base.
The total period, time T, is measured by using the main time-base. Then the time difference dT is measured using one of the methods previously described, depending on the distance between the two measuring points.
The ratio between this time duration dT and T, multiplied by 360 degrees gives the phase difference between the two signals.

PHOTOGRAPHING SCREEN TRACES

Photographic records of the screen traces can be made for periodic or single-shot events. Details are given in the manual of camera assembly PM 9380.

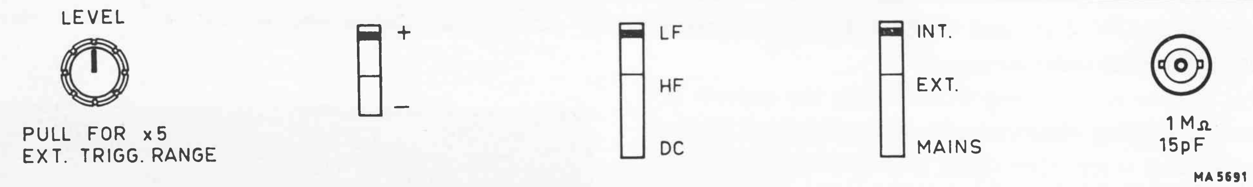
TRIGGERING

The precise functions of the trigger controls that are found on a modern oscilloscope may not be well-known to the occasional user. However, a brief excursion into the basic principles of triggering will facilitate correct adjustment of the controls.
Put simply, triggering circuits have two main functions:

1. to initiate a pulse at a predetermined point of the signal under observation,
2. to start the sweep by means of this pulse.

Figure 22 shows the PM 3370 main time-base trigger controls together with a brief explanation of their various functions.
Initially, the four trigger controls may be set to the following positions; i.e., all in UP position:

LEVEL – mid-range
SLOPE – +
COUPLING – LF
SOURCE – INT.



LEVEL CONTROL
– determines the d.c. level at which the oscilloscope will trigger. A signal passing through the desired level will only trigger the oscilloscope if its direction is that selected by the SLOPE control.

SLOPE CONTROL
– determines whether the oscilloscope will be triggered on a positive-going slope, or on a negative-going slope of the signal.

COUPLING CONTROL
– determines the method of coupling the signal into the trigger circuit. LF coupling blocks undesired d.c. levels and h.f. interference but responds to l.f. triggering. HF coupling blocks d.c. and l.f. (e.g., hum) but responds to h.f. triggering signals. DC coupling makes the full signal bandwidth available for triggering.

SOURCE CONTROL
– determines the origin of the trigger source. INT. – from the internal plug-in unit. (for multitrace units select the appropriate channel on the plug-in unit). EXT. – from an external trigger source, via the TRIGG. input. MAINS – from the mains transformer.

TRIGGER INPUT
– provides a high-impedance coaxial input (1 MΩ//15 pF) when triggering from an external source.

Fig. 22. Main Time-Base Trigger Controls

With this configuration, a display is generally produced which can then be easily adjusted to meet other requirements. Some of these applications are now considered with reference to the trigger control adjustments required for optimum display and measurement.

Double Triggering

Double triggering is an effect, inherent in all triggering systems, that can be produced when the signal point at which the circuit triggers occurs more than once in a single repetition time T as shown in Fig. 23. This phenomenon is exhibited particularly in the display of pulse trains.

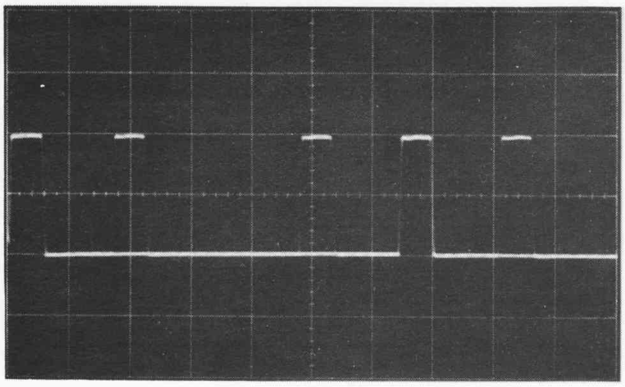


Fig. 23. Effect of Double Triggering

As can be seen, the double triggering is apparent by the "closed loops" that are present at various points on the trace.
Assume that the sawtooth starts on the first pulse of the composite waveform. During the flyback period the input is made insensitive to further trigger pulses by means of the hold-off pulse (see Chap. III). When this pulse terminates, the next trigger pulse will initiate the sawtooth again. However, if this trigger puls is derived from the second pulse of a multi-pulse waveform then a situation is obtained as illustrated in Fig. 23.

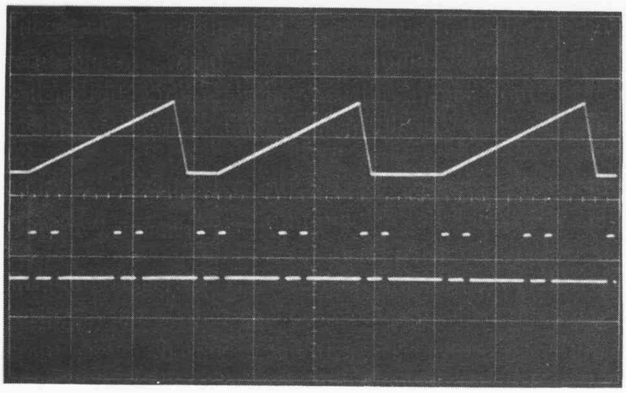


Fig. 24. Double Triggering on Pulse Trains

Now because both time-base are of the same length the next flyback period will end after a second pulse in the waveform and the new sawtooth will again be triggered on the first-pulse. So the sawtooth waveform will be alternately triggered by the first and second pulses resulting in an oscillogram as illustrated in Fig. 24.

If it is not possible to trigger on another pulse that occurs only once during the repetition time T, and which is related to the displayed pulse (e.g. via the EXT. trigger input), then the obvious remedy is to vary the sweep speed by means of the continuous time-base control. If a calibrated display is required, then the alternative is to vary the time-base switch control in steps to eliminate the double triggering.

However, if this produces an unsatisfactory time-base speed, the display can be rectified by switching the TIME/cm potentiometer to the UNCAL position and calibrated measurements can be made by using the delayed time-base.

In some instances, it is not obvious from the display that double triggering is occurring and, in these circumstances, time errors will inevitably result. If, for example, we apply the same signal as in Fig. 23 to both inputs of a dual-trace unit, then with the electronic switch in the ALTERN. position there will be a display as in Fig. 25. This is because the two channels are each triggered by different pulses. Consequently, when the sawtooth is triggered by the first pulse, for example, channel A is displayed and for the next sawtooth which is triggered by a second pulse, channel B is displayed. Since we know that the two waveforms are derived from the same source, then the displayed time displacement error is immediately apparent.

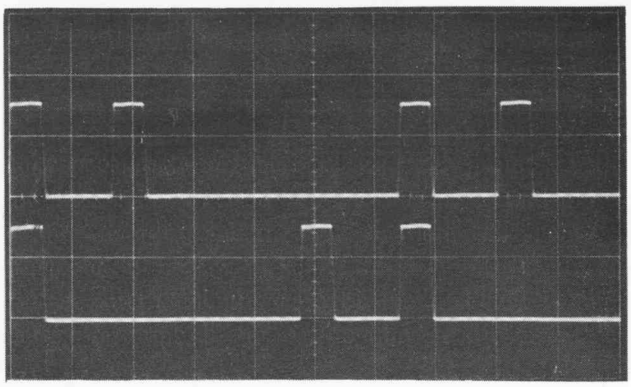


Fig. 25. Double Triggering in ALTERN. Mode

However, when we are observing two signals whose time relationship is unknown (and requires to be measured), this time error due to double triggering may invalidate the measurement. If the trigger signal

is such that it offers any possibility of double triggering, e.g., when the trigger signal crosses the trigger level twice or more during time T, the ALTERN. display position should not be used.
In the CHOPP. mode of the multi-trace unit, double triggering will appear as "closed loops", as illustrated in Fig. 26.

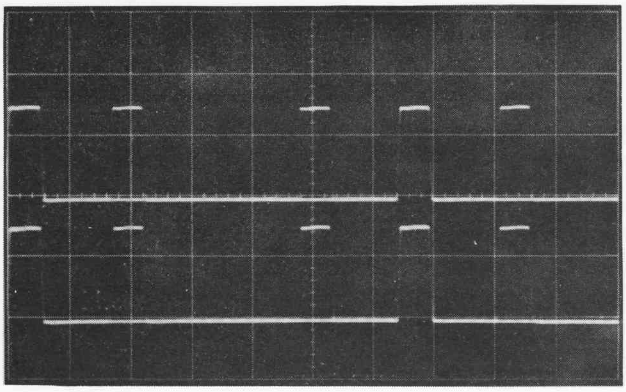


Fig. 26. Double Triggering in CHOPP. Mode

Thus switching to the chopped mode when double triggering is suspected provides a useful check. The remedies are the same as those already outlined.

Y OUTPUT SIGNAL

Many advantages accrue from the fact that in Philips multi-trace oscilloscopes the internal triggering signal can be derived from either channel and it is always taken off before the electronic switch. The main advantages are as follows:

- the trigger signal is merely a part of the input signal and is therefore devoid of interfering components such as are present in the chopped mode of operation which could result in display instability;
- in the alternate mode, the possibility of time relationship errors between the displayed waveforms is avoided since the trigger signal is not a combination of two or more signals;
- the trigger is unaffected by the continuous VOLTS/cm control, the POSITION control and the polarity selector switch of the Y plug-in unit;
- a simple method is provided for triggering from either channel without the necessity of changing input connections or applying one of the signals to the external trigger input.

In this way, the system used on the PM 3370 and its plug-in units safeguards the operator against unmeaningful displays whilst providing him with the facilities to obtain a stable display very easily.

However, there are some instances where a stable display may be required from two signals the frequencies of which are unrelated. The Y output signal, available at a socket outlet on the rear of the instrument, derived from the Y plug-in unit after the electronic switch, may be used for this purpose.
An example of this occurs when it is required to adjust a frequency to be a certain ratio of an accurately known frequency.
Assume that the known frequency is exactly 2 MHz and that the other frequency has to be adjusted to 5 MHz. The dual-trace plug-in unit used with the PM 3370 must be operated in the ALTERN. mode. The main time-base is set to display about 3 complete cycles of the 2 MHz signal. The input signals will be present at the Y output socket alternately for a complete sweep time. The Y output socket must be connected to the EXT. TRIGG. input socket of the main time-base. The d.c. level of each signal can be varied by means of the relevant POSITION control. Set the coupling selector to DC or HF to obtain main time-base triggering, and adjust the LEVEL control so that the sweep starts for both signals on the horizontal centre-line of the graticule.
The frequency can now be adjusted to the desired value by making the end of the fifth cycle coincide with the end of the second cycle of the known frequency, as shown in Fig. 27.

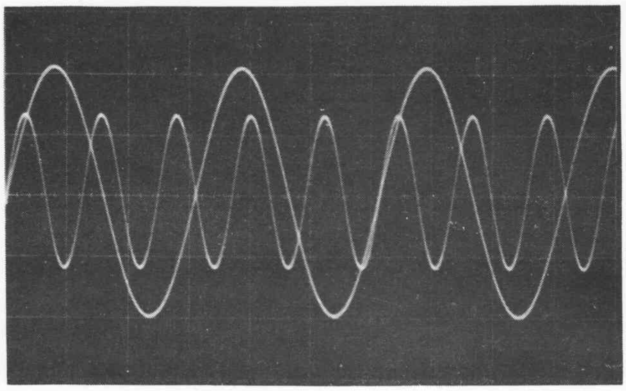


Fig. 27. Using the Y Output Signal

This method is extremely accurate since measurements are independent of time-base inaccuracies.
In order to make the read-off error as small possible, the coincidence area on the main time-base can be displayed enlarged by the delayed time-base using the ALTERN. mode of the display switch.
The intensified portion of the main time-base can be set to the point of interest by means of the DELAY TIME MULTIPLIER dial and the delayed display used for accurate adjustment.