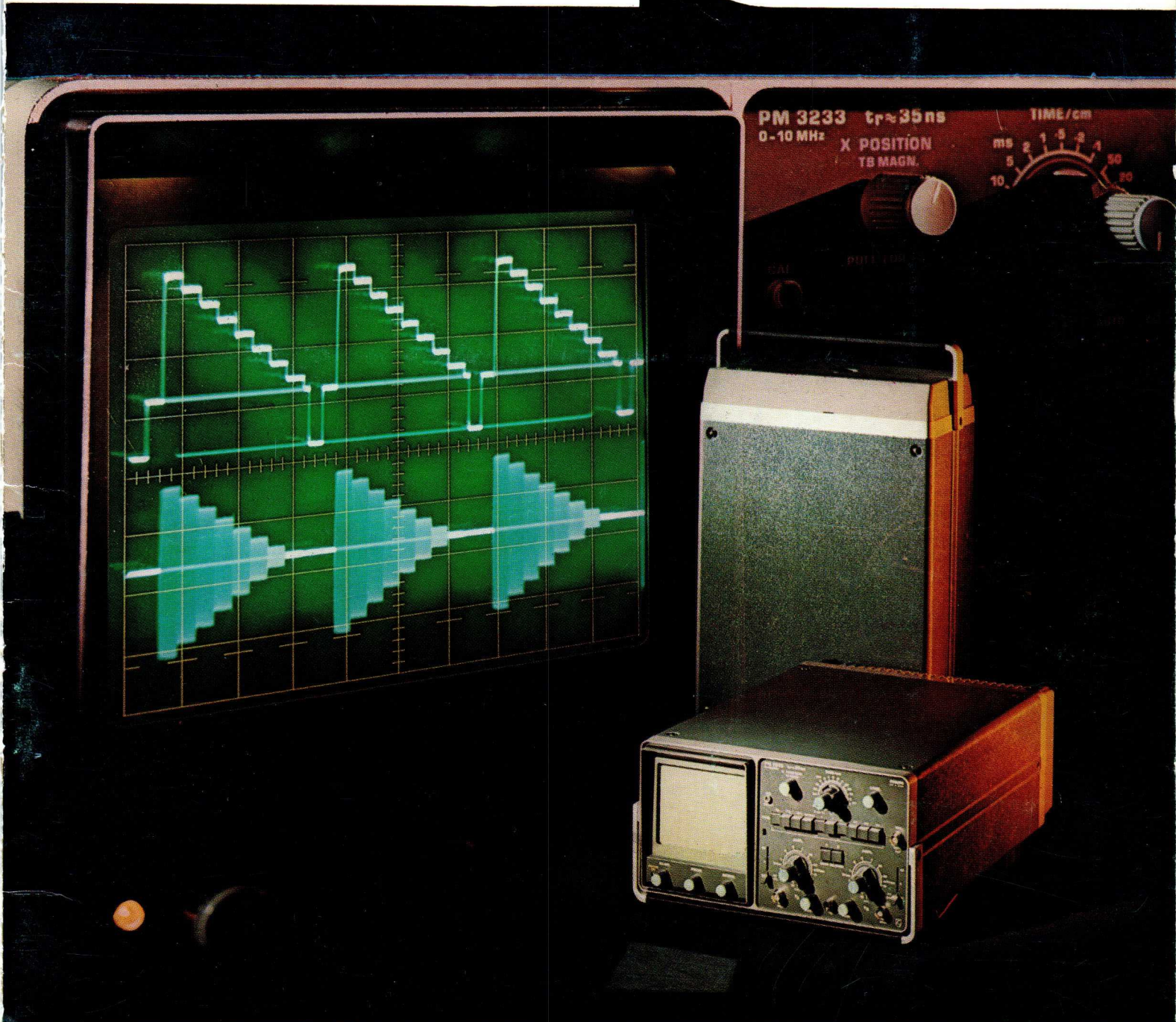




Splitbeam

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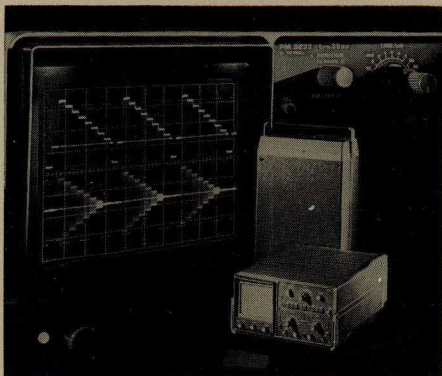
Introduction

The periodical **Test and Measuring Notes** provides information about the application and design of Philips electronic test and measuring instruments. The information is intended to assist users in getting the maximum benefit out of instruments which they already possess and to help them in choosing new equipment which will best meet their particular measuring needs.

Front cover

The PM 3232 new generation general purpose oscilloscope.

The compact design of this dual beam instrument enables maximum screen size with ease of operation through push-button controls



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General information

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

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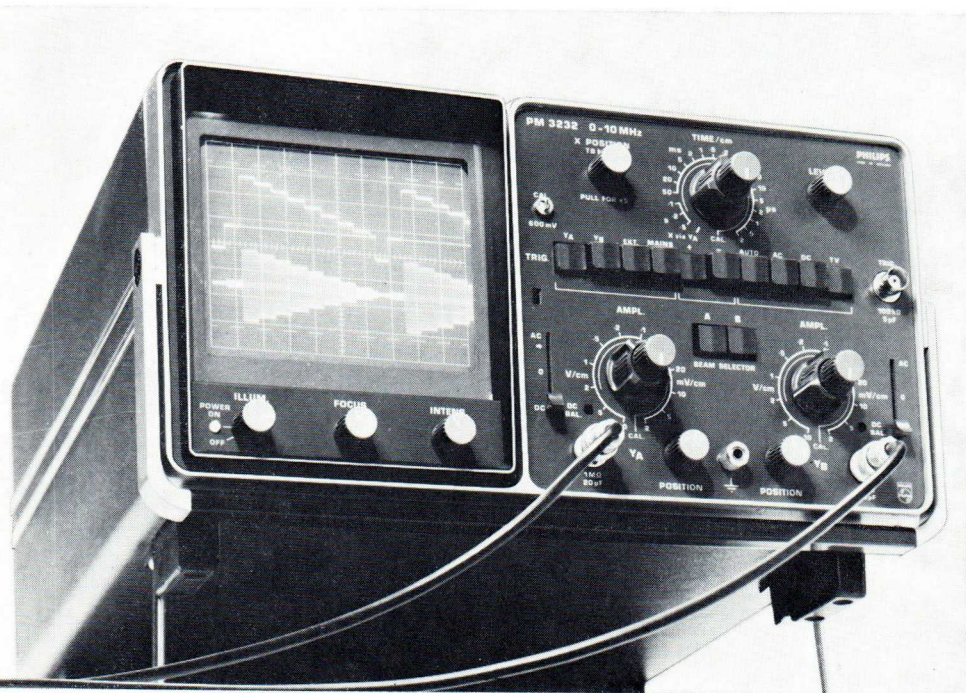
Layout

Mrs. M. Lansbergen-Laferte

What is new in the PM 3232

by H. Toorens

In this article a new 10 MHz dual-beam oscilloscope, using a newly developed Philips rectangular dual beam, 10 kV mesh type PDA tube, is described. The instrument features a.o. 8 x 10 cm, display-area, 2 mV/cm sensitivity, automatic level-detecting and DC triggering including auto-free-run. It can be powered from a wide range of AC voltages and external DC supply.



The PM 3232

The PM 3232 fulfils all of the above-mentioned requirements. Its modern styled cabinet provides a firm construction with good accessibility to all circuits and components. The total construction stands 4000 bumps of 10 g in three directions, perpendicular to each other. Testing also comprises vibration between 10 Hz and 150 Hz over an amplitude of 0.7 mm. with a maximum acceleration of 5 g in accordance with IEC 68 specifications. Furthermore, the PM 3232 can be used in a wide range of ambient temperatures; viz. $-10...+55^{\circ}\text{C}$. The obvious result of all this care is an excellent reliability. Its front panel lay-out and shape of controls, are ergonomically designed, so that operators' time and error are restricted to the minimum. But let us have a look at the most important part of any oscilloscope:

A 10 MHz oscilloscope having two inputs may not seem to be spectacular.

One can find many types of them on the market each with various properties. Instruments like these are used throughout the entire field of applied electronics, from medical/biological research to manufacture and service of electronic data-machines and their peripherals.

Because of the variety of applications for oscilloscopes in this class, one can not easily identify who is actually the user. Included are the highly-skilled electronic engineer, who knows and realises what an oscilloscope does or for instance the biological scientist who only wants to get a graphical presentation of his experiment. The latter possibly having little knowledge of electronics.

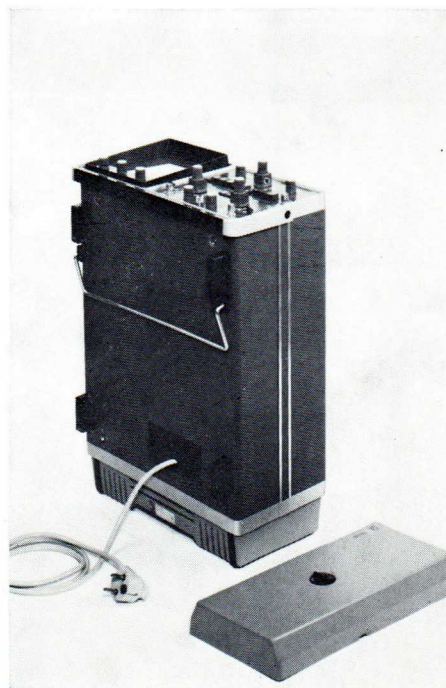
But, whoever might use the instrument, they have one thing in common: they need a tool, a simple to operate, and reliable instrument which allows them to face their problem, without introducing new problems of operation. They want to be able to use it anywhere, in the airconditioned

lab. or in the industrial environment of a steelmill and they want to take it from one place to another, easily.

The target

An oscilloscope with a specification which places it into many applications, including radio and TV design and development, industrial service and service of data machines, telecommunication and education. An oscilloscope, to be easy to operate and "fool-proof" to a high degree.

It should be ergonomically designed and resistant against severe environmental circumstances. And, because an oscilloscope is an instrument to show things, it must have a large screen, with a brightness of traces which clearly shows even the most difficult waveforms.

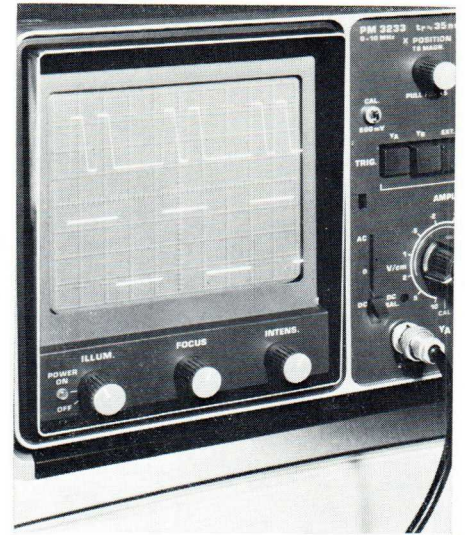


The display system

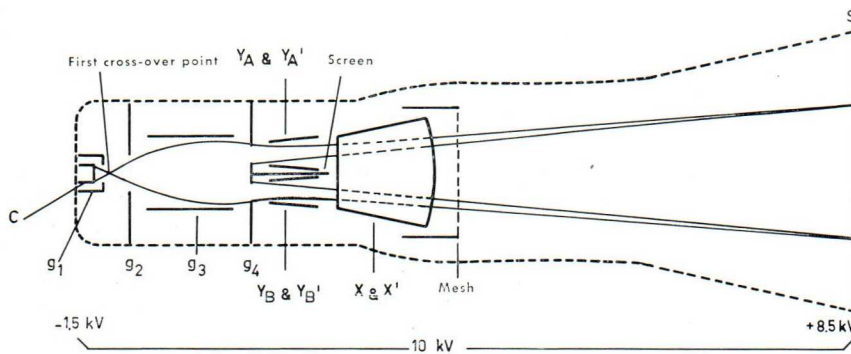
The heart of an oscilloscope is formed by the cathode-ray-tube on the screen of which all relevant information, like amplitude, time, and shape of a waveform are presented. As many applications of oscilloscopes require a means of comparison between two waveforms, this screen should be as large as possible.

The PM 3232 features a display area of 80 cm² (8 cm vertical and 10 cm horizontal) on a rectangular, post deflection accelerator dual-beam tube. The two beams, which can be deflected independently from each other, produce two bright traces. This brightness, which is the result of a relatively high screen-current for each individual beam and the high total accelerating potential of 10 kV allows the user

to see fast signals even at low repetition rates. Metal backing of the phosphor layer avoids burning, when high intensity is used. A simplified drawing of this newly developed Philips CRT is given hereunder in fig. 1.



1. Simplified diagram of the CRT



Electrons are emitted from the cathode (c) and accelerated by the first accelerator (g_2). The Wehnelt cylinder (g_1) acts as first grid and defines the beam current and thus, the intensity. Passing the first accelerator (g_2), the beam has a divergent shape. By means of the convergent lens, formed by g_2, g_3, g_4 , a sharp focussed projection of the first crossover point is produced on the screen (s) forming the spot. However, the second accelerator electrode (g_4) has two holes, instead of one.

The result is that the beam is split into two parts, thus producing two spots on the screen, instead of one as in a conventional CRT. So, behind the second accelerator, there are two beams.

These two beams are deflected individually, one with the balanced pair of deflection plates Y_A and $Y_{A'}$, the other with Y_B and $Y_{B'}$. Horizontal deflection is the same for each beam, by X and X', so that both spots are always accurately traced, ensuring optimum time correlation of the

two traces. After being deflected, the electron beams pass through a mesh, and are then accelerated by the post-deflection accelerating potential of 8.5 kV. This mesh acts as an electrostatic screen between the high post-accelerating voltage and the deflection plates. If this were not the case, the deflection sensitivity of the tube would have been considerably lower.

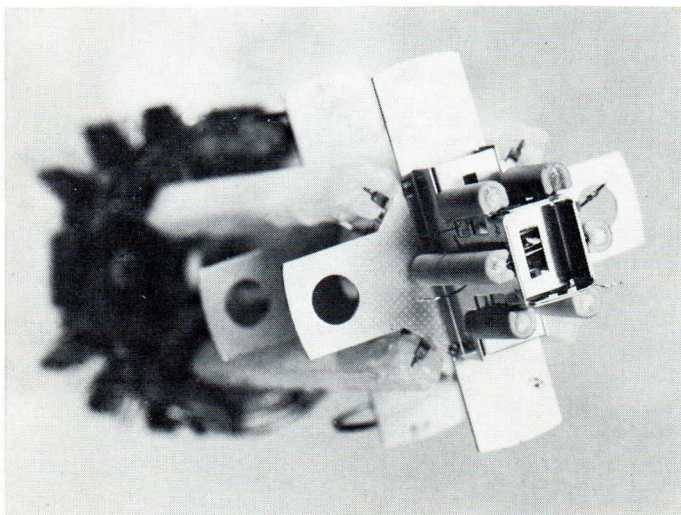


Photo shows assembly of vertical deflection plates

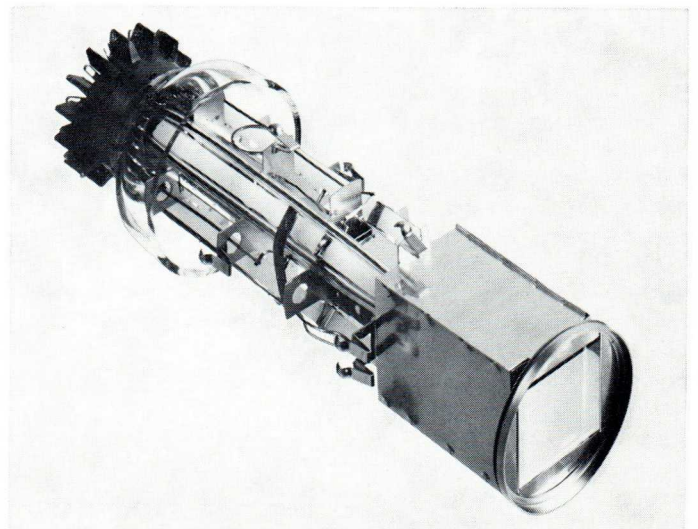


Photo shows complete gun of PM 3232 cathode ray tube

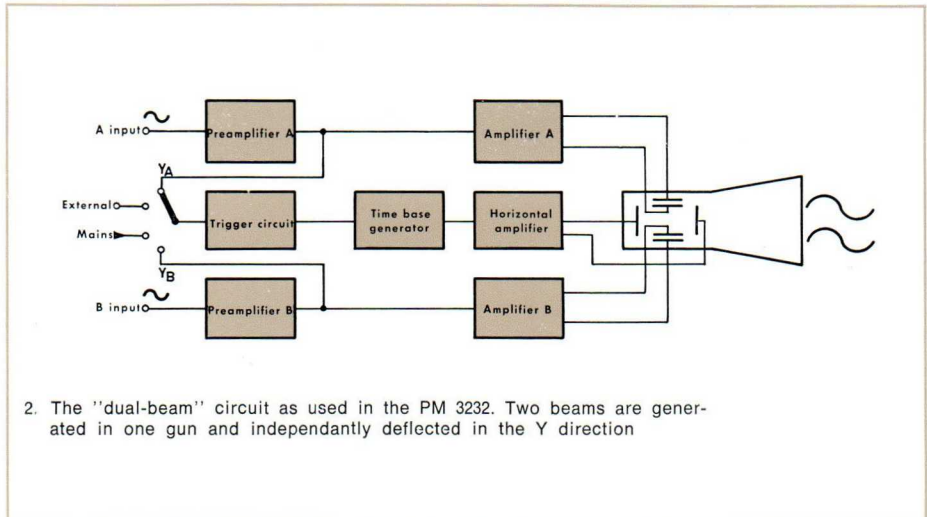
Why dual beam

The display of two waveforms simultaneously on one screen, can be done with two beams, which are individually deflected by two separate amplifiers. It can also be achieved by using a conventional single beam CRT, which displays parts of the two signals in a time-shared mode.

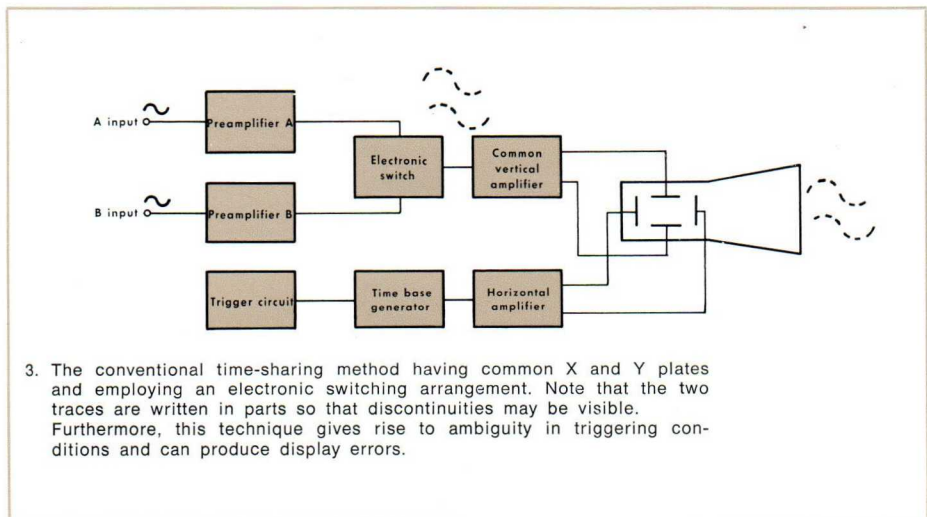
The different set-up is illustrated in the following (simplified) fig. 2 and fig. 3 on the page 3.

The dual-beam method requires a more complex CRT construction and an extra amplifier, but it brings some significant advantages over the simpler-to-construct time-sharing system.

The basic difference is that a dual-beam oscilloscope always produces two uninterrupted waveforms at the same time, while in the time shared system, the single spot is always moving from one trace to the other.



2. The "dual-beam" circuit as used in the PM 3232. Two beams are generated in one gun and independently deflected in the Y direction



3. The conventional time-sharing method having common X and Y plates and employing an electronic switching arrangement. Note that the two traces are written in parts so that discontinuities may be visible. Furthermore, this technique gives rise to ambiguity in triggering conditions and can produce display errors.

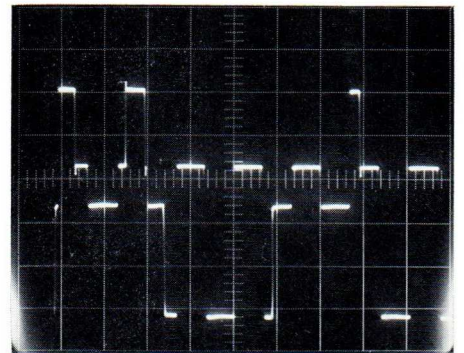


Fig. 4 illustrates one possible cause of error when a dual trace scope is in the chopped mode. Fundamentally this technique only shows half the waveform, the rest is interpolated. Although the display is not complete, note that the phase is correct.

Time-shared oscilloscopes offer two display-modes, known as "chopped" and "alternate". In the "chopped" mode switching occurs at a fixed switching rate. The higher the frequency, the better the resolution of the displays, but the switching frequency is limited by the bandwidth of the amplifier. In practice, this switching frequency is in the order of 50 times lower than the frequency limit of the oscilloscope.

A time-shared oscilloscope is preferable used in this chopped mode but on the other hand, discontinuities are visible when the input signal interferes with the chopper frequency. Also single shot phenomena or signals with low repetition rates cannot be displayed at relatively high sweep-speeds without visible interruptions (see fig. 4).

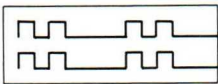
In the "alternate" mode, a time-shared oscilloscope displays one complete trace per sweep, because the electronic switch is operated at the end of each saw-tooth. The displaying sequence thus is for example A-B-A-B etc.

It will be clear that this method cannot be used for low-repetitive signals or single-shot phenomena, as only one trace is seen at the same time. And it may even show misleading results!



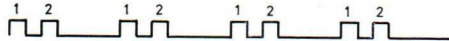
Imagine that this signal is connected to **both** inputs of a time-shared oscilloscope operating in the alternate mode.

It should be displayed as follows:



But it can go wrong! For example:

(a) is the signal to both inputs



(b) is the signal to trigger the time base



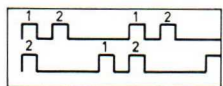
(c) is the time base signal



(d) shows that odd sweeps start with pulse 1 whilst even sweeps begin with pulse 2.



The result looks like this:



The more complex a pulse pattern is, the more chance that the display is not true. As has been mentioned before, a dual-beam oscilloscope always produces two uninterrupted waveforms **at the same time**, and therefore avoids the errors as mentioned above. Therefore, it is easier to work with and gives rise to less errors. Furthermore, it brings more advantage of the high accelerating potential as used in the PM 3232, because the maximum light output is not divided over two traces as it is in the time-shared system.

Significant electrical properties

The input sensitivity of the PM 3232 is high viz. 2 mV/cm. This not only makes display of weak signals possible, it also allows the user to employ passive attenuator probes, so that the parallel capacitance loading the circuit-under-test is reduced. Even when a 100 : 1 probe is used, like the PM 9358, (input capacitance of only 2 pF) a useful sensitivity at the probe tip is achieved.

The time base generator which has a wide range of sweep speeds (0.5 s/cm up to 200 ns/cm) can be triggered by Y_A , Y_B , Ext or Mains frequency. This trigger source selection makes the instrument really versatile. Triggering, by the way, is easy with the PM 3232. The trigger circuit can be DC coupled, a **must** when measuring

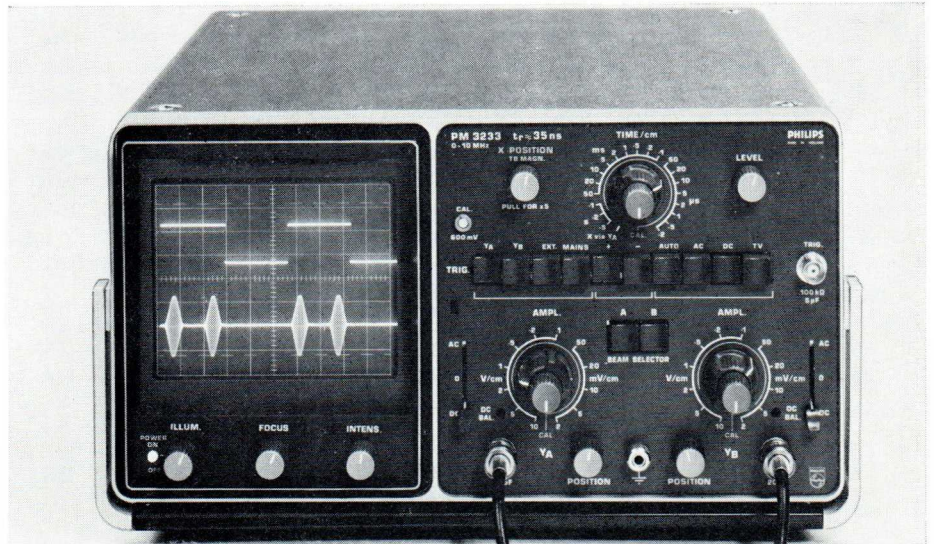
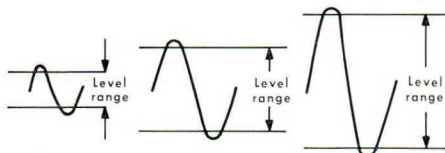


Photo shows the clear front-panel lay-out of the PM 3233, the delay line version of the PM 3232

digital waveforms where duty-cycles are most variable. There is also a refined Automatic trigger mode.

This Auto-mode ensures that a bright line is displayed under no-signal conditions for quick zero-reference. When a signal is applied the time base is triggered, automatically, on a level which is variable between the extremes of the waveform.



This feature implies that nearly all signals can be displayed without even touching the level control!

There is no "trigger-stability" control on the PM 3232. It triggers stable beyond 10 MHz.

Displaying video waveforms is also an automatic function. Pressing the button „TV" is all to be done to have the time-base triggered by the television's synchronisation pulses. Selection of "Frame" and "Line" triggering is done automatically while setting the time-base speed.

Conclusion

The PM 3232 is a general purpose oscilloscope, in which much attention is paid to the display system including the cathode-ray-tube. Many measurements can be made using the very convenient automatic trigger mode. DC trigger coupling ensures stable displays, even when repetition rates and/or duty cycles of the signals to be measured are variable.

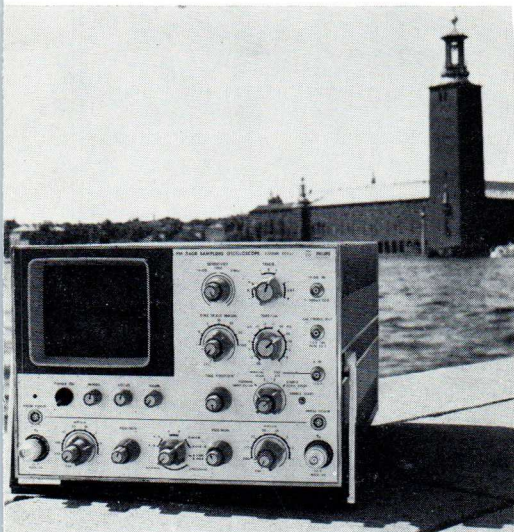
The photographs with this article will show the very clear, functional design with which every operator will feel familiar in a few seconds.

Thanks to the use of building-blocks, plug-in semiconductors and wiring, service-down-time is restricted to a minimum, increasing the efficiency and usefulness of the new PM 3232 dual-beam oscilloscope.

Some applications of the output signals of the PM 3400 sampling oscilloscope

by W. Spapens

The output signal of a sampling scope can be used to drive an X-Y recorder; accurate DC measurements can be made at any desired point on the trace; and signals can be measured up to 70 dB below the noise level.



Introduction

Electronic sampling techniques are becoming more and more important nowadays, because:

- a. they allow high-frequency recurrent signals to be brought into the frequency range where they can be conveniently processed by analog or digital methods.
- b. the increasing use of digital signal processing leads to a requirement for the signal to be sampled before being processed.

One device which is often used for applications of the first type is the sampling oscilloscope, which has been on the market for a good many years now but has recently been improved in a number of respects thanks to improvements in semiconductor techniques, so that it may now be regarded as a general-purpose measuring instrument.

While sampling oscilloscopes cannot display high-frequency single-shot phenomena, they do have a lot of advantages over real-time oscilloscopes. Benefits such as wide bandwidth, high sensitivity, broad dynamic range, the availability of the signal after sampling and accurate X-Y measurement facilities up to high bandwidths and many other points, are now quite common for sampling oscilloscopes.

The horizontal scan of a sampling oscilloscope

It is characteristic of sampling oscilloscopes that the equivalent time scale, that is the number of ns/cm or μ s/cm, and the movement of the spot over the screen, are completely independent of each other.

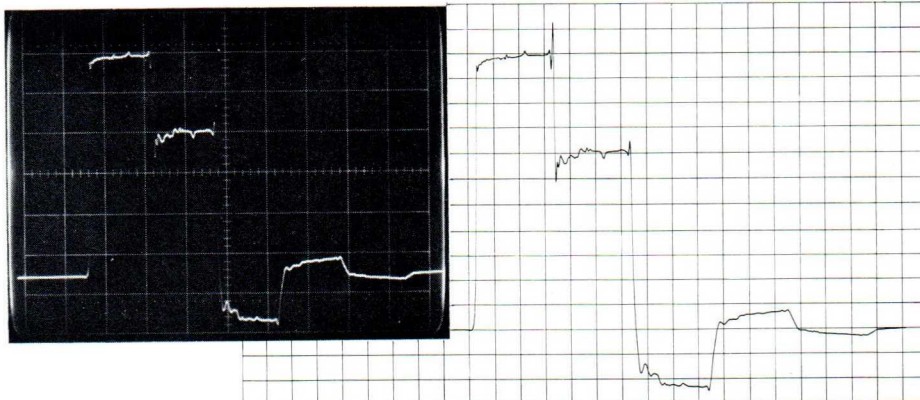
The display can be written at any speed and even backwards from right to left. One can, therefore, sweep the display at a speed which can be conveniently followed by an Y-T or X-Y recorder, thus allowing permanent recording to be made. An additional advantage of using a recorder is that it acts as a low-pass filter which effectively reduces noise and jitter. This freedom of scanning the signal facilitates closer investigation of the signal than is possible by simple observation of the oscilloscope screen.

In this article we will deal with some applications based on this principle, viz:

1. *the recording of signals*
2. *the accurate measurement of signals*
3. *measurements on signals completely submerged in noise.*

For readers who are not familiar with the operation of a sequential sampling oscilloscope, a brief description of the operating principles of the PM 3400 is given in an appendix.

1. Oscillogram of a fast-rise-time signal with reflections. Amplitude 200 mV/div, Time 20ns/div
2. The signal of fig. 1 recorded on an X-Y recorder. Amplitude 100 mV/cm, Time 10 ns/cm



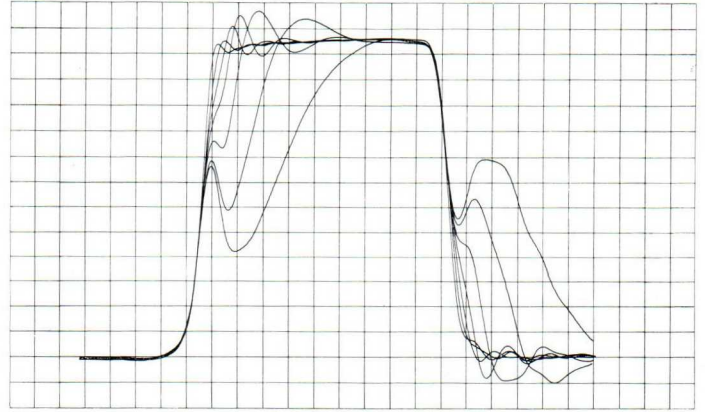
Recording signals with an X-Y recorder

One of the limitations of an oscilloscope is the relatively small size of the screen (generally 8x10 cm). If the trace is 0.3 mm thick this thus gives a resolution of about 270x330 lines. A photographic record of the trace on the screen will be subject to the same limitations as regards resolution, while the making of extra copies of Polaroid prints (the usual medium used in oscilloscope cameras) is by no means an easy matter, and is relatively expensive.

If we connect one of the vertical outputs and the X output of the PM 3400 to an X-Y recorder, we can get a recording of the signal on the screen of the CRT. A Polaroid photo and an X-Y recording of the same signal are shown in fig. 1 and 2 respectively. On the recording, 2 cm correspond to 1 cm on the screen, while the line width is about the same in the two cases.

The resolution of the X-Y recording will thus be about twice as good as that of the Polaroid oscillogram. Moreover, the X-Y recording has the advantage that it can be made on graph paper, thus making amplitude and time measurements much faster and more accurate. Finally, the X-Y recordings can be reproduced with normal copying equipment; this gives excellent, very cheap prints, which can be very important when a large number of copies of the recording are needed e.g. as educational material in schools and universities.

3. A multiple recording of a fast signal at the input of the PM 3400. The differences between the signals are caused by varying the value of a capacitor in the output circuit



The output voltage is specified as 0.5 V per cm deflection on the screen, with an accuracy of 5%. This means that, in order to improve the accuracy of the recording, we must adjust the sensitivity of the recorder so that a given deflection on the CRT screen gives a well defined deflection on the X-Y recorder. Very accurate adjustment of the X-Y recorder can be realized by recording a signal of calibrated amplitude and repetition time.

Since the signals are only processed by low-frequency circuits after the sampling gate, any desired portion of a signal can be magnified both vertically and horizontally without any of those troubles associated with overdriving of the amplifiers which are found in real-time oscilloscopes.

This property is particularly useful for the optimizing of electronic circuitry. We can e.g. record a particular test signal with the PM 3400 and the X-Y recorder, modify the circuit in question and record the same signal again. The changes in the signal can then be compared most efficiently, and often make it easy to predict which values of the components of the circuit will lead to an optimum result. An example of such an application is illustrated in fig. 3.

A similar application of the output signals of the PM 3400 is the multiplication of signals. In some types of measurements, the product of two signals gives valuable information about the properties of a certain device. At low frequencies this product can be obtained by means of analog multipliers. For some types of measurements (e.g. measuring peak power during the switching of fast transistors), however, these analog multipliers are not always applicable because of their limited bandwidth. If the low-frequency output signals of the PM 3400 are applied to a standard analog multiplier, the frequency capability of the latter is extended into the GHz region.

The output of the multiplier can of course be recorded on a normal X-Y recorder, giving a clear, accurate picture which is easy to analyse.

The accurate measurement of signals

The independence of the sweep of the PM 3400 from the time scale can be very effectively used for high-accuracy measurements on HF signals. We simply display the signal in question on the screen, switch over to MANUAL SCAN, adjust the spot manually to the point on the trace in which we are especially interested, and measure the amplitude of the signal from the appropriate vertical output with a DC voltmeter.

The linearity of the amplitude ratio between input and output signal was found by measurement on a number of instruments to be better than 0.2% for the middle 6 vertical divisions, measured between input and Y output. Measurements on the A and B outputs revealed a linearity of better than 0.05% for all 8 divisions. The difference in performance between the Y output and the A and B outputs is caused by a network in the Y amplifier which compensates for the slight non-linearity of the CRT found at extreme vertical deflections. The A and B output signals are taken off before this compensation network.

The amplitude ratio between output and input signal (V_o/V_i) depends on the setting of the V/cm control. If the V/cm potentiometer is set to CAL, then this ratio has the following values for the various V/cm settings, for the Y, A or B output:

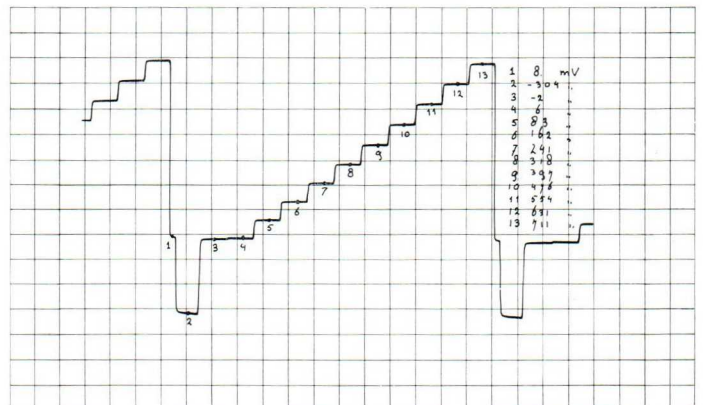
mV/cm	200	150	50	20	10	5	2	1
V_o/V_i	2.5	5	10	25	50	100	250	500

As mentioned above, the accuracy of the output voltage is $\pm 5\%$ and that of the V/cm control is $\pm 3\%$; a total of $\pm 8\%$. However, this error can be eliminated by introducing adjustable attenuation of the output signal to be measured. This attenuation can be calibrated by means of e.g. an accurately known DC voltage applied to the input of the PM 3400. In this way, the total error can be restricted to about 0.1%.

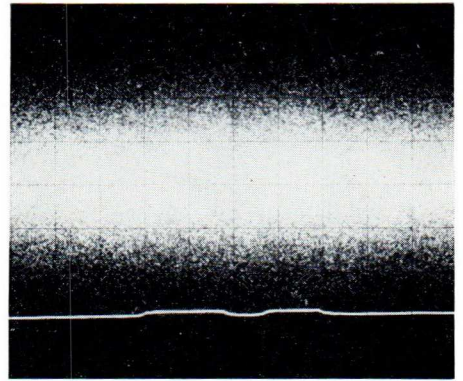
A very convenient way of making accurate measurements and recording a signal at the same time is shown in fig. 4. The signal is first recorded on an X-Y recorder in the SINGLE SCAN mode. Then, in the MANUAL SCAN mode, the spot is positioned at the point of interest and the OUTPUT signal is accurately measured. At the same time the pen lift of the recorder can be released so that an extra dot is obtained on the recording at the point in question. This procedure can then be repeated for other points on the signal.

Applications of this type are possible not only for signals with frequencies of several hundred MHz but also for signals of a few kHz. In fact, it is possible to measure every part of a signal up to 200 μ s (corresponding to the slowest time/cm setting of 20 μ s/cm) after a trig-

4. A TV video signal recorded by means of the PM 3400 and an X-Y recorder. At the numbered dots, the vertical output signal was measured by means of a digital voltmeter. The readings of the DVM are noted for each dot



6. Double exposure of a small signal (lower trace) and the same signal on which noise was superimposed (upper trace)



ger point, provided the repetition rate of the signal is about 10 Hz or more. The signal from the X output can also be used for time measurements, with the aid of a voltmeter.

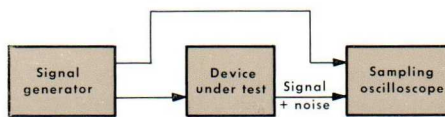
In the MANUAL SCAN mode the voltage at the X output is proportional to the distance between the spot and the left-hand side of the screen. In this mode we can also measure both the vertical as the horizontal coordinates of a point on the signal by means of an accurate DC voltmeter. By controlling the position of the spot externally (EXT.X), we convert the coordinates of every point of the signal into digital information. This digital information can e.g. be fed into a computer for calculation of all properties of signals up to 1.7 GHz such as rise time, amplitude, overshoot, undershoot, and time differences between the signals at the input of the PM 3400.

This thus makes it possible to realize automatic measurement systems with the PM 3400, which converts the fast signals to be measured into signals of lower frequencies which can be handled by analog-to-digital converters.

Measurements on signals below the noise level

As mentioned at the start of this article, the use of a recorder for handling the output signals of the PM 3400 has the ad-

vantage that the recorder acts as a low-pass filter that effectively reduces noise and jitter. It has been found possible to measure signals that lie considerably below the noise level in this way. Fig. 5 shows the block diagram of a set-up which can be used for this purpose.



5. Measuring set-up for signals below the noise level

As can be seen from this diagram the signal used for the experiment is also applied to the "TRIGG. IN" input of the PM 3400. When a signal containing only noise is measured in this way, the amplitude of the samples will have random values. The average amplitude will thus be zero. Recording noise on an X-Y recording via a sampling oscilloscope will give an enormous reduction of the noise because the X-Y recorder acts as an integrator. If however the "noise" signal contains a component which is coupled in frequency with the trigger signal, this part of the signal is recorded without attenuation.

The results obtainable with such a set-up are illustrated in fig. 6 and 7. Fig. 6 shows the oscillogram of a signal with noise

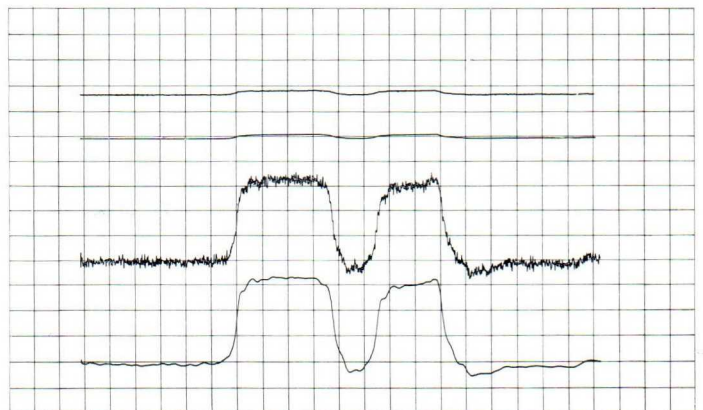
while fig. 7 shows the X-Y recording of the same signal as taken from the vertical output of the PM 3400.

As the repetition rate of the trigger signal determines the sampling frequency, the samples will follow low-frequency noise components. Such noise will thus give a residual signal on the recording.

An extra integrating network between the PM 3400 and the recorder can be used to give further attenuation of these LF noise components but the signal will then have to be scanned more slowly, because otherwise the signal itself will be affected by the integrating network. However, a simple modification to the PM 3400 (shunting an additional capacitance across a 100 nF capacitor) makes it possible to increase the SINGLE SCAN period to many minutes.

If it is not important to have the frequency characteristic of the PM 3400 extending right down to DC (e.g. for measurements on sinusoidal signals, or pulses with a high enough repetition frequency to permit the use of AC coupling), then a blocking capacitor can be used to convert the input of the PM 3400 into a high-pass filter. The low-frequency noise which shows up most when the output of the PM 3400 is recorded on an X-Y recorder is then filtered out right at the start, and the over-all noise attenuation improved again appreciably.

7. The signal with noise from fig. 6 recorded with an X-Y recorder (upper trace), and the same signal without noise (second trace). A deflection of 1 division on the PM 3400 corresponds to 2 cm deflection on the recording for traces 1 and 2. Traces 3 and 4 correspond to traces 1 and 2 respectively, but the sensitivity of the recorder has been increased 20-fold here



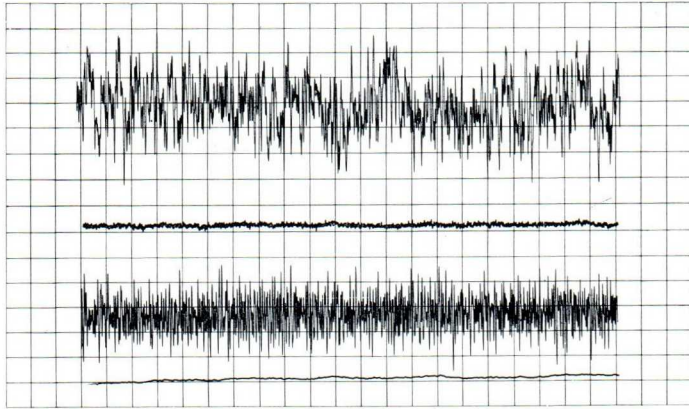


Fig. 8. shows four recording of the same 1600 mV_{pp} "pink noise" signal, with an over-all sensitivity of the recording system (PM 3400 + PM 8120 X-Y recorder) of 2 mV per cm. The upper trace shows the smoothing effect of the recorder alone, the peak-to-peak noise is 60 mm or 12 mV, which means approx. 43 dB noise reduction. The second trace shows the same signal with a 5 kHz high-pass filter at the input of the PM 3400. The third recording gives the signal of trace 1 with an 0.1 Hz low-pass filter between PM 3400 and X-Y recorder. The lower trace is recorded with a 5 kHz high-pass filter at the input, and an 0.1 Hz low-pass filter at the output of the PM 3400, the noise ripple is only about 3 mm = 600 μV_{pp}, representing the considerably noise reduction of about 70 dB. Fig. 9 shows what a 3.2 mV_{pp} sine wave with a frequency of about 600 kHz with 1.6 V_{pp} pink noise superimposed on it looks like after recording without an input filter, and with a 5 kHz high-pass filter at the input of the PM 3400. It is also possible to record the variation in signal amplitude with time, using the PM 3400 and Y-T recorder. For this purpose, the MANUAL SCAN adjustment is used to bring the spot to the peak of the signal before the recording starts. The output signal will then follow the amplitude variation of the input signal. A recording produced in this way is shown in fig. 10.

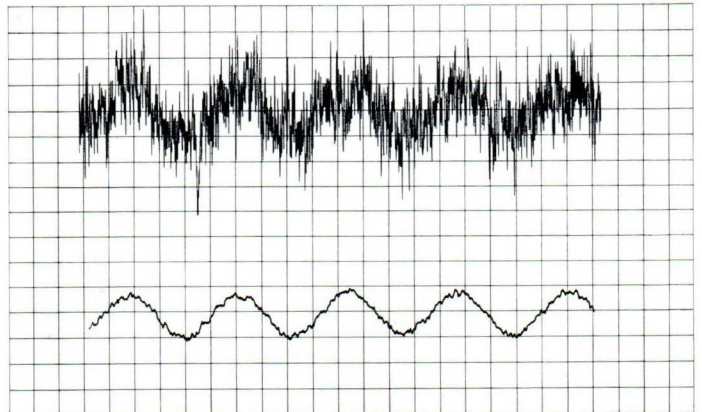
Conclusion

A sampling oscilloscope used in combination with a recorder opens new possibilities for the investigation or processing of signals in a way not possible with real-time equipment. Features such as accurate recording of signals, time and amplitude measurements with accuracies of 0.1% and recovery of signals which are some 70 dB below the noise level certainly widen the range of utility of the oscilloscope. The 50 Ω input impedance of the PM 3400 need not be a limitation of the versatility; when used together with the PM 9354 FET probe, the PM 3400 has an effective input impedance of 1 MΩ/3.5 pF. These facilities all combine to make the modern sampling oscilloscope a really general-purpose measuring instrument in-

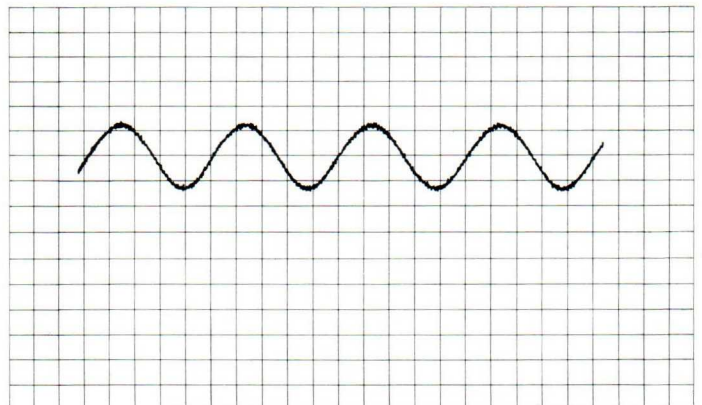
stead of specialistic equipment to measure high frequencies.

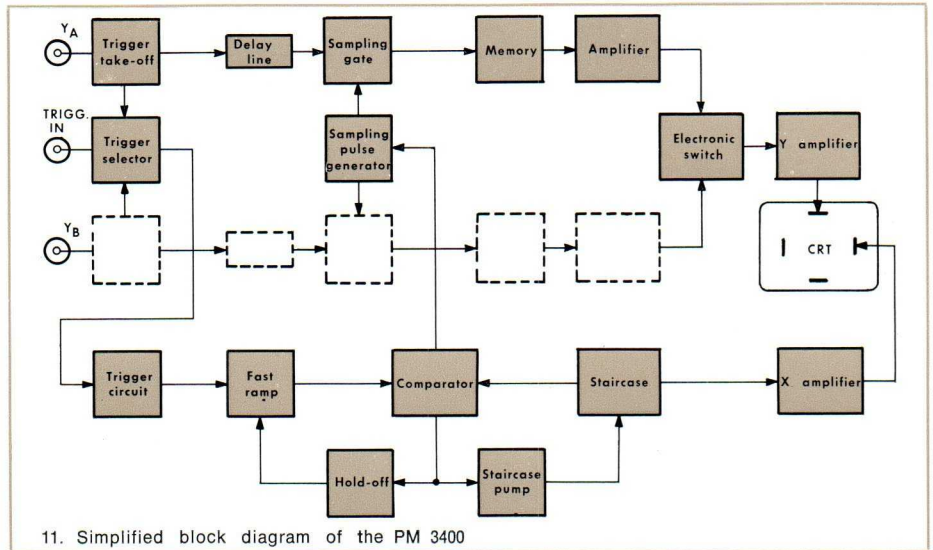
8. Trace 1 (counting from top to bottom) is the recording of a 1600 mV_{pp} "pink noise" signal made directly on the X-Y recorder
 - Trace 2: the same signal recorded with a 5 kHz high-pass filter at the input of the PM 3400
 - Trace 3: the signal of trace 1 recorded with a 0.1 Hz low-pass filter at the output of the PM 3400
 - Trace 4: the same signal recorded with a 5 kHz high-pass filter at the input of the PM 3400 and a 0.1 Hz low-pass filter at the output
- 1 cm vertical deflection on the recording corresponds to 2 mV at the input of the PM 3400

9. A 3.2 mV_{pp} sine wave with 1600 mV_{pp} noise superimposed on it, recorded without (upper trace) and with (lower trace) 5 kHz high-pass filter. Vertical deflection 2 mV/cm



10. A recording of the amplitude variation of a 1 MHz signal modulated with a 0.02 Hz signal. Vertical deflection 5 mV/cm Horizontal deflection 10 s/cm





Appendix

A simplified block diagram of the PM 3400 is given in fig. 11, while fig. 12 shows the signal waveforms occurring at various points in the circuit. The input signal goes first to the trigger take-off, where part of the signal is removed for triggering purposes.

The trigger selector allows the trigger signal to be chosen from the Y_A or Y_B channel, or from an external source TRIGG IN. The trigger signal passes via the trigger selector to the trigger circuit, where trigger pulses are formed at an adjustable point on the trigger signal. These trigger pulses start the "fast ramp" (sawtooth) generator, and this fast ramp is compared with the output signal of a staircase generator.

When the amplitudes of the ramp and the staircase are equal, three things happen:

- the ramp is reset
- we climb to the next step of the staircase
- the comparator delivers a drive pulse for the sampling-pulse generator, which opens the sampling gate for 200 ps.

During the time required for the opening of the gate, the input signal passes through a 30 ns delay line. When the staircase voltage is at its lowest value, it takes about 22 ns for a sampling pulse to be generated. This means that the first sample is actually taken about 8 ns before the triggering point. Subsequent sampling pulses will be produced with a longer delay with respect to the triggering point since as we climb the staircase it will take longer and longer for the ramp to reach the same level as the staircase voltage. The input signal is thus sampled at constant intervals.

The instantaneous value of the input signal is amplified by the sampling amplifier and stored in the memory until the next sample is taken.

The staircase voltage, the amplitude of which is a measure of the amplitude of the fast ramp (and hence the time), is used to drive the X deflection of the CRT when the mode selector is set to NORMAL. The signal in the memory is

passed via the mixer (which determines whether the signal displayed is A, B, $A+B$, $A-B$, A and B or A and $-B$) to the vertical plates of the CRT. In the setting A VERT. B HOR., the B-channel signal from the memory is used to drive the horizontal deflection.

When the mode selector is set to NORMAL, the central knob of this selector varies the step height of the staircase voltage. If the step height is reduced, more steps will be needed to get to a given level, so more samples will be taken from a given portion of the signal. The number of samples can be varied in this way from 5 to more than 1000 samples/cm (50 to more than 10 000 samples per scan).

When the mode selector is set to MANUAL, the staircase voltage at the input of the comparator is replaced by a DC voltage, the amplitude of which can be varied by means of the central knob to give the MANUAL SCAN facility. Since the ramp is compared with a DC level, the sampling gate will be opened at the same point of successive periods of the input signal for a given setting of the MANUAL SCAN control; we thus get a fixed spot of light on the screen. When the potentiometer is rotated, we can scan the signal by moving this point along the trace.

In the EXT setting, the staircase voltage is replaced by an external voltage, so that the X deflection mode can be determined

externally. The potentiometer driven by the central knob now serves as a continuous attenuator.

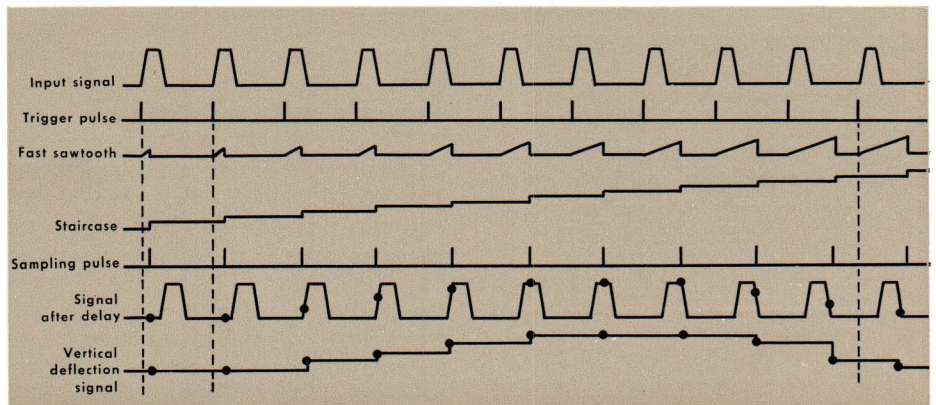
Finally, in the SINGLE setting the comparator is driven with a slow internal sawtooth, the length of which can be adjusted by the potentiometer (SCAN SPEED) between 5 and 60 s per sweep.

The single sweep is started by depressing the SINGLE START button.

The PM 3400 has four signal outputs. The A output gives the signal in channel A, the B output that in channel B, while the Y output gives the signal coming from the Y amplifier; depending on the setting of the display mode selector, this latter signal may be $A+B$, $A-B$, A, B, alternately A and B or alternately A and $-B$.

The X output gives the signal presented to the comparator, which may be the staircase voltage (NORMAL), the DC voltage (MANUAL SCAN), the external X signal (EXT) or the slow sawtooth (SINGLE) depending on the setting of the X deflection mode selector. In the position A vertical and B horizontal the X output still gives the signals mentioned above, and not the B signal.

The amplitude of all output signals is 0.5 V per cm deflection on the screen. The zero levels of the A, B and Y signals correspond to the centre of the screen, while that of the X signal corresponds to the left-hand side of the screen.



12. Waveforms present at various points in the PM 3400

Monitoring the dehydration of dialysis patients with the PM 8221 two line recorder

By R. H. Bathgate and J. F. Sistermans*

Some patients undergoing haemodialysis require constant attention to prevent or deal effectively with crises. Electronic blood-pressure and weight meters, used in conjunction with a simple two-line recorder such as the PM 8221, streamline the surveillance procedure.

There are thirty hospitals in the Netherlands with dialysis centres, where patients with chronic kidney impairment can be kept alive by means of the "artificial kidney" (haemodialyser).

Dialysis patients who drink more than permitted in their diet will put on weight, since the kidneys are no longer able to control the water balance in the organism. This represents an unacceptable load on their system, which is also reflected in hypertension. Such patients are therefore sometimes "dehydrated" during their regular visits to the centre: by suitable adjustment of the operating parameters of the haemodialyser, a net transfer of water from the patient to the external fluid circulation can be achieved; this is continued until the patient has reached the optimum weight and blood pressure again.

Now this 12-hours "slimming cure" puts quite a strain on the patient, and (especially with certain persons) there is a constant likelihood that the loss of body fluids will lead to a sudden drop in blood pressure and consequent shock, which could have serious or even fatal results if the patient is not immediately given a fluid transfusion of appropriate size, which will be determined by how much fluid he has already lost.

Patients who are known to respond poorly to this dehydration process thus have to be subjected to careful surveillance, and their blood pressure and if possible weight taken at frequent intervals in order to be able to anticipate a crisis, or at least to deal with it effectively once it occurs.

An electronic blood-pressure meter and electronic weight meter, together with a two-line recorder, form an ideal monitoring system for use in this application. The



time-consuming work of determining and plotting the weight and blood pressures is all taken care of automatically, the visible record shows at a glance the patient's condition now and the trend in his condition in the recent past; a permanent record is available for the patient's dossier; and more space is available for manoeuvring by the bedside.

The 17-bed dialysis centre at St. Joseph's Hospital, Eindhoven, is the biggest in the country, and is a leader in the use of electronic instrumentation in keeping a check on the condition of the patients during their twice-weekly day in hospital to get "new blood for old". It recently started work with a monitoring system of the type discussed above.

The monitoring set-up

A typical recording is shown in fig. 1 and the monitoring set-up may be seen from the sketch of fig. 2 and the accompanying photo.

The blood-pressure meter

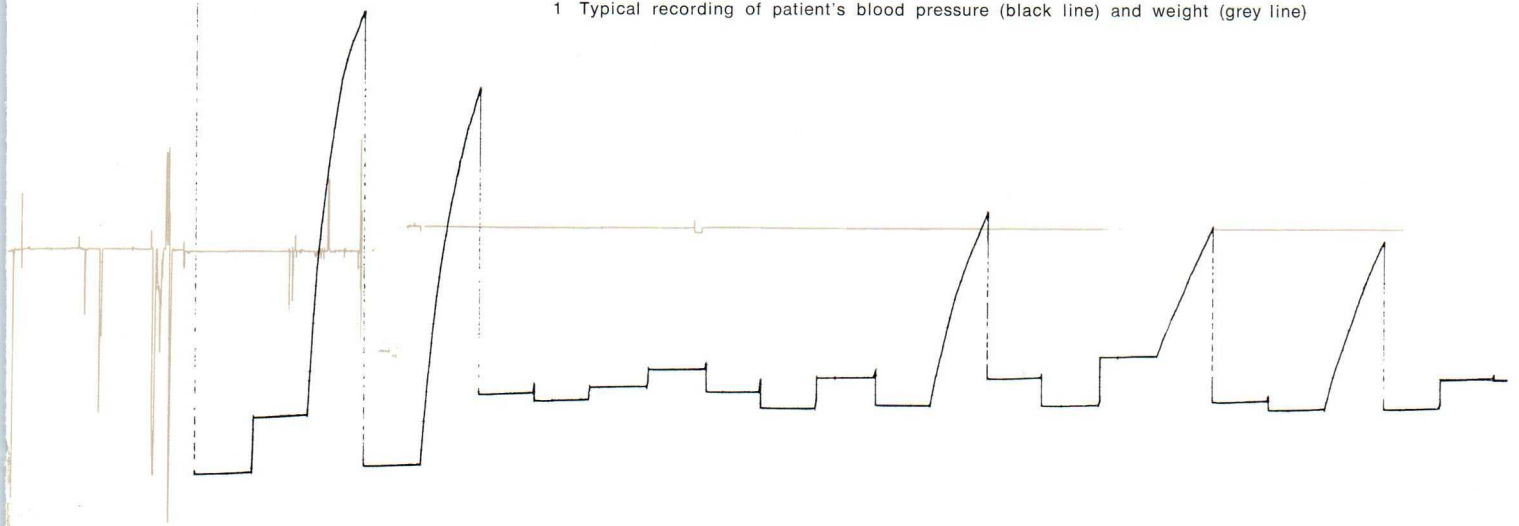
The blood-pressure meter XV 1030 works on the same basic principle as a normal blood-pressure meter: a cuff round the arm just above the elbow (it goes without saying that the arm which is *not* connected to the haemodialyser is used for this purpose) is inflated to a pressure above the blood pressure, thus cutting off the flow of blood in the arm.

The applied pressure now falls gradually until the pulse can just be sensed again, and the pressure at this moment is read off. The XV 1030 measures the blood pressure at intervals which can be adjusted from 5 minutes to 60 minutes in 5 steps.

The measured value is stored in a memory and is displayed on the front of the meter (and recorded with the recorder if the latter is used) until the next measured value comes along. The blood-pressure recording thus takes the form of a series of straight lines with abrupt transitions between them.

* Haemodialysis Centre, St. Joseph's Hospital, Eindhoven

1 Typical recording of patient's blood pressure (black line) and weight (grey line)



The weight meter

The weighing system consists of a compact strain-gauge load cell placed under each leg of the bed, and an electronic unit for processing and displaying the results. The difference between the total weight and the preset patient's weight + tare weight (weight of bed, etc.) is displayed on a dial and can be recorded on the recorder. The sensitivity of the curve on the recorder can be adjusted either by the sensitivity control of the weight meter or by that of the recorder. There is more than enough sensitivity available for this purpose; a value of about 100 - 200 g per cm on the chart is about the best for giving a clear indication of the changes taking place without too much interference from "noise".

The recorder

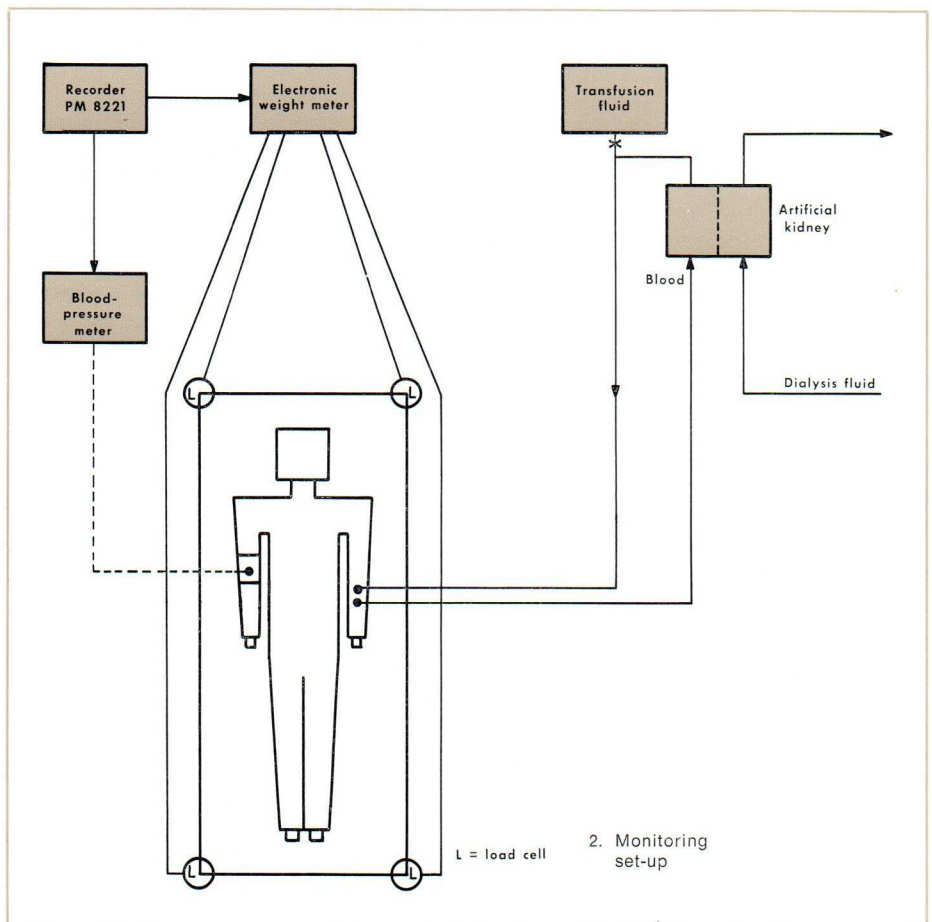
The recorder used for this application is the PM 8221 dual-pen recorder. The two pens, with their almost indestructible sapphire tips, deliver one red line and one blue line, thus providing a clear visual distinction between the two traces. The large ink reservoirs and the priming (presurizing) system by which the ink can be forced up to the pen tips by means of a rubber bulb applied to holes in the front panel make for long, trouble-free operation.

The Z-fold chart system is convenient in a number of ways. There is no long strip of paper trailing on the floor and getting in people's way during the recording; the record can be stored as a kind of book which can easily be flipped through to find a given part of the trace, which is much more convenient than manipulating with the roll of paper which is the usual form in which recordings are stored; and the Z-fold system lends itself much better to the inclusion of even long portions of the recording in the patient's dossier.

The recorder is also compact, and can easily be placed on top of other instruments or in a limited space next to them. Each channel has separate full-scale zero setting and a wide range of chart-speed and sensitivity controls; and all these controls are readily accessible on the front panel of the instrument. One practical advantage is that the sensitivity can be varied without altering the zero setting. These features, together with the 0.5% accuracy, make this recorder ideal for the present monitoring application. Its simple operation means that nursing staff not specially trained in electronic techniques, can easily learn to use this instrument.

It may be mentioned that the dialysis unit at St. Joseph's Hospital also has a 12-channel point recorder, which is widely used for the monitoring of cases where e.g. temperature, heart rate, respiration rate and systolic pressure have to be followed in addition to the above-mentioned variables.

It goes without saying that this recorder represents too much capacity for the present application; as we mentioned, the monitoring system described above is intended for backing up the treatment of critical cases, and these cases can never be planned to come along neatly six at a time.



A new digital voltmeter for bench work or automatic measurements

by H. G. Onstee

Decisions regarding the purchase of new instrumentation must be based on the expected short-term and long-term applications. With digital voltmeters as in many other fields, the long-term expectations are that automatic operation will be a must for research work as well as in production. However, in the medium-term view, there is still a definite need for a precision bench instrument for laboratory use.

Philips' new DVM, the PM 2441, meets both the above sets of requirements and thanks to its logical functional design costs no more than specialized equipment.

It is generally realized that automation of measurement as well as of production operations is becoming more and more essential, in the laboratory as well as in the factory. The demand for data is growing exponentially; and so are wages. Automation is the only way out.

However, a mass switch-over to automated measurements is hampered by the investments involved, while on the other hand there is still a definite need for normal bench equipment for the foreseeable future. One might expect that equipment that could be used for bench measurements now and could form part of an automatic measuring system in the future would be prohibitively expensive; but close analysis of the requirements made on both types of instruments and of the various functional elements of the circuitry involved has shown that this need not be the case. A concrete proof of this is Philips' new DVM, the PM 2441. High accuracy (worst-case as well as initial) with a guarded floating input and simple operation are the main features of importance for manual operation; while a high measuring rate, long-term stability and system compatibility are the plus points for automation use. Full remote control of all (really all!) functions makes this instrument ideal for application in complex systems. And it costs no more than a specialized voltmeter would. The PM 2441 digital voltmeter thus represents a safe first step towards automation of laboratory or workshop measurements, while still providing valuable facilities for hand measurements now.

The integrator/comparator, heart of a DVM

The input signal is passed via a variable attenuator and DC amplifier to the integrating analog-to-digital converter, which is of the dual-slope type. There the signal is integrated for a fixed time. The charge on the integrating capacitor is measured by discharging it at a constant current and measuring the discharge time.

This method of measuring suppresses hum and noise to such an extent that a series more rejection of 60 dB is obtained, while the response time is kept short. The converter has a basic sensitivity of 1 mV per digit, which can be increased to 100 μ V, 10 μ V or 1 μ V per digit by means of the above-mentioned DC amplifier, which has a very high stability. Thanks to the use of this DC amplifier, a high input impedance (> 1000 Mohm) is obtained up to 20 V f.s.d. Use of the above mentioned attenuator allows the range to be extended to 1000 V.

The entire analog section of the voltmeter including the integrator and comparator, is enclosed by a "guard"; isolators separate the whole section galvanically from the rest of the instrument, thus permitting floating measurements with a common-mode rejection factor of 150 dB for DC and 120 dB for AC.

Each measurement is started by the START oscillator and the length of the integration period is determined by the fixed number of pulses from the clock frequency generator. The discharge time is counted by measuring the number of clock pulses during this time.

Each reading is stored in a memory until

it is complete and then transferred to the display; this eliminates blinking.

Controls

The range-selection controls of the instrument can be made fully automatic, even for normal bench use. If the reading in a given range would be less than 01800 or more than 19999, the voltmeter then automatically switches to the next more sensitive or less sensitive range, thus ensuring that the reading displayed always consists of at least 4 digits.

In the AUTOMATIC mode the integration time is 100 msec, and the START oscillator is set to give 4 measurements per second. However, special provisions are made to increase the measuring rate to a maximum as long as the range selector has not yet reached its final setting (which will give a reading between 1800 and 20 000). In this way, the range setting time is reduced to a real minimum. A switch on the front panel allows the automatic ranging to be switched off: this permits all measurements of a given series to be made in the same units, which can be useful for purposes of comparison.

For system use, two plug-in cards are inserted into the voltmeter. One of these is a remote-control input unit which takes over all control functions from the front panel, while the other is an output unit which gives the reading with sign and range setting in BCD code at a 50-pole output socket. In addition, the measuring rate can be increased to 20 or 100 measurements per second (and the integration time decreased accordingly), as measuring systems often require measurements to be made at very high speed.

In both the manual and the remote control settings, the start of the measurement can be synchronized with external events. To give optimum accuracy and stability, the start of a measurement is always triggered by the clock oscillator.



Accuracy means more than a specified tolerance at a given temperature under optimum conditions. With high-precision instruments, great attention must be paid to secondary error sources to bring the operational accuracy close to the initial accuracy. The influence of temperature and humidity, long-term drift, mains-voltage variations, noise, common-mode and series-mode signals, loading of the signal source by the input impedance of the voltmeter and kick-back signals are all factors which can decrease initial accuracy drastically. By paying close attention to all these points, the design, development and production teams have succeeded in reducing the specified error of the PM 2441 to 0.03% of reading plus 0.03% of full-scale deflection (f.s.d.) under all conditions.

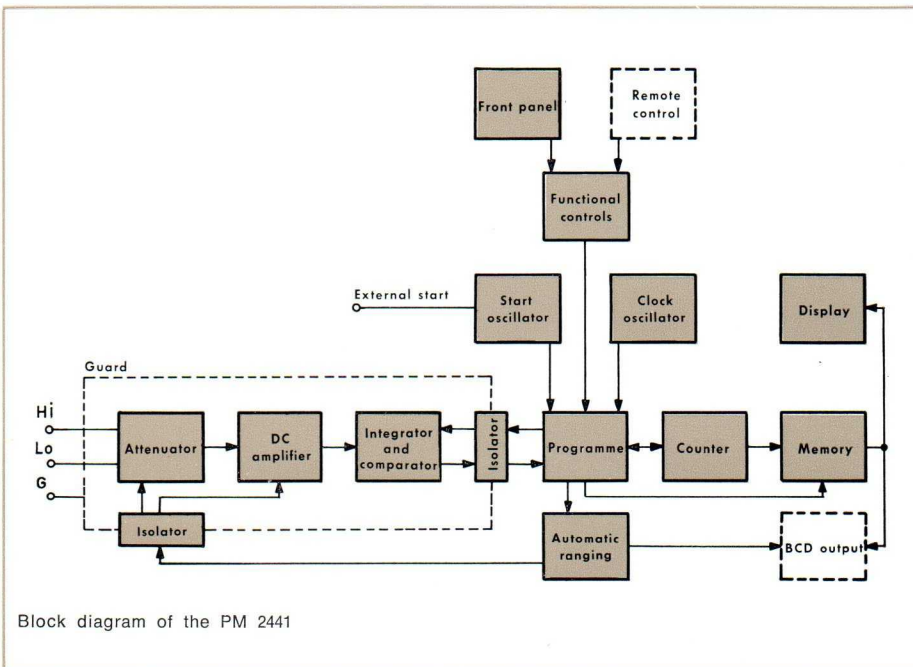
Error

The initial error of a measuring instrument is defined as the guaranteed maximum error under reference conditions. For the PM 2441, this amounts to 0.005% of f.s.d. + 0.005% of reading at $23^\circ \pm 1^\circ\text{C}$. This results in an average error of not more than 1 digit under very good measuring conditions. However, the „operational error“ is often of more relevance in practice. This is defined as the maximum error which can occur under normal operating conditions over a long period. If temperature coefficient, long-term drift, noise etc.

are taken into account separately, we can get a reasonable estimate of the maximum error to be expected. But the parameter which is really meaningful in practice is the worse-case error, which is specified as 0.03% of reading + 0.03% of f.s.d. for the PM 2441; this represents the over-all limits of accuracy under real practical conditions.

These error limits represent the sum of the contributions from all secondary error sources, and thus form in a way a recapitulation of a large number of other points in the technical specifications. For

example, one source of error is loading of the signal source by the input impedance of the meter. In order to keep this contribution so low that the over-all worst-case error is not exceeded, the input impedance must be made very high. The PM 2441 offers a range of input impedances (depending on the operating conditions) going up to 10 000 Mohms. This means that even when the source impedance is up to 20 Mohms, the over-all error of the instrument can still be kept within the above-mentioned limits. The noise levels encountered in practice will never add appreciably to the error signal when the full integration time is used; the same goes for kick-back signals. The guarded input gives a very high common-mode rejection factor. As mentioned above, the guard separates the input circuit from the rest of the instrument. All connections through the guard are made via isolators, which give an isolation of about 60 000 Mohm in parallel with 0.7 nF between the input and ground. Thanks to this very high impedance, unbalance between the high and low connections has an almost negligible effect on the accuracy of the reading, so that full use can be made of the voltmeter for floating measurements too. The range of integration times available enables the user to reach the best possible compromise between measuring speed and series-mode rejection; and to ensure that all digits displayed are meaningful, the last digit is blanked out when the controls are set to the shortest integration time.



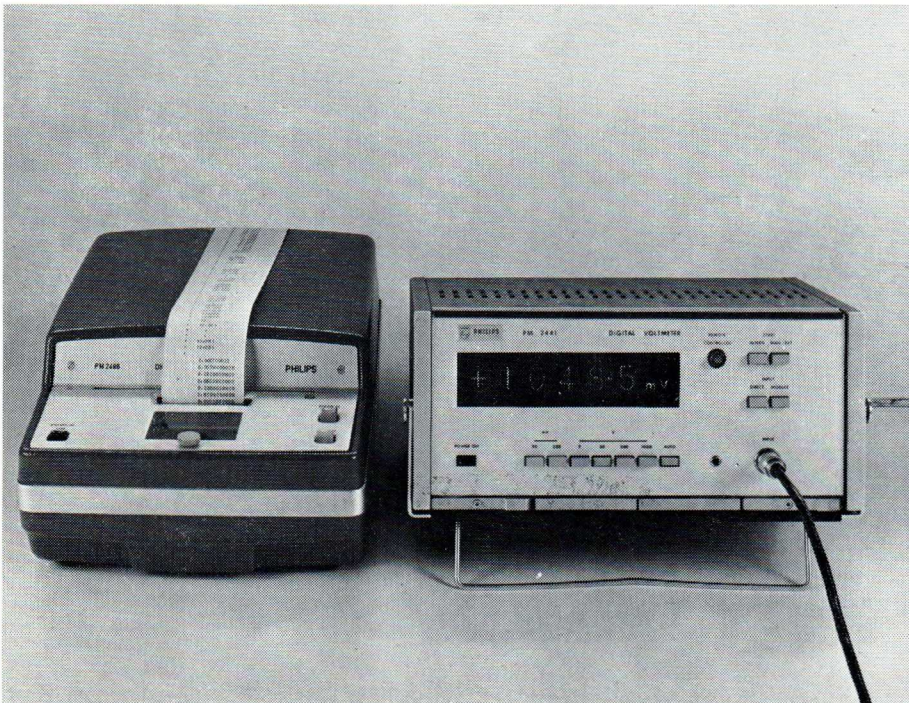
When the PM 2441 is used in the AUTOMATIC mode, the intervention of the operator is really brought back to the absolute minimum: all he has to do is to make sure the signal voltage gets to the meter. Within a fraction of a second the meter then displays the sign of the reading (+ or —), the reading proper with optimum resolution (the quantity measured may have any value between 1 μ V and 1000 V), the decimal point in the appropriate place and the unit (mV or V). And operation is ultra-safe: safe for the operator, and safe for the circuitry. The voltmeter can take an overload of up to 1000 V on all ranges, and even double this amount won't damage the instrument. Moreover, as we have seen, a high accuracy is guaranteed, since secondary error sources can generally be neglected; in cases where a slightly higher error than normal may be expected, the instrument automatically blanks out the last digit of the display. And the PM 2441 is nice and small for a fully automatic instrument.

Use of the PM 2441 in measuring systems

For the purposes of data acquisition, the PM 2441 can be used in combination with analog scanners, counters, a digital clock, Philips' automatic printer control unit (PM 2465) and various types of printers or punchers. Depending on the requirements, the system used can be made very simple, or very complex. All the units

mentioned above are available in the Philips programme. One very important feature of Philips' range of automatic measuring instrumentation is that all interconnections can be made with standard components, thus reducing system engineering to a real minimum. An example of such a system has been described in these Notes (1972/3). As mentioned above

the measuring speed for systems applications can be increased to 100 measurements per second, with a 1+3 digit reading. Both the remote-control input and the digital output (BCD (8421) coded, positive logic) are compatible for all levels from TTL level to 15 V. All control facilities available on the front panel, can also be realized by remote control, thus making the instrument suitable for incorporation in any system. A special version of the PM 2441 designed for rack mounting is available on request. This instrument has a module connection on the rear panel, intended for plugging in additional modules permitting automatic measurement of resistance and AC voltage (under development). These additional modules will be designed to fit into the rack-mounted version of the voltmeter.



This is the fifth and last instalment of part 1 of our five-part course on digital instruments based on a successful series of lectures given to the instrument specialists of Philips' European sales organisation

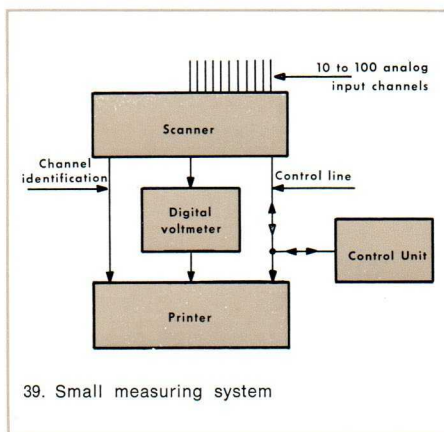
Interfaces

In the language of modern technology, the combination of a number (often a large number) of instruments, machines, etc, for a single or over-all purpose is called a "system". Thanks to the simplicity of their "logic", digital measuring instruments lend themselves very well to use in test systems.

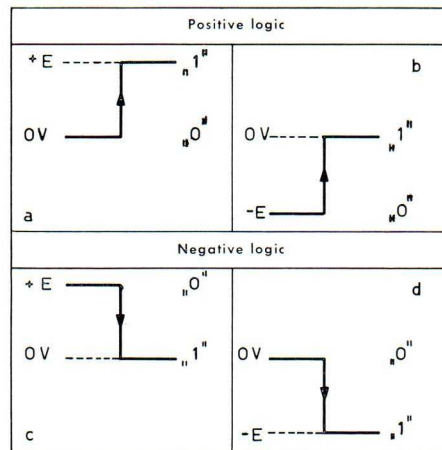
An example of a simple system is a digital voltmeter (DVM) and a printer. The value measured by the DVM is encoded (e.g. in the BCD code) and transported to the printer. In this example the instrument (DVM) has a digital output, figure 39.

One can also imagine an instrument being remote-controlled by means of digital signals (in case of the DVM, e.g. the voltage range could be controlled in this way); the instrument then also has a digital input. It follows that one could build up a more or less automatic measuring system by connecting the digital inputs and outputs of the instruments involved in some appropriate way. Addition of a computer to the system would make it fully automatic.

In order to get all these instruments working together, it is necessary to establish a standard digital "language" for the various signals passing between them. These signals (mostly in digital form) are processed in the "interface" (a special circuit in which the connections between the instruments are realized). This interface can be regarded as a kind of trans-



39. Small measuring system



40. Logic polarities

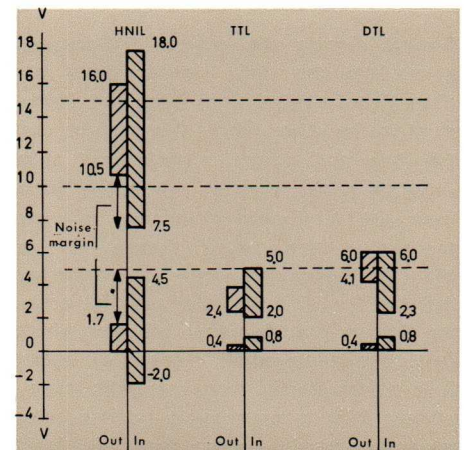
lator for the various communication signals passing to and from the instruments in the system. As there are no international standards for digital systems yet, the interface can also play the role of interpreter for the various logics.

Logic polarity and level

First of all, the *logic polarity*, must be defined; either positive or negative logic can be used, as described in the previous instalment. The two offer equal performance and flexibility (figure 40). Secondly, the *logic level* must be fixed. Any voltage could be used in theory, but in practice we naturally tend to choose the levels used in standard integrated circuits (e.g. 5 V TTL; 6 V DTL; 12 V HNIL). The choice of the type of IC family used in the instrument thus more or less defines the logic levels.

Each level has its specific advantages and disadvantage. The levels typical of DTL (6 V) and TTL (5 V) have the advantages of rather low price and direct compatibility with other instruments using these types of IC's (and this includes most of the instruments made today). They have, however, the big disadvantage of poor noise immunity and poor protection against overload (figure 41).

The higher logic levels (such as HNIL), however, have the disadvantages of higher



41. Logic levels (HNIL, TTL, DTL)

price, slower speed and restricted availability which weigh against the big advantages of good noise immunity and good overload protection.

Depending on the technical requirements on the signal lines between the various instruments, a lower or a higher voltage level will be chosen.

Data signals and control signals

The various digital signals passing between the instruments can roughly be divided into two main groups:

- a. Data signals
- b. Control signals

a) *Data signals* are the signals which contain information concerning the results of measurements (e.g. the BCD output of counters or DVM's) or concerning the remote control of an instrument.

In case of a 9-digit counter, the output data would contain $9 \times 4 = 36$ bits. As regards the use of data signals for programming (control) purposes, a two-position switch can be controlled by one bit or information (e.g. "0" is OFF and "1" is ON), while e.g. a 6-position rotary switch (for selection of the voltage range, for example) can be controlled by 3 bits of binary encoded information.

* The numbers of figures tables and questions is consecutive throughout the whole course

b) *Control signals* are signals which do not contain DATA, but morely initiate or prevent a certain action, e.g.:

- START (starts the measurement of e.g. a DVM or counter)
- READY (gives the information that the DVM (or counter) has completed its measurement)
- CALL (sets the required signal at the output of an instrument - e.g. output voltage of power supply or generator).
- INHIBIT (prevents the start of a new measurement by a counter or DVM until another instrument (e.g. printer) has fully processed a previous batch of data from the instrument involved)
- STOP (stops the instrument)

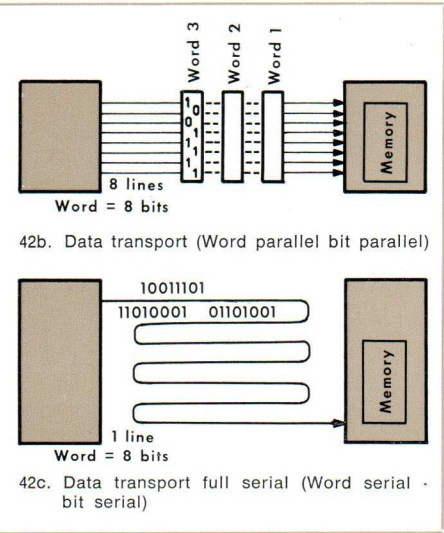
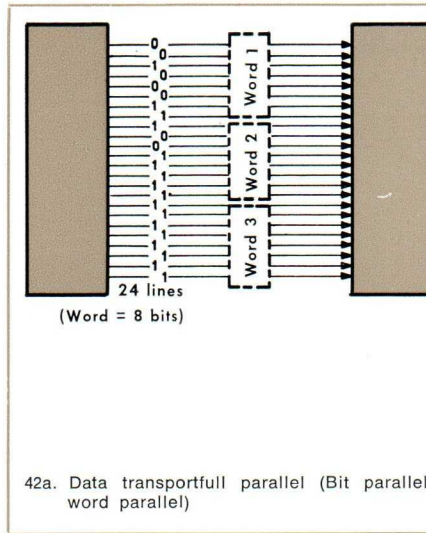
Control signals are generally processed apart from the data signals; there are often direct control lines from one instrument to the other, since this ensures that the data and control signals kept quite separate at the cost of only a few extra lines. DATA signals often require more processing than control signals. This is easy to understand when we remember that e.g. the BCD output of a 9-digit counter already has 36 output bits and would thus require an equal number of output lines unless special measures were taken), while a fully programmable modern pulse generator requires more than 100 input bits (lines). Especially when these DATA have to be transported, the number of lines involved can give trouble.

A number of data signals (bits) are generally grouped together in a WORD (or BYTE). Such a word can contain any number of bits (8, 12, 16, etc.).

Now the transport of DATA generally occurs in one of three different ways:

a) Full parallel (figure 42a). All signals (words and bits) are sent (or received) simultaneously. The advantage of this method is the speed at which the transfer is realized; the disadvantage is the higher number of lines required.

b) Word serial - bit parallel (figure 42b). Here the total information is split up into N words, each containing P bits. The words are transferred one after the other, while the bits in each word are transferred in parallel. Since the information is not all sent at the same time, the receiving instruments need a STORAGE (or memory, e.g. D flip-flops) for the information contained in the various words. The disadvantage of this method is quite clear: it takes at least N times longer to transfer all the information. The advantage on the other hand, is that only P lines are required (N times less than in full parallel).



c) Full serial (figure 42c). In this mode of transfer not only the words but also the bits in each word are transported one after the other: first of all the bits of the first words are transferred serially, then those of the second word and so on. Here too, the receiving instrument requires a memory. It will be clear that the transfer speed is drastically reduced in this method (N x P times compared with full parallel). The great advantage, however, is that only one signal line is needed, which can be very useful for transmission via telephone lines, radio lines etc.

Code conversion

As we have explained above, digital signals have quite a number of different parameters which may have to be changed at the interface between two different parts of a system, or between two different systems. We shall now discuss the various converters, used for this purpose.

a) *Positive to negative logic converter* (and vice versa)

This is in fact nothing but the NOT gate or inverter mentioned earlier in this course (figure 43).

b) *Logic-level converter*

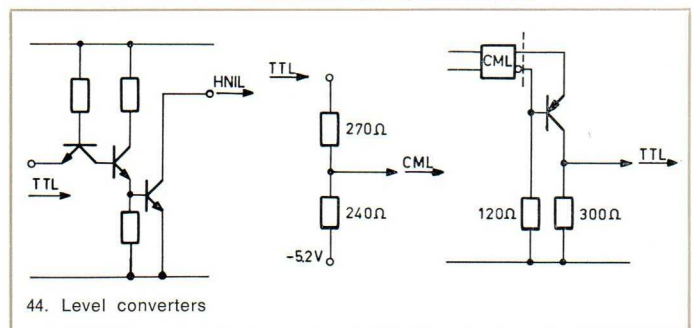
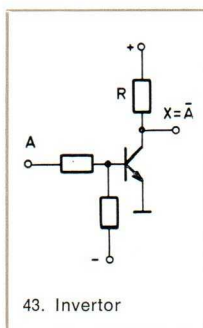
Conversion of a logic level generally means amplification of the logic signal (low to high) or an attenuation (high to low). The average DC value is sometimes shifted at the same time. For low-to-high conversion one or more transistors are used, while either active or passive de-

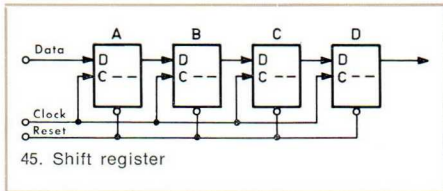
vices (resistor networks) can be used for the opposite conversion. Some examples are shown in figure 44.

c1) Series parallel converter

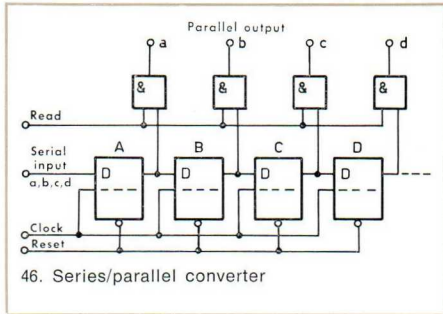
Serial data can be converted into parallel by means of a shift register.

In a shift register a number of flip-flops are connected in series as shown in figure 45 (where D-type flip-flops are used). In order to understand the operation of this circuit, let us suppose that a logic "1" is applied to the D input of flip-flop A. As long as there is no clock pulse, nothing happens (as we saw in instalment 3 of this course), but as soon as the clock pulse is given the "1" at the input of flip-flop A will also appear at the Q output, and hence at the D input of flip-flop B. One clock pulse thus shifts the "1" at the input of flip-flop A one flip-flop (one binary place) to the "right", to the input of flip-flop B. The next clock pulse shifts this "1" one place further and so on, until at the fifth clock pulse the "1" is shifted out of the register. When now e.g. a 4-bit serial-data word a, b, c, d is applied to the input of the shift register as shown in figure 46, in such a manner that bit d (which can be either "0" or "1", as can a, b and c) is the first to enter, then after the first clock pulse flip-flop A contains bit d, after the next clock pulse bit d is shifted to flip-flop B and bit c enters flip-flop A and so on, until after the fourth clock pulse the four flip-flop A, B, C and D contain the bits a, b, c and d, which remain there until the shift register is reset. It is obvious that clock rate and data rate must be synchronized.

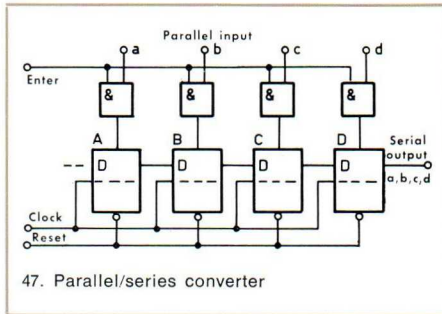




45. Shift register



46. Series/parallel converter



47. Parallel/series converter

Truth table

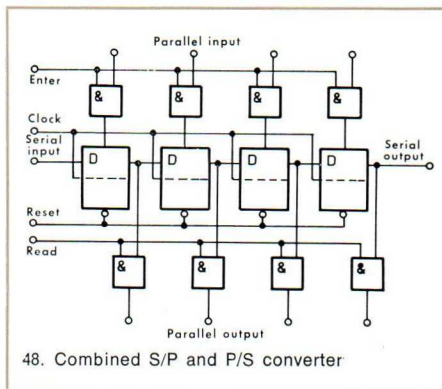
Clock pulse	Q _A	Q _B	Q _C	Q _D
0	0	0	0	0
1	d	0	0	0
2	c	d	0	0
3	b	c	d	0
4	a	b	c	d

The data is now available in parallel form at the outputs of the four flip-flops, and can be read out via the four AND gates shown in fig. 46, with the aid of a read pulse. It will be clear that the capacity of this converter can easily be expanded by adding more flip-flops to the shift, and an equal number of AND gates.

c2) Parallel series (P/S) converter

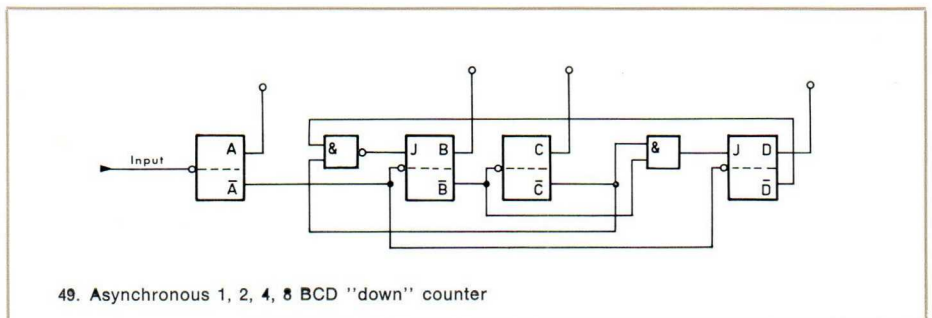
The circuit diagram of the parallel series converter is given in figure 47. This circuit also uses a shift register the other way round. First the parallel data are fed into the appropriate flip-flops by means of the ENTER pulse. (For this purpose, the flip-flops used have a special input for setting them independent of the previous state). After the first clock pulse, bit "d" appears at the output and bits a, b and c shift one place to the right. The second clock pulse will then produce bit "c" at the output while bits a and b shift one place further and so on. After the fourth clock pulse (in this example) the parallel word will have been completely transformed into a serialized version.

Because of the great similarity between S/P and P/S converters, it is an obvious idea to combine the two into a single circuit. This combined converter is depicted in figure 48, which is self-explanatory.

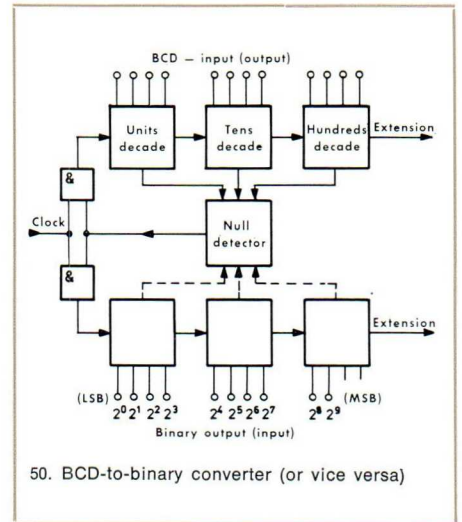


48. Combined S/P and P/S converter

d) Binary-to-BCD converter (and vice versa)
 BCD-to-binary conversion is sometimes used to cut down the number of lines needed for the transport of large amounts of data (only 3.3 binary bits are needed for one decade, as compared with 4 BCD bits). The disadvantage of the pure binary code is that it is not easily readable, so a binary-to-BCD converter will generally be needed too. There are many possible ways of carrying out this conversion; the one described below makes use of forward and reverse counters. The down counter only differs with the normal BCD or binary up counter (described in instalment 4 of this course) in that at each clock pulse the total BCD or binary value stored is decreased by 1 bit (so that e.g. 0111 becomes in turn 0110, 0101, 0100, 0011 and so on). The logic diagram of such a BCD down counter is shown in figure 49.

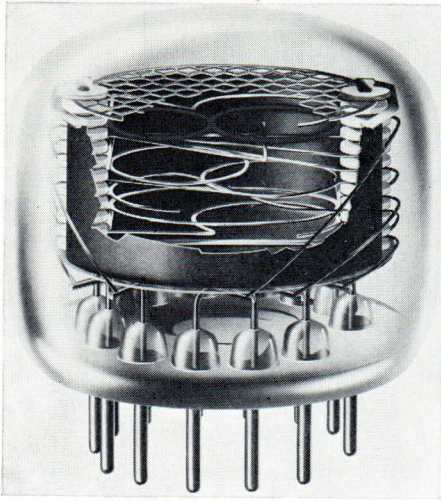


49. Asynchronous 1, 2, 4, 8 BCD "down" counter



50. BCD-to-binary converter (or vice versa)

Now a BCD-to-binary converter works as follows: First the appropriate BCD value is set in the BCD down counter (as done by the parallel/series converter). Then the clock pulse is applied simultaneously to the BCD chain (figure 50) and to the up-counting binary chain. At each clock pulse the value stored in the BCD chain decrease by one bit, while that in the binary chain increases by one bit, in a pure binary fashion. As soon as the contents of the BCD counter have become zero, which is detected by the NULL detector, both AND gates in figure 50 are closed, and counting is stopped; the binary chain now contains the pure binary equivalent of the value initially set in the BCD chain. The mechanism of the conversion from binary to BCD is indicated in figure 50 by the dotted lines; in this case the BCD chain will be a 1, 2, 4, 8 "up" counter and the binary will be a "down" counter. As with the S/P converters, the similarity of the two BCD-to-binary and binary-to-BCD converters often leads to their being combined in one circuit.



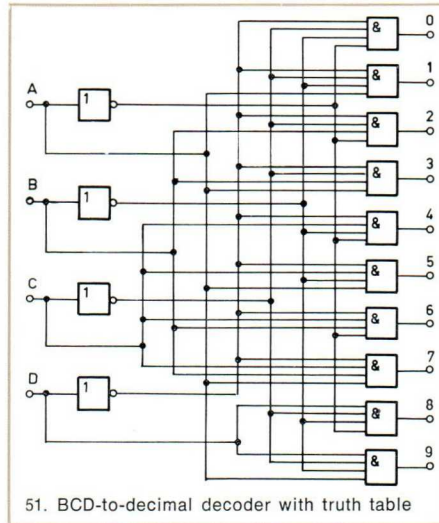
Example of a numerical indicator tube

e) *BCD-to-decimal converters*

In many cases BCD information has to be converted into decimal form, e.g. for driving numerical indicator tubes (NIT's). Special decoders have been developed for this purpose. The logic diagram of such a decoder is given in figure 51.

The BCD value applied to inputs A, B, C and D is decoded and will cause one of the decimal outputs to become high. Let us assume by way of example that the information presented at the input is the BCD value for 6, so A and D will be low and B and C will be high. When D is low, the inverter following D will make the signal high again and the upper input of gate 6 will be high. Input C, which is high, is directly connected to the second input of gate 6 as is the case with input B. Finally input A will also after inversion, give a high at gate 6, resulting in 4 highs at the AND gate, so the output will be high and all other outputs will remain low, because at least one of their inputs will be low.

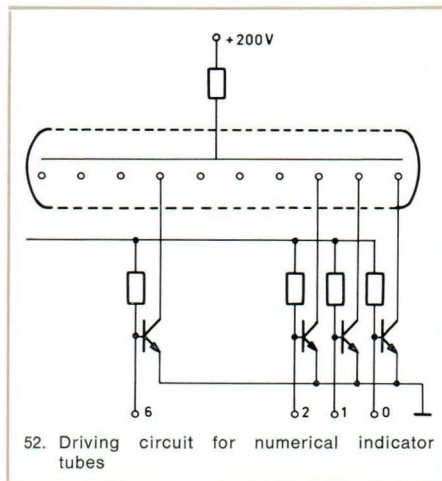
As can be seen from figure 52, a high level at the decoder's output will open the appropriate driving transistor for the NIT, causing ignition of the proper cathode; in the present case, the digit 6 will light up. In modern IC's the drive transistors (10 of them) are incorporated in the decoder, giving direct compatibility between the BCD code and the numerical indicator tube. A specific feature of the decoder circuit shown in figure 51 is the fact that the forbidden states of the BCD code (positions 10 to 15) are recognised and all outputs are then held low (see also truth table).



51. BCD-to-decimal decoder with truth table

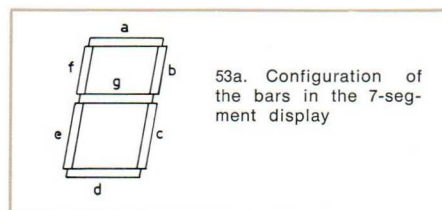
Truth table

Inputs				Outputs										Dec	
A	B	C	D	0	1	2	3	4	5	6	7	8	9		
0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	2
1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	3
0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	4
1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	5
0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	6
1	1	1	0	0	0	0	0	0	0	0	1	0	0	0	7
0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	8
1	0	0	1	0	0	0	0	0	0	0	0	0	1	0	9
0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0



52. Driving circuit for numerical indicator tubes

The "seven-segment display" (fig. 53a) is another type which is becoming quite popular nowadays. This numerical indicator contains 7 bars positioned in such a way that the required figure can be displayed



53a. Configuration of the bars in the 7-segment display

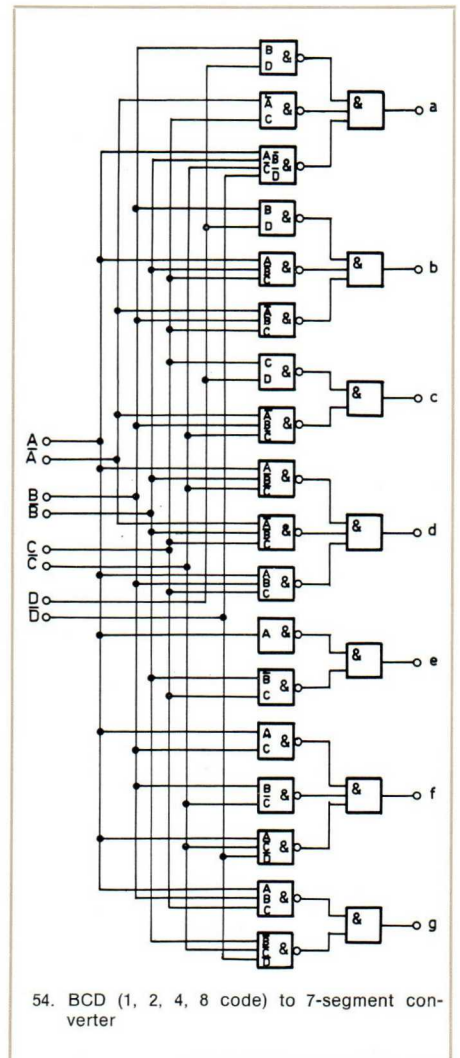
DEC.	D	C	B	A	a	b	c	d	e	f	g	DIS-PLAY
0	0	0	0	0	1	1	1	1	1	1	0	0
1	0	0	0	1	0	1	1	0	0	0	0	1
2	0	0	1	0	1	1	0	1	1	0	1	2
3	0	0	1	1	1	1	1	1	0	0	1	3
4	0	1	0	0	0	1	1	0	0	1	1	4
5	0	1	0	1	1	0	1	1	0	1	1	5
6	0	1	1	0	0	0	1	1	1	1	1	6
7	0	1	1	1	1	1	1	0	0	0	0	7
8	1	0	0	0	1	1	1	1	1	1	1	8
9	1	0	0	1	1	1	1	0	0	1	1	9

53b. Truth table of 7-segment display decoder

by selection of the appropriate bars. For example, when the decimal digit 4 has to be shown bars b, c, f and g are illuminated. Of course, a special decoder is required for driving such an indicator from a BCD code. As a BCD-to-decimal decoder already exists, a decimal-to-7-segment decoder would be sufficient - but it is simpler to combine the two converters into one. The logic diagram of such a decoder is shown in fig. 54, and its truth table is given in fig. 53b. These are self-explanatory.

f) *Digital-to-analog converters*

It is often necessary to change binary or



54. BCD (1, 2, 4, 8 code) to 7-segment converter

BCD data into an analog signal. Where output data is concerned, this conversion may be needed e.g. to make the signal suitable for driving a recorder, while with input data it may be needed e.g. for controlling the frequency range of a signal generator. The simplest form of a digital-to-analog converter (DAC) is illustrated in figure 55. The summing resistors of an operational amplifier are weighted in a binary fashion (i.e. $R_1:R_2:R_3... = 1:2:4$) and all are connected via an electronic switch (logic gate) to a reference voltage or to ground.

A logic "1" applied to a given input connects the corresponding resistor to the reference voltage and increases the output voltage by the binary weighted increment in question. When all inputs are "1", the output is maximum. A big disadvantage of this simple weighted-resistor approach is that the value of each input resistance is twice the preceding one, so absolute values become quite large. Furthermore, because the resistances are spread over such a wide scale, it becomes rather difficult to match the resistors in physical properties such as tolerance, temperature stability and so on, so that it is no simple matter to design a reasonably stable, accurate converter on this basis.

One way of overcoming these problems is to make use of the "R-2R ladder" network illustrated in figure 56. This works as follows:

If one "leg" of the ladder is connected to the reference voltage by means of the electronic switch and the remaining "legs" are grounded, a current is produced in the first-mentioned leg and travels through the ladder, being divided by a factor of two at each junction.

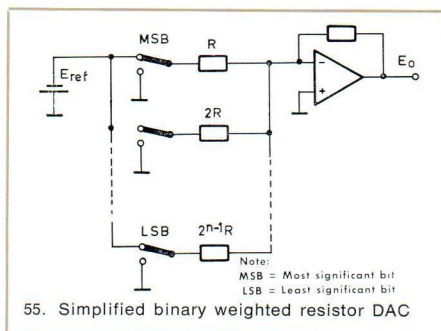
The current contribution from the "leg" (e.g. bit) in question at the summing input of the operational amplifier is thus given binary weighted in accordance with the number of junctions through which it passes; hence the LSB (least significant bit) is on the far left of the circuit shown. A very specific feature of the ladder converter is that the input resistance of the operational amplifier is independent of the binary word.

The above two converter types are pure binary. It is of course easily possible to adapt the circuits to BCD logic.

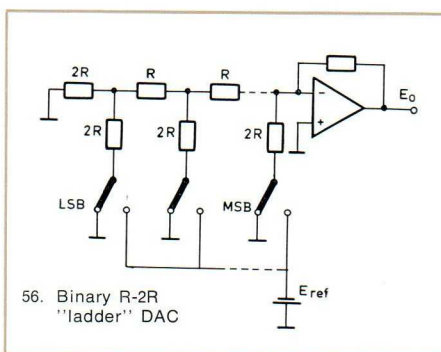
In the case of the weighted-resistor arrangement, we only have to change the resistances and not the basic configuration (fig. 57). The R-2R ladder may be

adapted to BCD by using R-2R subsections for each decade and summing these in parallel, with additional decade-weighted resistors (fig. 58).

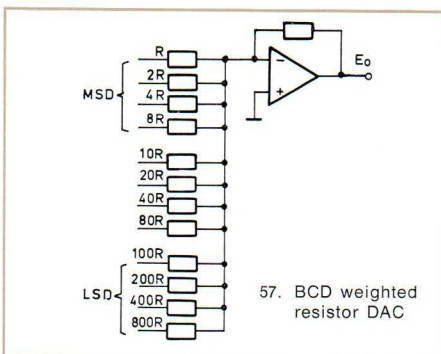
It should be noted that a 3-decade BCD-DAC (with 12 lines) has a basic resolution of 0.1% (1 part in 1000). In a pure binary set-up, the same number of lines would



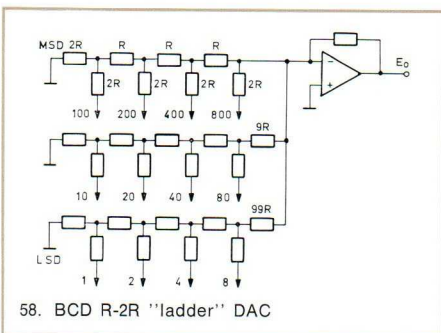
55. Simplified binary weighted resistor DAC



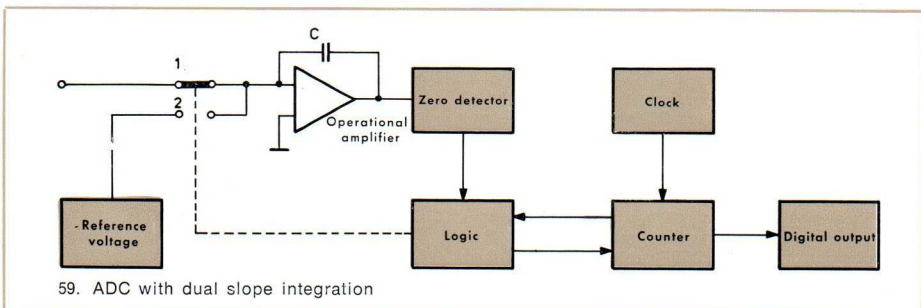
56. Binary R-2R "ladder" DAC



57. BCD weighted resistor DAC



58. BCD R-2R "ladder" DAC



59. ADC with dual slope integration

give a resolution of 0.025% ($2^{12} = 4096$). This illustrates once again that pure binary coding makes more efficient use of the capacity available than BCD (which as we know is caused by the 6 unused code combinations of BCD).

g) Analog-to-digital converter (ADC)

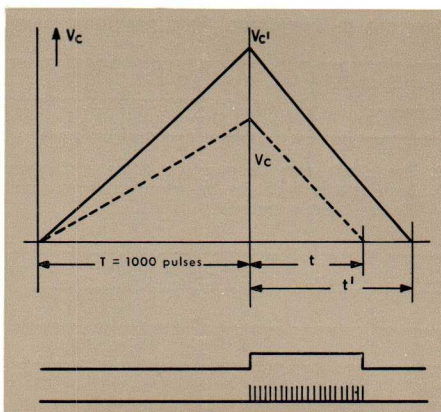
As most physical or electrical properties which need to be measured or analysed are in analog form, we will need a converter for making analog data suitable for processing in digital systems.

The digital voltmeter (DVM) is one of the most important examples of analog-to-digital converters. A detailed description of this instrument really belongs to a separate chapter. However, for the sake of completeness we shall give here a brief description of one of the most popular basic circuits used in DVM's, that is based on the dual-slope integration method. (fig. 59).

When switch 1 is in position 1 for a fixed time T, the input voltage V_i will be integrated as a charge in capacitor C; V_c is thus a linear function of V_i .

After this fixed integration time, switch 1 is opened and switch 2 is closed so as to connect V_{ref} to the input of the operational amplifier. However, care must be taken to ensure that V_{ref} is of opposite polarity to V_i . The capacitor C will now be discharged with a constant current (since V_{ref} is constant). The time t needed to discharge C completely is thus a linear function of V_c and hence also of V_i . In practice, the circuit operates as follows. On receipt of a start pulse switch 1 is closed and the counter starts counting 1000 clock pulses (fig. 60).

Upward integration in capacitor C is started with a slope depending on V_i . After the 1000 pulses, the switches are reset so that V_{ref} is connected to the amplifier input while the counter (which has been reset to 0) is started again. The capacitor is now discharged with a constant slope. As soon as the zero detector at the output finds that V_c is zero, the counter is stopped. The pulses counted by the counter in this way thus have a direct relation with the input voltage. If a BCD counter is used the original analog value is converted into BCD code, while a pure binary counter gives conversion into binary code.



60. Time diagram of dual-slope ADC

Measuring systems

As we mentioned above, the great advantage of digital signals is the ease of building test systems which use such signals. In view of the present trend from manual testing and measurement via semi-automatic systems to the use of fully automatic and computer-controlled systems, it would seem to be worth while to conclude this instalment of our course with a short description of the various systems involved. In general, automated electronic measurement systems can be defined as a combination of a number of electronic instruments, controlled by some central unit. This central unit cannot only control the operation of the individual instruments but also determine the *sequence* of the measurements more or less automatically, and make it possible for the operations of

- a. sorting
- b. recording
- c. calculating

Kinds of automated measuring systems

We can sub-divide automated measuring systems into three groups:

1. Programmer-operated systems

These are preset test and measuring setups with partly manual control or operation. The various test programmes are preset *manually* (e.g. by means of a diode matrix) in the central unit (programmer) and are initiated by a push-button, or by automatic sequencing.

2. Controller-operated systems

These test and measuring systems have simple processing facilities (e.g. sorting and recording), but no calculation facilities. The various test programmes are stored on punched tape or another medium in the central unit ("controller").

3. Computer-operated systems

These fully automated measuring systems have all processing facilities, e.g.

- a. sorting
- b. recording
- c. computing

The various test programmes are stored in a computer memory, or on punched tape.

Organisation of automated measuring systems

1. Star system (fig. 61)*

Each instrument is individually connected to the central unit by its own bundle of control lines.

In STAR systems, the programming information is given as levels; or in other words, for each code a continuous control level is applied as long as a certain function is required. A "programmer" (programme board) is often used for presetting the programme of operation in such systems. Inserting diode pins at the appropriate spot in the programme board closes a contact to ground, thus giving the right voltage level at the right place in the system. Further, a programmer normally carries a number of push-buttons, each of which activates a complete test programme by controlling a number of lines (e.g. 64). It will often also have a number of analog control lines by means of which continuous functions can easily be set.

The input and output information of a STAR-programmed instrument is given simultaneously via a separate input and output connector.

2. BUS-line system** (fig. 62)

All instruments are connected to the central unit via a common set of lines.

For each test, the instrument is "activated" by means of the appropriate INPUT/OUTPUT LINES (I/O lines) and the ADDRESS and FUNCTION lines.

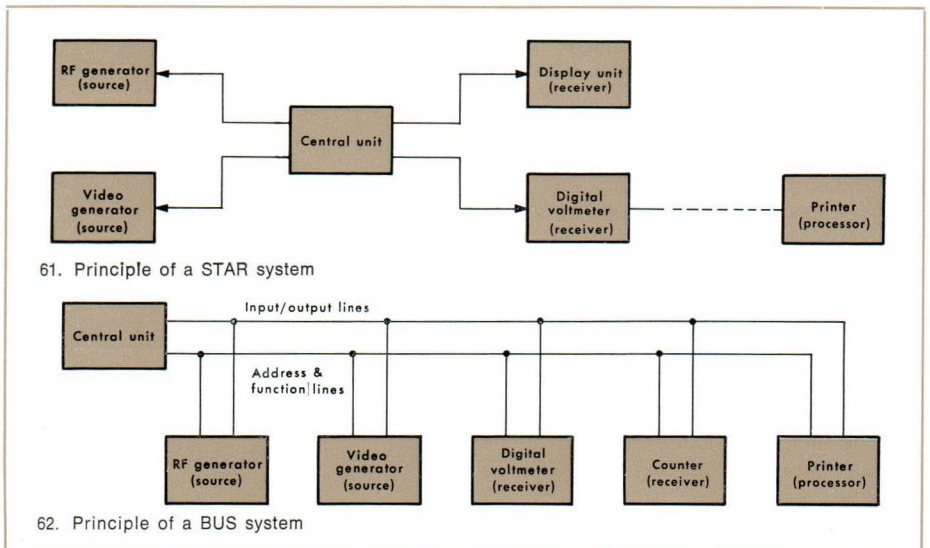
In BUS-line systems, the programming information is given as a number of pulses. Because of the short duration of these pulses, the programming information must be stored in the instrument to be programmed by means of a "memory". This memory retains the information as long the functional setting of the instrument is required. When a new setting is required the memory is first reset and then the new code is read in.

Because *all* instruments to be programmed are connected in parallel to the DATA BUS line, measures have to be taken to ensure that only one specific instrument is set during each run of coded information, while the next run of pulse codes will set another instrument. For this purpose each instrument has its own ADDRESS, given via a separate ADDRESS BUS LINE. Only when the instrument recognises its own address will it read the information on the DATA bus. The DATA bus line is generally designed as a DUAL DATA BUS, in other words can be used for both input and output information, depending on the instrument concerned and on the code given on the ADDRESS bus.

This sequential provided information makes the BUS-line system ideal for computer or punched-tape control.

* An example of a STAR-operated system is given in T&M Notes 1971/3.

**Also called "Party-line" system, "Serial system", "Highway system" or "Dataway system" in the literature.



Answers to questions from previous issue

Questions:	22	23	24	25	26	27	28	29	30
Answers:	A	B	B	B	B	B	B	C	A

22. The diode gate in question is an AND gate (answer A) which can be very well seen from the truth table below:

A	B	X	Diodes
0	0	0	Both conduct
1	0	0	D_B conducts
0	1	0	D_A conducts
1	1	1	Both cut off

23. The circuit can be either a NOR or a NAND-gate depending on the values of the resistors in the circuit.

When the input resistors are chosen so that the transistor can only conduct when all inputs are LOW, the circuit is a NOR gate, in other cases it will be a NAND gate.

24. The circuit is a NAND gate (answer B) because the output is LOW when any one transistor or both transistors conduct (Input LOW).

25. The correct answer is B. As a matter of fact, answer A is also correct. However, this solution has the disadvantage that all three inputs (tied together) could be connected to the output of another gate and thus loading the latter unnecessarily.

26. A positive pulse must be applied to the base of TS_1 (Answer B - Set input). TS_1 is then cut off, causing the base voltage of TS_2 to drop; TS_2 then starts to conduct, making output Q (an hence the base of TS_1) more positive. This gives a new stable state.

27. The stand-off diodes are included to increase the threshold level (The voltage drop over the diodes have to be added to the switching signal).

28. Answer B is correct, as can be seen clearly from the table: 2.4 V is the minimum output voltage of a TTL gate in its HIGH state. A noise signal of more than 0.4 V added to the output brings the signal into the undefined region of the logic gate.

29. The basic HNIL gate is nothing but a DTL gate with a higher threshold voltage, which means that the basic HNIL gate is also a NAND (Answer C).

30. As we explained, keeping semiconductors out of saturation increases the switching speed which is one of the features of ECL; so answer A is the right one. (The emitter coupling features a larger fan-out; positive or negative logic is of course only a matter of definition and has nothing to do with the actual circuit parameters).

DXing and DX expeditions

by P. Zwart

In mid-1962, the Archipelago of San Felix/San Ambrosio became the target of a group of ambitious DXpeditioners. The islands, which straddle the 80th parallel, are Chilean territory and are approximately 560 miles east of the nearest Chilean mainland.

The two simple letters DX mean a lot to a radio amateur but are rather difficult to explain to a layman. Basically, a DX contact means radio communication with a distant station and/or a very rare one. But there's more to it than that. A contact between Europe and an Australian station is certainly a long-distance contact, but it is hardly a DX when established on the 15 or 20 m short wave band where it is quite simple to raise the antipodes providing you choose the right time of day or night. However, it is certainly a DX contact if you manage to do it on 80 or 160 meters. For the VHF enthusiast, DX means something else again: for him all distances over 300 miles are really DX.

And DX is a matter of feeling as well. . . . as soon as you have your first written confirmation (QSL) from that rare St. Helena station, it is not DX any more and you are eagerly looking for a new rarity. The American Radio Relay league lists more than 300 countries and they decide whether some rock in the Pacific can be considered as a separate country or whether it belongs to a continental country. That is why this list contains more countries than are registered in the United Nations. And this list changes with the political situations: for example, now that the original state of Belgian Congo is divided we get a new country in our list. Nevertheless, a large number of amateurs all over the world have managed to raise all the listed countries and for them either "new countries" have to be created, or rare ones equipped with an amateur radio station.

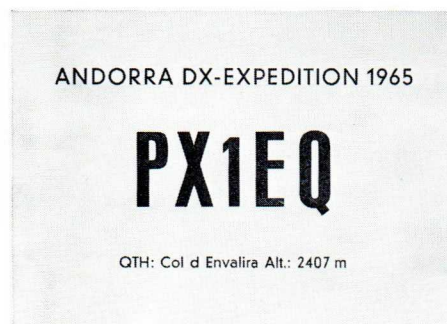
This is how the "DX-pedition" arose. This hybrid name denotes a visit by a number of radio amateurs to a rare spot on the globe for a certain period to contact as many other amateurs as possible. In many cases these expeditions are really a thrill. The "countries" in question are often uninhabited islands and generators have to be used to get power supply. These trips can be dangerous as well: several years ago two amateurs lost their lives in a hurricane in the Pacific.



1. HZ3TYQ/8Z4 was operating from a temporary seismological oil exploratory camp in the Saudi-Arabian/Iraqi Neutral Zone.

The difficulties involved in organizing such a DX-pedition are legion. They start with the problem of getting an official license from the government concerned; and since these places are often hundred of miles from the inhabited land transport is a huge problem as well, not too mention catering, living and power supply.

Famous DX-peditions in the past have been the Danny Weil trip to the Carribean, the Don Miller trips to the Pacific, and expeditions of other amateurs to Socorro Island (Mexican) in the Pacific, Andaman Island (India) Navassa (Carribean) and Kure Island which is just a coral reef not more than a square mile in area near the Midway Islands (Pacific), inhabited by gooney birds, frigate birds etc. Sometimes these DX-peditions are combined with a real expedition e.g. to the North Pole or the Antarctic.



2. Andorra, a favourite spot for summer DX-expeditions

By the way . . .

The costs of such an affair are high, so many are sponsored either by telecommunication firms (who then deliver equipment for promotional reasons) or by a large number of amateurs.

Of course this raises the question of whether this still can be called an "amateur" activity. Since these stations are very much in demand among the amateur fraternity, many are willing to pay for their contact confirmation; pre-paid schedules have even been made to guarantee contact with the rare spot!

These DX-peditions can lead to excesses on the home side too. Some amateurs use more than the legal transmitter power to be heard on the rare island. A control check by the US-postal authorities (FCC) on a number of amateurs showed that about 10 stations had a foot-switch-controlled 10 kW input instead of the legal 1 kW; when you combine that power with the enormous directional beam antennas they use, you end up with an E.R.P. (effective radiated power) which a medium-sized broadcasting transmitter would not be ashamed of. . . .

Another point is the nature of the contact established. All that happens is that the DX-stations mentions your call-sign with a signal strength report, and notes you in its logbook. No exchange of surnames, other personal information or technical details; can such marginal contact contribute to a better understanding between nations as many say amateur radio can?

But are things so much different in top-class sport? Doping really comes down to using more than the legal power, and during the Olympic Games competitors do not fraternize all that much, as they need all their concentration effort to give their best in the competitions.

So guess we just have to live with the top-class sport mentality in amateur radio too. After all, there is one advantage: you needn't join the rat-race, and you can have a lot of fun in amateur radio without it.

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Dear Readers,

In the beginning of 1973, T & M Notes will be getting a new face. It will appear (6 times a year) as an eightpage newsletter, in uniform English, French, German and Swedish editions. You can indicate the language you prefer on the attached reply card.

T & M Notes "new style" will concentrate on short news items and application stories; one of the new features will be a column giving answers to readers' queries, which we hope you will make full use of. Longer articles of a more general or theoretical nature (including the continua-

tion of the digital course, and of the articles "By the way", which are too good to miss) will be published in Supplements. These supplements will appear irregularly, and will be available on request. Supplements of potential interest to a wide section of our readers will be sent to you together with T & M Notes "new style".

These changes have been made in the interests of a more efficient, snappy flow of information from us to you - and from you to us. Communication is an essential nowadays; let's make good use of our new medium.

Glossary of terms

ANALOG - An analog signal which is continuously variable and unlike a digital signal which has discrete levels.

AND gate - A binary circuit having two or more inputs and a single output in which the output is ON (1) only if all inputs are ON (1) together, and is OFF (0) if any one of the inputs is OFF (0).

BINARY SYSTEM - A system for mathematical computation based on the scale of 2, or a system in which all stages can only have one of two possible states.

BINARY CODED DECIMAL - Four bits of binary information can be used to encode one decimal digit. When a decimal digit is encoded in this way it is called a Binary Coded Decimal (BCD).

BIT - The words "binary digit" are often abbreviated to BIT.

CLOCKED R-S FLIP-FLOP - The clocked R-S flip-flop has two conditioning inputs which control the state to which the flip-flop will go at the arrival of the clock pulse. If the S (Set) input is enabled, the flip-flop goes to the "1" state when clocked. If the R (Reset) input is enabled, the flip-flop goes to the "0" state when clocked. The clock pulse is required to change the state of the flip-flop.

COMPARATOR - A comparator is a device used to determine whether two numbers of bits of information are equal.

COMPLEMENT - The complement of a variable or function is the binary opposite of that variable or function. If a variable or function is 1, its complement will be 0. If a variable or function is 0, its complement will be 1. The complement of 011010 is 100101.

C-MOS - Complementary MOS. An MOST or IC involving both P-channel and N-channel MOS-FETS.

CML - Current mode logic. Basically equivalent to ECL.

COUNTER - A counter is a device which will maintain a continuous record of the number of pulses which it has received at its input. The output of the counter indicates the sum of the number of input pulses.

CTL - Complementary Transistor Logic. A logic system using emitter-coupled circuits with a combination of P-N-P and N-P-N transistors.

CUT-OFF - The condition when the emitter junction of a transistor is at zero voltage or is reverse biased so that no collector current flows.

DCTL - Direct Coupled Transistor Logic. A system of transistor logic in which the collector output of one gate is connected directly to the base input of the next gate.

DTL - Diode Transistor Logic. A logic system in which the logic decisions are carried out by a group of diodes and the resulting output coupled through a transistor output stage.

D-TYPE FLIP-FLOP - A D-type flip-flop will propagate whatever information is at its D (data) conditioning input prior to the clock pulse, to the Q output, on receipt of a clock pulse.

DECODER - A decoder is a device used to convert information from a coded form into a more usable form (e.g., binary-to-decimal decoder).

DIGIT - A digit is one character in a number. There are 10 digits in the decimal number system. There are two digits in the binary number system.

ECL - Emitter Coupled Logic - A logic system using emitter coupled transistor circuits.

ENCODER - An encoder is a device which takes information in one code and encodes it into another (e.g., BCD-to-binary encoder).

EXCLUSIVE OR - The Exclusive OR function is valid, or its value is 1, if one and only one of the input variables is present. The Exclusive OR applied to two variables is present, or 1, if the two binary input variables are different.

FAN-IN - The number of inputs connected to a logic gate.

FAN-OUT - The fan-out of an output is a number which indicates the number of the unit loads an output can drive.

FLIP-FLOP - A flip-flop is a storage device which can be used to retain one bit of information. A flip-flop can be in the "1" state or the "0" state. In the "1" state, its Q output presents a HIGH level and its \bar{Q} output a LOW level. In the "0" state, its Q output present a LOW level and its \bar{Q} output a HIGH level.

FET - Field effect transistor, a voltage controlled semiconductor analogous to a triode.

GATE - A logic circuit having two or more inputs and a single output designed to give an output signal only when a certain combination of input signals exists.

HNIL - High noise immunity logic. Closely resembling DTL, the basic difference being that HNIL uses a Zener diode for stand-off (raising the threshold voltage).

INVERTER - An inverter (NOT gate) is a device which performs the operation of inversion. It will present at its output the inverse or complement of the information at its input.

J K FLIP-FLOP - A JK flip-flop has two conditioning groups of inputs (J and K) and a clock input. If both J and K input are LOW prior to the clock pulse it will remain in its initial condition when the clock pulse appears. If the J input is HIGH and the K input LOW, the flip-flop will go to the "1" state on receipt of the clock pulse, when J is LOW, and K is HIGH, the flip-flop will switch to the "0" position at the clock pulse. When both J and K are HIGH the flip-flop will complement its initial state.

LOGIC - In computer language logic is a form of mathematics based upon two-state truth tables. Electronic logic uses two-state gates and flip-flops to perform decision making functions.

MASTER-SLAVE - A master-slave flip-flop is one which contains two flip-flops, a master flip-flop and a slave flip-flop. The master flip-flop receives its information during the leading edge of a clock pulse and the slave or output flip-flop receives its information during the trailing edge of the pulse.

MOSFET - Metal oxide semiconductor field effect transistor, which consist of source and drain regions on either side of a P-type of N-type channel plus a gate electrode insulated from the channel by silicon dioxide.

NAND GATE - A NAND gate is enabled when both its inputs are present or HIGH. When a NAND gate is enabled, its output is LOW. The term NAND is a contraction of the words NOT AND.

NOISE MARGIN or noise immunity is a critical IC parameter. It is the difference between the normal operating logic levels and the threshold voltage.

NOR GATE - A combination of a NOT and an OR circuit. A binary circuit having two or more inputs and a single output, in which the output is OFF (0) if any one of the inputs is ON (1) and is ON (1) only if all inputs are OFF (0) together.

NOT CIRCUIT - A binary circuit having a single input and a single output, in which the output is always the opposite of the input. When the input is ON (1) the output is OFF (0) and vice versa. This circuit is also called an inverter circuit.

OCTAL - The octal number system is one which has 8 distinct digits, namely, 0, 1, 2, 3, 4, 5, 6, 7.

ONE'S COMPLEMENT - One's Complement arithmetic provides a method of negating a binary number so that binary subtraction can be performed using addition techniques. To obtain the 1's complement of a binary number, all bits in that number must be complemented.

OR GATE - A binary circuit having two or more inputs and a single output, in which the output is ON (1) if any one of the inputs is ON (1), and is OFF (0) only if all inputs are OFF (0) together.

POWER DISSIPATION OF A LOGIC CIRCUIT - The supply power when a logic circuit is operating with a 50% duty cycle, when it is in the 0 state half the time and the 1 state the other half of the time.

PROPAGATION DELAY - The time delay between the application of a signal to the input of a logic circuit and the change of state at the output.

RCTL - Resistor-Capacitor Transistor Logic. A variant of resistor transistor logic in which a capacitor is connected across the series resistor to permit faster switching.

RTL - Resistor-Transistor Logic - A system of transistor logic in which a resistor is included in series with the base of each transistor in order to reduce differences in transistor currents.

RESET - If a Reset input to a flip-flop is enabled, the flip-flop will go to the "0" state.

R-S FLIP-FLOP - The R-S flip-flop has two inputs, a Set input and a Reset input. If the Set input is enabled (HIGH), the flip-flop goes to the "1" state. If the Reset input is enabled (HIGH), the flip-flop goes to the "0" state.

SATURATION - A transistor is saturated when a further increase of base current causes no further increase in collector current.

SET INPUT - When the Set input to a flip-flop is enabled, the flip-flop goes to the "1" state.

SHIFT REGISTER - A shift register can contain several bits of information. When a shift instruction is received, all the information in the register is shifted one place.

THRESHOLD VOLTAGE - The input voltage level at which a binary logic circuit changes from one state to the other.

TTL - Transistor-Transistor Logic. A logic system similar to diode-transistor logic in which the logic diodes are replaced by a multi-emitter transistor.