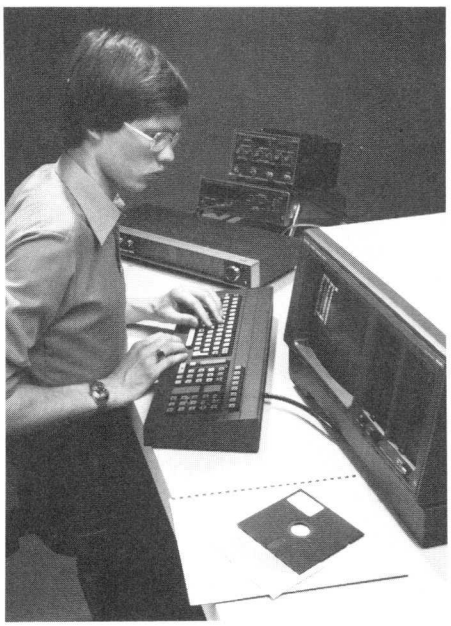
Automatic test and measuring

Introduction

The need for automation

Skilled labour and the making available of information in the right form at the right place and time form a major part of todays high cost factors in all aspects of modern society, be they industrial, educational, medical, scientific or commercial. Automation in its many and varied forms can provide an answer by undertaking extremely high work volumes in very short times. But frequently the sophisticated systems required can be costly to install, operate and maintain and are only useable by specialists. Thus, the initial advantages are minimized by new constraints in the form of high capital costs, high salaries, restriction of use by experts only, due to technical complexities.



What is really needed?

Obviously, a need has developed for automated systems which do *not* introduce such problems. Systems which can be used by a wide cross-section of any semi-skilled work force without specialist knowledge and *certainly* without computer knowledge. These systems should be compact, versatile, reliable, relatively inexpensive when compared with their costly counterparts, yet capable of undertaking a wide variety of functions.
Such devices will immediately be of wide general interest, either in continuous (dedicated) operation, unchanging routines or in new or rapidly changing situations. Which demands that they must be speedily adaptable to any new role, without loss of time or extra financial investment.

Philips has the answer

The Philips programme of automation systems meets these requirements precisely. Advantages include simplicity of operation, compact styling, considerable versatility and expandability. There is also an in-built compatability allowing any system to be latterly integrated into other computer-based operations, should this become necessary at some future date. Thus, capital expended is not only of a significantly lower order, but is never wasted.

The basic family of systems is designed around the PM 4000 compact data logger and the PM 4400 compact computer system. These systems are desk-mounted and occupy minimal space. The basic easy-to-use units can be operated simply and can be used in conjunction with several other complementary units to cope with a wide variety of tasks.

No programming knowledge necessary

Fully interactive keyboard/display input

Rejects incomplete or impossible instructions

Full linearization of TC inputs

Internal cold junction compensation

Optional interfaces for peripherals, IEC-bus

100-hour batteries for memory and internal clock back-up

IEC-625

Compact data logger PM 4000

No technical or programming knowledge is required to operate the PM 4000 datalogger. Input is by a keyboard/display conversation in everyday language. The logical sequence of the programme is clearly and progressively indicated on the display until the logger is ready to go 'on-line'. Impossible or incomplete instructions will not be accepted so that the process cannot start without correct loading of the memory.

Used programs can be included in a library by means of the dump-in/dump-out facility which transfers a complete program on to a tape cassette in seconds.

The basic mainframe will accommodate up to 50 channels and the logger capacity can be extended up to a maximum of 950 channels using add-on/satellites (PM 4010) holding up to 100 channels each. Inputs are fully protected against common-mode and noise effects allowing the system to maintain a very high resolution and accuracy for all measurements. High/low alarm monitoring is possible on all channels and operates a panel warning lamp and contact closure for triggering other alarm systems if required. Measurements can be taken at speeds from 4 to 30 channels per second; up to 100 channels per second for digital inputs.

Inputs include:
- DC voltages: 40mV, 400mV and 4V full scale
- DC currents: 0...20mA, 4...20mA, 0...5mA and 4...50mA
- Thermocouples: Types J, K, T, E, R, S and B; results are in °C
- Pt100 resistance thermometers; results in °C
- Transducers: most normal types, results in %
- Digital: Status signals, binary and BCD
- Strain gauge (1/4, 1/2 and full bridge)

Thermocouple and Pt100 inputs are linearized by the logger and cold junctions of thermocouples can be connected to an isothermal input block. Where the thermocouple is a long distance from the datalogger, a compensation cable is used for the interconnection: up to four different external reference junctions allow four groups of cold junction temperatures to be programmed.

A 5-way security check indicates any human error or hardware failure. Memory is retained for up to 100 hours by battery, during transportation, or in the event of the AC line failure.

It is possible to operate the PM 4000 by remote control via its two I/O interfaces. The whole program or memory content can be checked if required and printed out via the internal printer. In this mode it is also possible, for example, to select a monitor channel, which gives a single-step scan back via the interface. The appropriate commands are given by a peripheral or computer, via the I/O interfaces.

The PM 4000 can be used in simple, stand-alone automated set-ups, in conjunction with a mini-computer, or as part of a large, complex system employing mini-computer control plus a large number of peripherals. A typical application described on P 134.

SPECIFICATIONS

Datalogger main frame includes:
Cabinet
Key-board
Fluorescent-display
Strip-printer
Power Supply
2K RAM
Printer control
Clock
Analogue Sub-system control

Physical
Table top and rack mount
High 3E, width 19-in, depth 53.5cm
220V ±10%, 50–60Hz ±5%
Operating temperature: +5 to +40°C
Storing: −40 to +70°C (excl. battery)
IEC 348 and VDE 0871 standards > 100 hours rechargeable, NiCd battery back-up
Weight: ca. 13kg

SOFTWARE

PM 9490 Standard software package (incl. CPU and 8K prom)
DC voltages in 4 ranges; 40mV, 400mV, 4V, and 40V
DC currents in 4 ranges; 0–20mA, 4–20mA, 0–50mA, and 10–50mA
Temperatures via thermocouples and/or resistor thermometers (outputs in °C)
Outputs from voltage/current producing transducers
Resistance measurements

PM 9491 Extended software package (incl. CPU and 11K prom)
As Standard software package PM 9490 plus:
Digital input possibility in 3 modes: BCD, binary and status signals
Additional engineering unit outputs (up to 63 types)

PM 9492 All purpose software package (incl. CPU and 14K prom)
As extended software package PM 9491 plus: complete power supply facilities and measuring system for strain gauges and transducers based on strain gauges connected as 1/4, 1/2 and full bridge 4mV DC Voltage range.

AVAILABLE OPTIONS

PM 4010 Scanner extension unit
Includes: cabinet, power supply, analog subsystem control and cable driver

PM 9410 General purpose ADC
Sampling rate: 16 measurements/sec maximum
Measurement: Dual slope (PLL)
Full scale capability: 4096 points
Ranges/resolution:
4V/1mV
400mV/100μV
40mV/10μV

PM 9411 High performance ADC
Sampling rate: 30 measurements/sec maximum without inversion of bridge supply
15 measurements/sec maximum with inversion of bridge supply
Measurement: Dual slope method (PLL)
Dynamic range: 4096 points
Ranges/resolution:
4mV/1μV
40mV/10μV
400mV/100μV
4V/1mV

PM 9412 High resolution ADC
Sampling rate: 4 measurements/sec maximum
Measurement: Dual slope (PLL)
Dynamic range: 16.384 points
Ranges/resolution:
4V/250μV
400mV/25μV
40mV/2.5μV

PM 9414 Scanner card for Pt 100
Input channels: 8 with 4 contacts per channel

PM 9415 Analog general purpose scanner
Input channels: 10
Poles per channel: 2+guard

PM 9416 Digital input card
50 pole amphenol input connector type 57–50
3 INPUT MODES:
STATUS SIGNALS
Number of lines: 40 with common return
Logic: short circuit=0, open circuit=1
Energising voltage: 5 or 12V
Overload immunity: ±50V, channel to common
BCD SIGNALS
2 operating modes +4 status signals may be used in parallel
A. Dynamic
2×4 digit sources:
Each source is independent of the other
Number of lines: 2×16 plus common return
Maximum value of each source: 9999
1×9 digit source:
Number of lines: 36+common return
Maximum value: A 9 digit input of 999999999 may be displayed.
B. Static
1×9 digit source
Number of lines: 36+common return
Maximum value
A 9 digit of 999999999 may be displayed
BINARY INPUTS
2 input modes +4 status signals, may be used in parallel
A. 14 bit+sign-bit
B. 15 bit in two's compliment representation
Number of lines: 36+common return

PM 9417 Analog high resolution scanner
Input channels: 10
Poles per channel: 2+guard

PM 9418 Half and full bridge scanner
Input channel: 5
Poles per channel 6+guard

PM 9419 Quarter bridge scanner
Input channels: 10+dummy
Poles per channel: 2 (+5 for common dummy per card)

PM 9420 DC-voltage input block
Input channels: 10
Terminals per channel: 2+guard
Kind of terminals: screw
Connectable to: PM 9417, PM 9415
DC currents are measured with shunt resistors supplied

PM 9421 Input block for Pt 100
Intput channels: 8
Terminals per channel: 4
Kind of terminals: screw
Connectable to: PM 9414

PM 9422 Isothermal input block
Input channels: 10
Terminals per channel: 2+guard
Kind of terminals: screw

PM 9423 40V input block
Input channels: 10
Terminals per channel: 2
Kind of terminal: screw
Connectable to: PM 9415, PM 9417

PM 9428 Half and full bridge input block
Input channels: 5
Terminals per channel: 6+guard
Kind of terminals: screw
Connectable to PM 9418

PM 9429 Quarter bridge input block
Input channels: 10+common dummy
Terminals per channel: 2 (+5 for common dummy per card)
Connectable to PM 9419

PM 9450 IEC-Bus Interface
Operating modes: Listen only; talk only, addressable listener, talker with SRQ
Data transfer: BYTE serial, BIT parallel
Interface: handshake interface in accordance with DIN–IEC 66.22
To be applied with cables
PM 9480 1 meter
PM 9481 2 meters
PM 9482 4 meters
or PM 9483 IEC–IEEE adapter cable

PM 9453 FACIT Interface
8 bit parallel byte serial with handshake
To be used for:
FACIT 4070 Paper-tape punch or Data dynamics 1133
Connector: 15 pole, Philips series F 161.

PM 9456 Serial interface
Operation mode: transmitter, receiver, active or passive selectable
Data transfer: BYTE-serial/bit serial
Charater length: ISO-7 bit code/ASC II
7 data bit
1 parity bit (even)
1 start bit
1 stop bit (which can be switched to 2 stop bits)
Interface: current loop, fully duplex
Line current: 20mA
Data transfer speed: 110 Baud can be switched to 135.5; 150; 200; 300; 600; 1200; 1800; 2400; 4800; 9600 Baud)
Connection: 9-pole
type: Philips serie F 161
To be used for: Teletype ASR 33
Texas Instruments silent 700
Minicomputer

PM 9460 Alarm relay card
2 relays (24V, 6A)

PM 9470 Memory extension 292 channels
(for use with standard software package PM 9490)

PM 9471 Cable drive card
For interconnection of extension unit
PM 4010 to mainframe PM 4000
(digital transmission)

IEC-625

Data logging systems

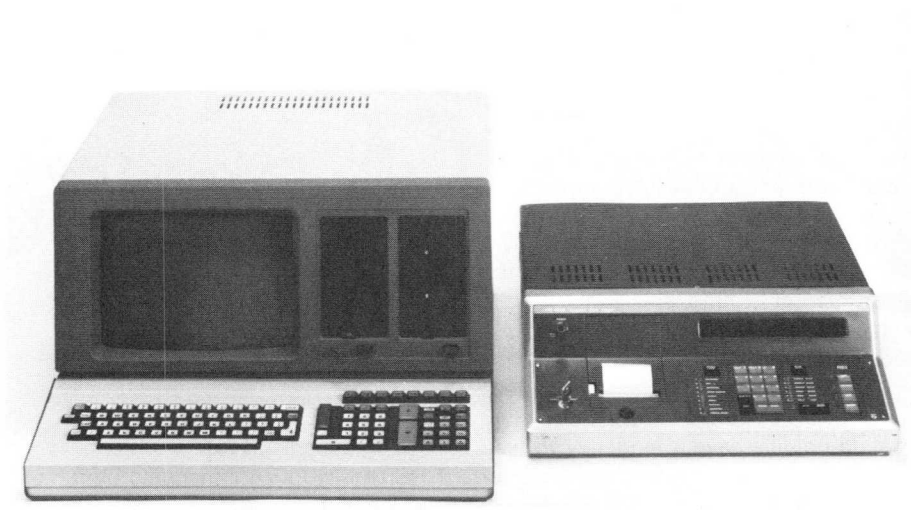
Data acquisition systems operate either in an active or passive mode. The PM 4000 operating in a stand-alone function can be generally regarded as taking the passive role, as a straight-forward data logger. However, it is also designed for participation within an active system. In the combination of the PM 4000 and PM 4400 shown, the PM 4000 is operating as an ordinary IEC-bus instrument, coupled to the IEC-bus controller.

This set-up could be used for example, in an automated chemical, pharmaceutical or general manufacturing plant. Any type of computer supporting a serial or IEC-bus compatible interface can be used to control and accept data from the PM 4000.

It is important to emphasize the facilities offered by the 'Remote control' command set on the PM 4000, which are as follows:

- keyboard functions are available as remote commands
- the built-in strip printer on the PM 4000 can be used to print out **any form of data** coming from the serial or IEC-bus interfaces.
- The complete parameter memory content can be overwritten very quickly by another version of the parameter program, previously stored within the controlling computer.

The major advantage of using the PM 4000 in an active role is that its output data is 'clean', fully compensated where necessary and expressed in everyday engineering units. All these tasks are performed independently of the computer and do not occupy any of its valuable memory space or time.

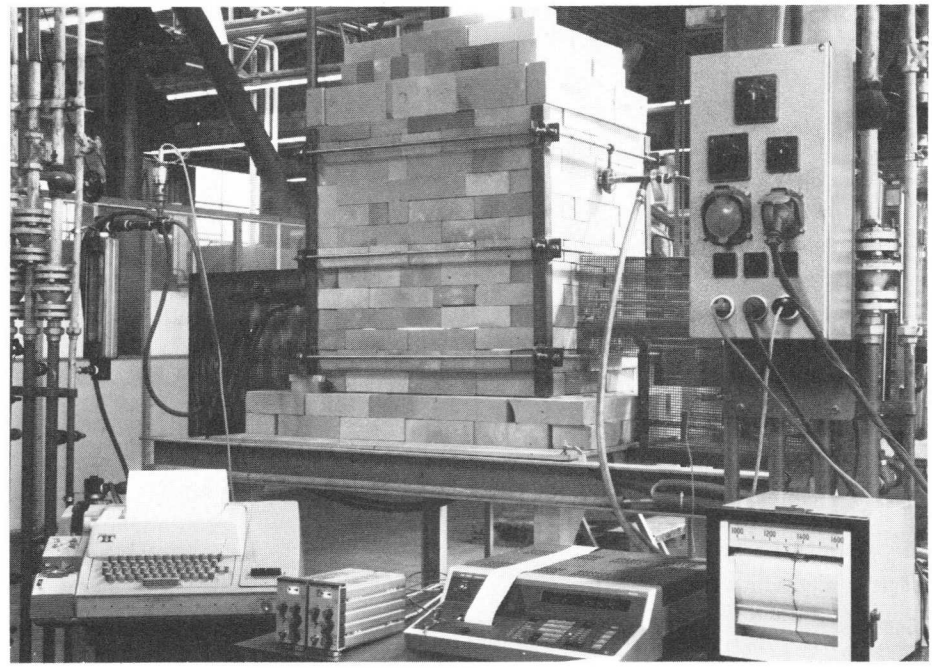


PM 4000 Data logger operating in conjunction with PM 4400 IEC-bus controller.

PM 4000 data logger operating in conjunction with a Philips P 800 series minicomputer.

IEC-625

Data logging applications



Oven temperature logging

The Central Development Laboratory of a leading glass manufacturer uses a PM 4000 to monitor the operating conditions in and around a small furnace. The laboratory works closely with research and production departments to improve the quality and raise the efficiency of the glass making process. Over 300 types of glass pass through the laboratory for testing and analysis in a normal operating week.

A current project is to develop an improved water-cooled holder for the electrodes of an electric furnace.

Existing holders have a tendency to leak due to the extremes in temperature over a small area, causing serious production problems.

The furnace shown in the photograph is scaled-down from a production version, and is subjected to similar temperatures, pressures and stresses etc. Initially the furnace is gas fired. When the glass becomes molten, heavy current is passed through it via the molybdenum electrodes. Element holders are of two-piece construction with high-pressure water cooling. A combination of thermocouples, pressure transducers and transformers enable the PM 4000 to log 16 channels of data.

The following parameters are measured:

Furnace temperatures around 1400°C in six zones using S-type thermocouples of Platinum and Rhodium connected to an isothermal input block.

Cooling water temperature of between 15–30°C entering and leaving element holders and ambient using K type thermocouples and isothermal input block.

Cooling water pressure via resistive strain-gauge pressure transducers and separate amplifiers, typical pressure 2.5/3 atmospheres.

Both heating element currents of about 150A, reduced to 5mA by a transformer.

Both heating element voltages of about 100V, reduced to 5mA.

Total energy in VA consumed by furnace and converted to 5mA by 3-winding transformer.

Conductance (MHO) of molten glass using own developed measuring method.

A secondary objective of the project is to study the conductance of molten glass to develop a heating method by passing a current directly through the glass. This process offers many benefits including low leakage and higher energy conversion factors. This application has also given considerable experience to the development staff in applying modern data-logging techniques to a traditional manufacturing process.

Frequent temperature measurement from the six thermocouples would be very difficult with a single operator and the additional checks on water pressures and temperatures would have been impossible. All channels are now automatically scanned every 30 minutes except when an alarm condition is reached. Scan times are then at 5 minute intervals with the monitor channel being used to show the highest temperature continuously.

Measurements are taken from the logger via the serial interface to an ASR 33 teletype, via the parallel interface to a Facit high speed punch and the alarm relay enables both audible and visual signals to be given, as the furnace and data logging system are now unmaned, except for removal of data. Results may be seen as a continuously record on the logger's internal printer or in three-column form on the teletype. Tape is used for comparison with previous results taken and stored in an off-line computer.

Checking the efficiency of an experimental central heating system

This application is for a new type of domestic central heating system.

A PM 4000 compact data logger monitors air temperatures in 30 different locations, water inlet and outlet temperatures and pulse counter outputs from the gas and electricity supply meters. Data is recorded both on the built-in printer and on magnetic tape for processing by computer.

A combination of measuring programs enables parameters to monitored on:

- a continuous basis
- at 5 minute intervals
- at 24 hour intervals
- at weekly intervals

The outcome of this particular experiment will allow direct comparison between the efficiency of conventional domestic central heating using a gas-fired boiler with that of a system employing a stirling engine driving a heat pump.

IEC-625

IEC-bus controller PM 4400

Based on PM 4400 compact computer

IEC-bus interface and 'Instrumental' BASIC

High computing power

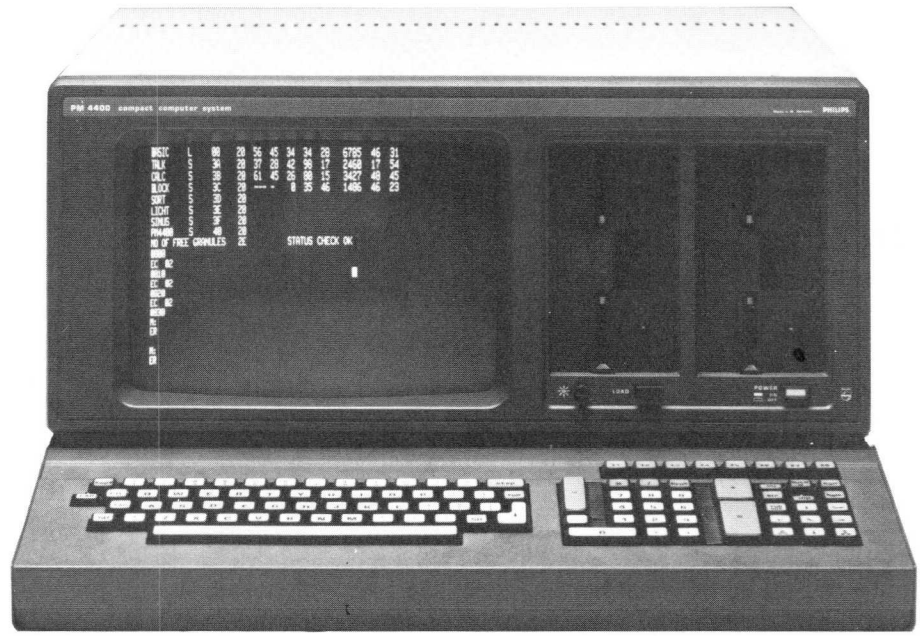
Computer experience unnecessary

12-in video display

Mini-floppy disk memory

Compatible with P800 Philips minicomputer range

Contained in compact desk unit



The PM 4400 IEC-bus controller is part of the family of products based on the PM 4400 compact computer system. The basic facilities of the PM 4400 are first described, followed by data and applications of the IEC-bus controller.

PM 4400 compact computer system

The PM 4400 compact computer system has been designed to provide considerable, low-cost computing power, without extensive hardware or operational complexity. Its extreme versatility allows it to be used for a very wide range of applications within industry, engineering and science.

Operation is extremely simple, extending its use to personnel other than those having specialized computer knowledge. This fact further extends the range of applications.

Easy to program

Simple programming, due to the conversational-style BASIC language makes it possible to start work quickly. Program steps are entered as simple statements which are easy to understand and check. An instructional program is available to let new users teach themselves how to start programming in BASIC.

Because PM 4400 is based on well-proved Philips P 851 mini-computer technology, all the special programs that users may develop for their own applications are compatible with P 800 mini-computers in the Philips range. So, any investment in time and manpower is protected if it is ultimately required to move up to a bigger system and existing programs can still be used.

For the first-time user, a PM 4400 system is the optimum entry level. It offers real computing power and versatility for a moderate cost. Its simplicity allows existing manual tasks to be converted quickly and efficiently.

For the experienced user, PM 4400 can form a valuable and powerful addition to an existing large computer system – for example for data aquisition and pre-processing.

Easy to use

The PM 4400 system makes computing simple. It is very convenient and easy to use because all necessary functions are integrated into a single low-cost desktop computing facility. Keyboards, video display and compact 'mini-floppy disk' memory units for data and programs are all built into a single neat, well-designed unit. Everything is correctly located for efficient operation.

Working alone, the PM 4400 is an easy-to-use calculator. Using the standard IEC-bus interconnection facility, it's a programmable controller for automatic operation of instruments and test equipment. Application programs are used to carry out engineering and design analysis functions. And for scientific and industrial administration, it can take care of tasks like documentation, project control and analysis.

Integrated functions for convenience and simplicity

Because the PM 4400 is a unique, fully integrated compact computer it has all the facilities needed to start work directly, without having to connect it to additional units.

Keyboard facilities include a calculator-format panel for quick and convenient arithmetical entries. 16 user definable functions can be selected at the touch of a key. And the specific keyboard area for BASIC control functions greatly simplifies the entry of program steps and instructions. Fast-access memory with high capacity for data and programs is provided by the new mini-floppy disk units. Disks are very low-cost and instantly interchangeable allowing quick transfer of programs – written by the user and stored on disk – for other applications or operating modes. PM 4400's versatility means the ability to be connected directly to many different types and brands of peripheral units, instruments and test equipment – both for automatic operation under program control, and for data acquisition, processing and storage. This facility is provided by the standard IEC-bus interface, to provide simple, plug-in connections.

A real-time clock is included to provide interval time facilities, such as date/time and to prevent the system from 'hanging-into' a faulty device.

A fast hard-copy printer PM 4490 is available as an option, which will give a printout of the screen display, the program in use, or of output data – all on normal paper. Also available is an intelligent digital plotter PM 8151 to present measurement results graphically.

Many applications

Examples of the many applications of the PM 4400 include measurement and adjustment, data acquisition and operation as a stand-alone calculator.

These particular examples can all be performed using an integrated system which is a combination of

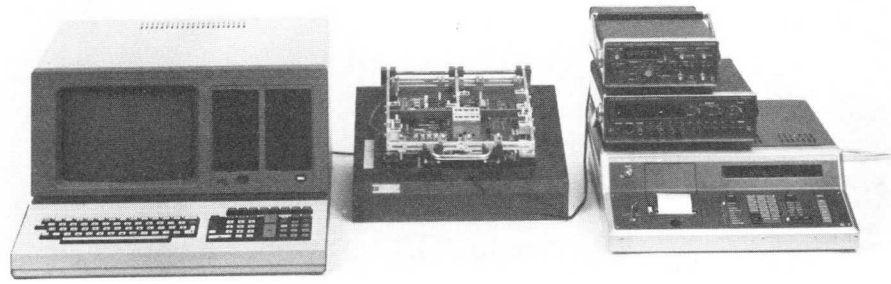
– PM 4400 compact computer
– IEC-bus interface
– Appropriate system software

This ready-to-use system exists as an integrated package and is designated PM 4400 (IEC-bus controller).

The following examples are all based on the use of the PM 4400.

Measurement and adjustment with PM 4400

Adjustment/calibration of measuring instruments or other electronic equipment at final production stage to replace manual measuring and adjustment. Multitesting facility means many interdependent adjustments can be made quickly. Tests carried out under program control from PM 4400 – eliminates manual reading of instruments, calculation and entry of values.



PM 4400 controlling test and measuring instruments for automatic testing via the IEC-bus interface.

Data acquisition with PM 4400

Quality-control tests of products and equipment. Testing under program control from PM 4400 and automatic data collection for recording on mini-floppy disk. Data can be statistically processed and 'condensed' if necessary for efficient storage. Eliminates bulky paper printouts needing manual search to find any particular data.

Stand-alone calculator

Powerful, easy-to-use calculator functions, available when used on its own. Special 'calculator-format' keyboards allows convenient arithmetical entries. E.g. mechanical engineering calculations.

BASIC is a powerful, yet easy to use language

The BASIC programming language used in the PM 4400 is the computer language most like normal English. That means that it is unnecessary for the user to be an experienced programmer to use it. In fact, a user with mathematical knowledge but no specific programming experience can generally learn to use PM 4400's 'instrumental' BASIC language and begin to write his own programs within half a day. An instructional program is available to help new users understand and apply BASIC quickly.

PM 4400 BASIC contains an extensive range of built-in error messages designed to help the user and guide him in program fault-finding. These messages display errors in individual program steps and in program structure, and errors arising during program execution.

When the PM 4400 is operated as a powerful calculator, the normal arithmetic

One line sample testing of component board using PM 4400.

functions are available at the touch of a key on the 'calculator' panel, and the BASIC language contains a full range of other mathematical and trigonometric functions.
PM 4400's BASIC language can work in three modes:

- Conversational programming – the user communicates with the system via the keyboard. Programs are entered step by step with prompting if necessary for assistance. Each step is checked as it is entered, and errors are displayed straight away.
- Execution mode – a program which may already be written and stored on a mini-floppy disk is 'read' by PM 4400 and put into action. Using this mode, you can simply select the program you need from your own 'library' and run it.
- Direct mode – allows PM 4400 to be used as a desktop calculator with direct uncomplicated entry of calculations in normal arithmetic style.

TECHNICAL SPECIFICATION

CENTRAL PROCESSOR UNIT (CPU)

Type
LSI miniprocessor (Philips P 851) 16 bit capability microprogrammed for divide/multiply routines

MAIN STORE (RAM)

Fast dynamic MOS-RAM (16k-1 LSI chip)
up to 64k-bytes on one card memory sizes available:
32k-bytes
48k-bytes
64k-bytes

Access time
450ns for 16 bits. Low power consumption.

MASS STORAGE

Type
Mini-floppy disc drive type SA 400 controlled by bipolar micro-processor based control unit

Hard error rate
1 in 10^{11} bits read

Transfer rate
125k bits/s

Average access time
463m s

Track to track access time
40m s

Media life
30×10^6 passes per track
Software sectored format

Nett capacity
80k-bytes approx.

KEYBOARD

Free-standing unit

Type
Alphanumeric, numeric and miscellaneous
Generates 128 ASCII-characters, with cursor-control and function codes
Serial data transmission allows input of up to 800 characters/sec. to mainframe
Error checks
Indicators for I/O, Input and CAP/LOCK

Keyboard groups
typewriter part 53 keys
special functions 8 keys
numeric pad 18 keys
cursor control/editing 9 keys
user-definable 2 × 8 keys
indicators 3 LED's

MONITOR

Type:
Video display, P 4 white

Screen size
12-in diagonal

Alphanumeric representation
24 lines of 80 characters each

Graphical representation
7 × 9 dots

Character set
128 ASCII characters

INTERFACES

IEC-bus interface
In conformity with DIN IEC 66.22
Transmission byte-serial/bit-parallel
Logic compatible with IEEE 488/75

Maximum data transmission rate
5M byte/sec
Up to 15 devices
Up to 32 addresses
Easily programmed by 'BASIC' language
Serial poll
All controller functions

Serial interface
V 24-bit serial or current loop (20mA)
Baud rate selectable within 50-9600 baud input/output independent
Word length 5-8 bits
Parity check
Cable lengths of up to 300M

PHYSICAL DATA

Dimensions and weight
(w × h × d) 540 × 300 × 500mm
(22.7 × 11.8 × 19.7-in)
35kg approx.

Power supply
110-220V (±10%)

Power frequency
48...63Hz

Power consumption
Approx. 250W, dependent on configuration

Operating temperature
+4°C to +40°C

Peripheral equipment

HIGH-SPEED LINE PRINTER

Type
PM 4490

Printing rate
160 characters/s

Printing width
132 characters max.

Paper
Fan fold forms

Paper width
Adjustable between 4 and 15-in

Paper transport
Tractor feed mechanism

Character style
7 × 7 dot matrix

INTELLIGENT DIGITAL PLOTTER

Type
PM 8151

Effective drawing surface
280 × 388 mm, DIN A3
(297 × 240 is accepted)

Internal buffer
800 bytes expandable with additional 1k byte

Plotting rate
30cm/s (can be preset to 10cm/s)

IEC-625

IEC-bus control application

The application is concerned with the measurement and recording, both in alphanumeric and graphical form, of the efficiency of a bandpass filter. The complete programme involves:

- continuous measurement of the performance of the device under test
- printing out the individual measurements taken on a serial alphanumeric printer type PM 4490
- drawing the actual performance curve on a linear/log scale using the digital X-Y plotter PM 8151
- printing and drawing of: frequency, bandwidth, efficiency (calculated), upper and lower frequency limits

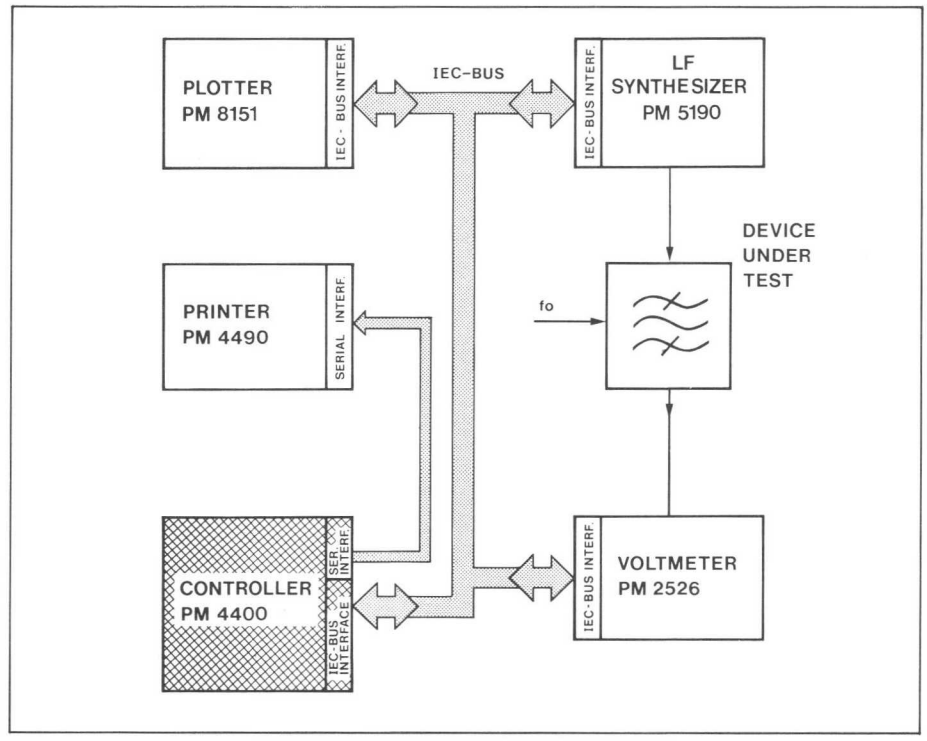
The following instruments are required.
1. IEC-bus controller PM 4400
2. Digital X-Y plotter PM 8151
3. Line printer PM 4490
4. LF-synthesizer PM 5190
5. Digital multimeter PM 2526

Programme sequence
The sequence is as follows:
1. First comes the preparation stage. This involves layouting, drawing the grid for the log/linear graph, labelling, printing out the desired table headings, etc., ready for the test run.
2. Measuring the frequency response of the filter by progressive sampling and computing the results.
3. Drawing the curve and overprinting the measured values (in alphanumerics).
4. Calculation, printing and drawing of
- frequency
- voltage
- bandwidth
- efficiency
- upper and lower limits
5. Where repeat 'runs' are made for the purposes of averaging the results, calculating, printing and drawing of the average of several runs.

The set-up described is shown in block diagram form.

Using this set-up, test times will be considerably reduced, whilst the overall test procedure itself in terms of batch accuracy and unit throughput, will be substantially improved.

This example of automatic testing using the PM 4400 IEC-bus controller therefore demonstrates the opportunity to achieve higher efficiencies and improved quality output, in electronic testing laboratories.



Block diagram shows how the various instruments are inter-connected, with the appropriate interfaces and the IEC-bus line, clearly defined.