TEXTBOOK NO. 7001B

Digimatic Tool Series
(Digital Measuring Tools)

TEXTBOOK

Mitutoyo

CONTENTS

1. INTRODUCTION

Demand for digital measurement systems

When the diameter of a round bar or the thickness of a plate is measured using a conventional micrometer, the measurement is indicated by an analog scale. If the true value of the dimension could be expressed, it would require an infinite number of decimal digits. While a dimension may be represented by a finite number of digits, say 10.24mm or 10.25mm, this number is actually the best estimate that the operator can read from the scale of his gage. In other words, the operator has converted the analog value into a digital value based on his judgement.

But a measuring instrument which can instantly display digital values dispenses with need for the operator's judgement in reading the scale. The introduction of devices that provide digital readout is motivated by the need to facilitate reading, even under insufficient lighting, and especially in the case of tools like a micrometer, to avoid reading errors of the smallest graduation on the micrometer's sleeve.

In order to provide digital readout, a mechanism to convert analog data into digital values is necessary. Much research has been conducted to build a digital readout system into measuring instruments using mechanical counters and electrical A/D converters. In the early stages, some measuring equipment makers developed instruments such as digital micrometer heads to be installed on the workstage of a profile projector and digital height gages. These systems had to be connected to a separate digital counter with a cable, and did not meet with much success as popular measuring devices due the lack of convenience and the high price.

• The advent of digital measuring tools

Since then, the development of electronic technology has been remarkable. In the late 1970s, the advent of new types of digital measuring tools that do not require cables was brought about by the rapid progress of LSI technology along with the development of digital display devices such as a liquid crystal display (LCD) and miniaturized battery cells. In 1980 and 1981, Mitutoyo introduced a series of digital height gages and micrometers and indicators to the market, followed by digital calipers in 1982, which was a difficult item to digitalize because of its small size.

Adoption of advanced electronic technology has not only paved the way to digital measuring tools but has also made it possible to expand their functions in a way that was difficult to do with the mechanical systems. The price inevitably increased, but the improved functionality more than offset the increased price. Multi-function measuring tools have also become available with the extensive application of microprocessors.

Requirements for more accurate measurement have intensified to meet rising standards of manufacturing techniques. Digital measuring tools give measurement values only up to a certain decimal place, and do not indicate the mid-graduation data values which the analog type permits by visual estimation. Due to this limitation, and in order to minimize errors that arise from the truncation of fractions which accumulate in complex data processing such as statistical calculations, requirements have increased for higher resolution to provide an additional decimal place.

For some types of measurement, analog readout better serves the purpose, as with the dial test indicator. Digital systems, however, have permitted new applications which were not available with conventional measuring tools because the digital systems can incorporate data processing functions and can output data to external devices. Some of the expected future directions of digital measuring tools are the following.

(1) Miniaturization and lower price with a minimal number of functions, to replace conventional measuring tools
(2) Multi-purpose type with many functions and high accuracy
(3) Integration into measurement and quality control systems by connecting to a data processor or host computer

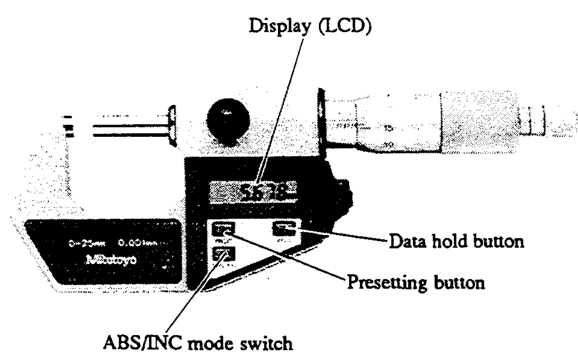


Fig. 1 Digimatic Outside Micrometer (standard type)

2. POSITION SENSORS

Table 1 and **Figs. 2, 3** and **4** show various types of position sensors used for measuring tools.

Table 1 Position sensors

Classification	Sensor type	Micrometer	Caliper	Height gage	Indicator
Rotary type	Photoelectric device (incremental)	◎		◎	○
	Electric contact (incremental)	○	○	○	
	Capacitive transducer (incremental or absolute)	◎			
Linear type	Photoelectric device (incremental)	○	○	◎	◎
	Capacitive transducer (incremental or absolute)		◎	◎	◎
	Magnetic scale (incremental)			○	
	Differential transformer (absolute)				◎

Note: Those marked by ◎ are the systems used in Mitutoyo products.

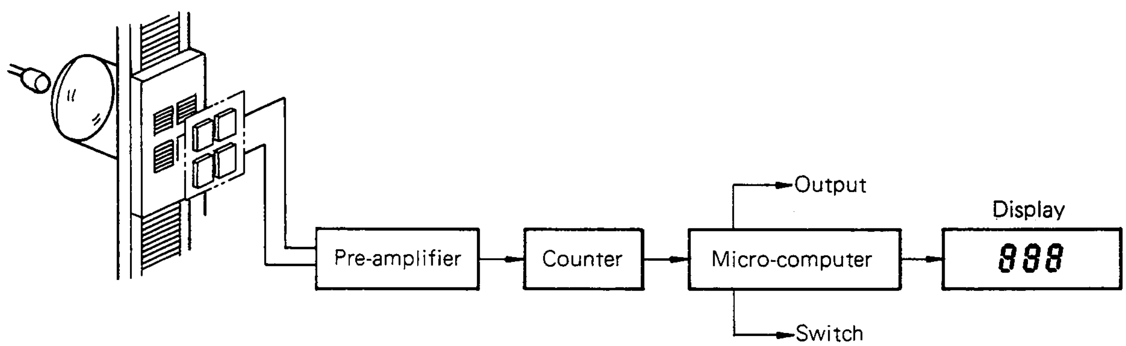


Fig. 2 Linear type photoelectric position sensor

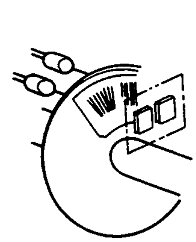


Fig. 3 Rotary type photoelectric position sensor

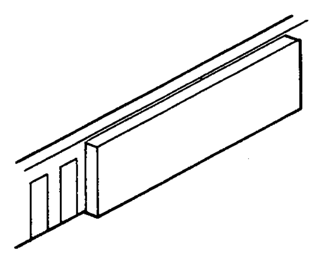


Fig. 4 Linear type capacitative position sensor

3. BASIC FUNCTIONS OF DIGITAL MEASURING TOOLS

Basic functions of digital measuring tools are as follows. The available functions vary depending on the type of product.

(1) Power ON/OFF

When a measuring tool is not going to be used for a long time, the power should be turned off to save the batteries, or for safety if line source power is used. Some products have an auto power-off function which automatically turns off the power when the tool is left idle for a certain period of time. A disadvantage of this system is that once the power is switched off, the operator has to set the origin or reference point again. To save this inconvenience, some products have an "auto-sleep" or automatic power-down function which automatically lowers the power to a level just enough to retain the settings in memory.

Recently, ultra-low power consumption products have been developed which have no ON/OFF switch and can be operated with a small cell for a few years without replacement.

(2) Origin setting

Used to set the origin when starting measurement. Some micrometers allow their datum point value (e.g. 25.000 for 25-50mm range micrometers) to be set as the origin value.

(3) Presetting

Allows a desired value to be preset on the display from which counting starts.

(4) Zero setting

Zeroes the display at any point during measurement so that measurements relative to this datum point can be determined. This function facilitates comparative and step measurements. When zero setting is executed, the origin point is either lost or retained, depending on the model of the measuring tool. In many cases, the zero-setting function is also used to clear errors or alarm messages.

(5) Origin restoration (returning to ABS mode)

If the origin point was set at the start of measurement, this function permits the absolute distance from the origin to be displayed even after zero setting.

(6) Inch/metric selection

This is used to switch the unit of measurement between inch and metric. A very few measuring tools require origin setting each time inch/metric changeover is made.

(7) Direction changeover

Used to change the direction of counting with respect to the direction of motion of the detector; some types of measuring tools require this function.

(8) Hold mode (Freezing the display)

This function freezes a measured value on the display, while the detector continues to move. The counting of the detector displacement continues internally, so by clearing the Hold mode the current position of the detector can be displayed. The Hold mode is activated manually by using a switch, or triggered automatically the moment the probe contacts a measured point, depending on the system.

(9) Peak hold mode (Freezing the display at the maximum/minimum value)

This function permits the display to retain the maximum or minimum value during continuous measuring.

(10) Runout measurement (TIR < Total Indicator Reading > mode)

Used to display the difference between the maximum and the minimum values retained with the Peak hold mode.

(11) Tolerance setting and go/nogo judgment

This function displays and/or outputs a go/nogo judgment for each measurement according to the preset upper and lower tolerance limits. There are two methods of setting tolerances: keying-in the limit values, and setting the gage to display the upper and lower limits by using the master workpieces.

(12) Statistical calculation

Used to perform statistical calculations on measurements and display the results. Statistical parameters include the sample size, the maximum and minimum values, the mean, and the standard deviation. Some units provide additional parameters such as the fraction defective and the process capability index.

(13) Data output

Outputs measurement data, go/nogo judgment, and the results of statistical calculations to peripheral devices such as a printer and a data processor. Depending on the system, data output may be initiated by using a switch on the measuring tool, a switch on the peripheral device, or from either. Recently, a wireless system has been developed to issue the data output command over infrared rays or radio waves. The output format of Mitutoyo Digimatic measuring tools are all standardized as one-bit serial transmission.

(14) Miscount alarm
The counter has a certain speed limit for logging data. High speed movement of the detector may result in errors. There is also a possibility of miscounting due to electrical interference. This function is used avoid erroneous counting by displaying an error message when the speed of the detector exceeds a certain limit.
(15) Low battery voltage alarm
For battery-powered measuring tools, an alarm message displays when the battery voltage lowers to a certain level.
(16) Remote control
This function allows a command, such as zero setting, presetting, holding the display, data output and tolerance setting, to be issued from a remote control unit. The control unit is either connected to the measuring tool with a cable or is wireless using infrared rays.

4. CARE REQUIRED IN USING DIGITAL MEASURING TOOLS (DIGIMATIC TOOLS)

Digimatic tools may be used in as many different environmental conditions as conventional measuring tools. Since they have more applications, they might even be used in more adverse conditions such as production lines. In using Digimatic tools, the same care should be taken as that required for conventional measuring tools. In addition, because Digimatic tools contain high precision sensors and electronic devices, they need additional care in handling and special attention to the environmental conditions under which they are used.

4.1 Care Required for Measuring Tools

Digimatic tools are free from reading errors and parallax errors. With regards to other points of measuring accuracy, the same care should be taken as that exercised with conventional tools, of which the main points are as follows.

- According to Abbe's principle, maximum accuracy may be obtained only when the standard is in line with the axis of the workpiece being measured. Accordingly, it is important that the measuring tool be set up with minimum inclination or misalignment and with minimum distance between the scale axis and the measured point.
- The dimensions of a workpiece vary with the positions of the supporting points. (Airy points, Bes points)
- The zero point of a measuring tool also varies with the way it is supported and how it is oriented.
- Measuring tools deflect due to the measuring force. (Hooke's law, Hertz deformation, the length of the supporting arm). The applied measuring force should therefore be kept constant. It is also necessary that the measuring tool be secured with rigid fixtures.
- The influence of temperature: Measuring tools are calibrated so that their rated accuracy is obtained at 20°C (the standard temperature). At other temperatures, according to accuracy requirements, countermeasures such as compensation for the temperatures of the measuring tool and workpiece become necessary.
- The temperature of measuring tools rises when held with a bare hand, resulting in localized thermal expansion.
- Under rapidly changing ambient temperatures, repeatability of measurements cannot be ensured. When a measuring tool is moved from one place to another where there is a significant difference in temperatu it is necessary to leave the measuring tool for at least two hours before it thermally stabilizes to the new temperature.
- Reference setting and measuring should be carried out under as similar conditions as possible in order to minimize errors.

For detailed instructions, refer to the textbook on mechanical type micrometers, calipers and dial indicators.

4.2 Specific Care Required for Digimatic Tools

[1] Temperature
a. Storage temperature range: -20°C to 60°C
Parts made of different materials (such as plastics and metals) are bonded in Digimatic tools, and under excessively severe temperature conditions, they may be damaged due to the difference in thermal expansion coefficients between them. The thermal printing papers and the batteries may deteriorate if they are stored for long periods of time.
b. Operating temperature range: 5°C to 40°C

The electronic components of Digimatic tools are designed to ensure operation and meet their specifica- ns for function, performance and reliability within this temperature range. When measurements are taken at temperatures other than 20°C it is necessary to compensate for the temperature difference to determine the equivalent measurements at 20°C, as both the measuring tool and workpieces expand or contract.

c. Maximum temperature gradient: 1.5°C/min

Significant changes in the ambient temperature not only affect the measuring accuracy and dimensional stability but the resultant condensation can damage measuring tools, interfere with detection by the sensor and cause rust. Do not use measuring tools near a heater or under direct sunlight.

[2] Relative humidity: Below 80%

Do not use measuring tools in high relative humidity for a prolonged period of time in order to avoid condensation (which interferes with detection by the sensor), swelling of the parts made from organic materials and adverse effects to the electric circuits. On the other hand, if the atmosphere is too dry, static electricity may cause malfunctions and personal in- iury.

] Cutting oil: Avoid contamination

Ensure that measuring tools are not contaminated with cutting oil. After measuring, wipe oil from the measuring tool.

[4] Oil mist and dust: Undesirable

Frequently wipe oil mist and dust from the moving parts to keep them clean.

[5] Ultraviolet rays, direct sunlight: Avoid exposure

Do not expose measuring tools to ultraviolet rays, as they deteriorate the plastic parts, the LCD (liquid crystal display), etc.

[6] Static electricity: Undesirable

The degree of the effects of static electricity varies according to the type of measuring tool and the place where the static discharge takes place. When a static discharge takes place directly on the connector pin of the data output port, erroneous data may be transmitted. If the static discharge is very strong, the IC components may be damaged.

When the atmosphere is dry (especially in winter time), synthetic fiber clothing, foam polystyrene and other resin products are easily electrified. In such a .se, it is necessary to avoid static discharge by grounding the workpiece, operator's body and clothing, work stand, and measuring tools, as shown in **Fig. 5**. Make sure to attach a resistance to the grounding lead line for protection from electric shock.

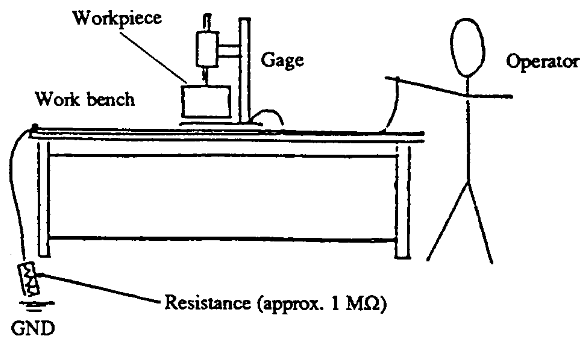


Fig. 5 Grounding

[7] Electrical interference

a. Interference from power source: The limit value varies with the type of measuring tool and the method of connection.

Errors may occur due to electrical interference by the power source when an AC adapter is used. This is also the case when the tool is connected with a data processing unit that uses AC power even if the tool itself is battery-powered. When errors frequently occur, provide a dedicated power source for the measuring tool and the connected units, separated from the equipment that causes the interference. (The sources of interference include motors, ultrasonic cleaners, machines that uses an electric arc, electric pens, etc.) A voltage stabilizer is also effective in reducing electrical interference.

b. Voltage fluctuation of source power: Within ±10% of the rated voltage

c. Radio-frequency interference (RFI)

Errors may occur when a measuring tool is operated in a place near equipment that generates an electric spark such as an arc welder. Use measuring tools as far away as possible from these sources of interference. The longer the data output cable is, the more it is subjected to interference. When using a cable longer than 3m, it is necessary to check the radio-frequency interference.

[8] Solvents and other chemical liquids

a. Acid and alkali: Avoid using

Wipe off any acid and alkali when the measuring tool is contaminated, as they lead to corrosion of metal parts. When these are left on the surface of the plastic cover or display window shield for a long time, they can produce cracks.

b. Organic solvent: Do not use thinners or benzine. These solvents dissolve plastic parts and produce cracks. Use a dry cloth or a cloth soaked with neutral detergent to wipe them off.

[9] Electric pen: Do not use

When an electric pen is used on a measuring tool, it may damage the internal circuitry. Any other types of voltage loads should also be avoided.

[10] Impact and vibration: Do not apply

Normal environmental vibration presents no problem. If a measuring tool is dropped or subjected to an impact from a sharp collision, check its measuring accuracy before resuming operation.

[11] Magnetic field (electromagnetic field)

A weak magnetic field generated by a magnetic chuck or a demagnetizer presents no problem. A demagnetizer can be used on measuring tools.

[12] Vacuum: Over 10^{-2} Torr

A vacuum above this can damage the LCD display and cause the battery to leak.

Note: 1 Torr = 1mm Hg = 1/760 atm

[13] Radioactive rays: Avoid exposure

The design gives no consideration for protection against radioactive rays. When a tool is used in radiation, electrical interference may take place within the circuit, causing functional errors. A prolonged exposure to radioactive rays will cause deterioration of the IC's and other components, resulting in failures or malfunctions.

[14] Flame and explosion

The design gives no consideration for protection against flames or explosions.

Note 1: Batteries must be installed in correct polarity. If the measuring tool will not be used for long periods of time, remove the batteries to avoid damage by leakage from the batteries.

Note 2: Do not disassemble measuring tools. Return them to the manufacturer for repairs.

Note 3: (See [10] above): Digimatic tools are designed and packaged to operate correctly after undergoing the falling test (JIS Z 0200), stipulated as follows.
"Drop a package, containing a hand-held tool, six times from a 90cm height with each of the six packing sides alternately facing down."

5. SPECIFICATIONS AND FUNCTIONS OF DIGIMATIC TOOLS

5.1 Digimatic Micrometer MDC

The shape is similar to conventional micrometers familiar to any user. It is the world's lightest micrometer of its kind and can be operated easily with one hand.

Resolution: 0.001mm

Detecting method: Screw thread and capacitance type rotary encoder

Power source: SR44 (button type silver oxide cell), 1pc.
Power saving by "auto-sleep" function (automatic power-down in two hours after last operation).
Battery life: approx. 6 months under normal use

Accuracy: Instrumental error (± Maximum measurement length /75) µm (fraction rounded up)
(Not including quantizing error, within ± 1 count)
Note: The accuracy is higher than that specified in JIS B 7502 "Outside Micrometer" by 1 µm.

Flatness: 0.3 µm or less

Functions:

- Zero setting
- Origin restoration
- Hold mode
- Presetting
- Error alarm
- Auto-sleep
- Data output (M type)

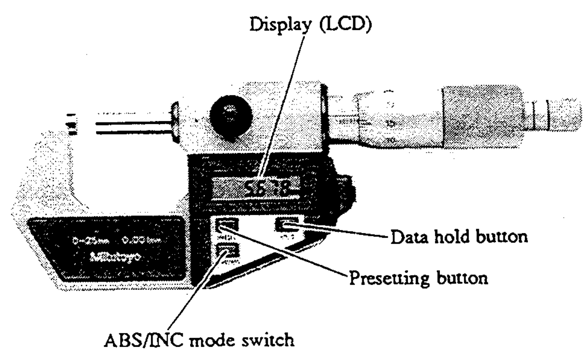


Fig. 6 Digimatic micrometer

5.2 Digimatic Caliper CD

5.2.1 Standard type

The standard type with a built-in electronic circuit has a compact design and can be as conveniently operated as conventional calipers.

Resolution: 0.01mm
Detecting method: Capacitance type linear encoder
Power source: SR44 (Button type silver oxide cell), 1pc.
Battery life: approx. 2 years under normal use. (approx. 1 year in continuous use)
Response speed: 6000mm/s (when opening jaws)
1600mm/s (when closing jaws)
Accuracy: Conforms to JIS B 7507 "Calipers" for 0.02mm reading, with higher accuracy for up to 300mm range models.
Functions:
- Zero setting
- Hold mode
- Error alarm
- Low battery voltage alarm
- Data output

Note: The data output and hold functions cannot be used simultaneously.

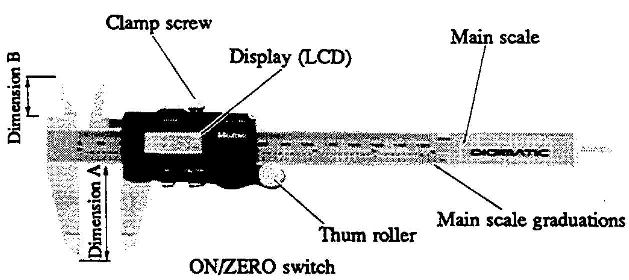


Fig. 7 Digimatic Caliper

With the zero-setting function, the intervals of pins of the same diameter, hole bottom thickness, etc. can be measured directly.
Obtain the value 'x' by measuring dimension ② after setting the caliper to zero at ①.

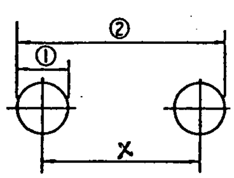


Fig. 8

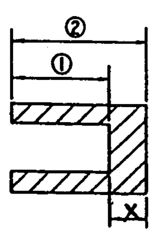


Fig. 9

5.2.2 Digimatic Solar Caliper CDS

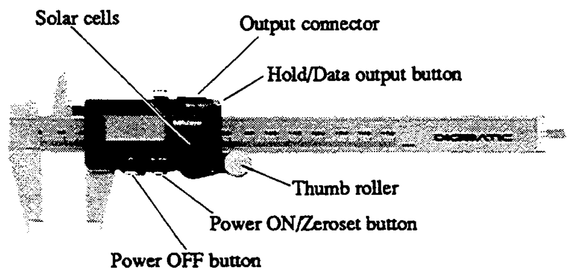


Fig. 10

The Digimatic Solar Caliper, the world's first length measuring tool to use solar cells, has eliminated the need for battery replacement. It can be turned on as soon as it receives a specific minimum intensity of light. If the illumination is brighter than the minimum level, the batteries are charged so that the caliper can be used in a dark place. The Digimatic Solar Caliper can be used as easily as the CD series calipers described above.

Resolution: 0.01mm
Detecting method: Capacitance type linear encoder
Power source:
Amorphous solar cells (Minimum light intensity: 200lux)
The batteries are charged if the illumination is more intense than the minimum level. The caliper can be continuously operated in a dark place for about three hours after the batteries are fully charged. The charging time varies depending on the intensity of the illumination, as shown below.

Illumination intensity	1000 lux	2000 lux
Charging time	Approx. 3 hours	Approx. 1.5 hours

Functions:
- Zero setting
- Hold mode (when the output cable is not connected)
- Data output
- Error alarm
- Low battery voltage alarm (when the illumination is below the minimum intensity and the battery voltage has lowered)
- Auto power-off (when the battery voltage has lowered to a specific level)

5.2.3 Digimatic Carbon Caliper CF (Digital caliper with CFRP beam)

Because of the caliper's weight, it is difficult to handle a large caliper of over 1000mm range for a long time. If the caliper could be made lighter then measurement would be more easy to make with reliability.
Among new, high-tech materials the CFRP (carbon fiber reinforced plastics) are distinguished for their light weight, high strength, and high elasticity. The Digimatic Carbon Caliper has been developed to combine the CFRP's light weight with the advantages of conventional digital calipers. (**Fig. 11**)
An additional feature of the Digimatic Carbon Caliper is that the main jaw is not fixed to the main scale (beam) so it can be slid along the scale in order to maintain the balance of the caliper when a workpiece is measured. (See **Fig. 12.**) The interchangeable jaw model allows the user to perform a wide variety of measurements; in addition to the standard jaw, the replacement jaws include those for hole interval and for internal measurements.
Table 2 shows the comparison of physical properties between CFRP and conventional stainless steel using 1000mm beams. The weight of the CFRP beam is approximately one-fifth that of the stainless steel beam. The total weight of the CFRP caliper (beam and slider), however, is about half that of the conventional stainless steel type because the weight of the main jaw and slider (with jaw) for both types is almost the same. The Young's modulus (modulus of longitudinal elasticity) of CFRP is approximately two-fifth that of stainless steel. Because the weight of the CFRP beam is one-fifth that of the steel beam, the unloaded flexure of the CFRP beam is about half that of the steel beam. (The ratio of flexure becomes a little greater because of the attached jaws.)

Range: 450, 600, 1000mm
Display: 6-digit LCD, character height 7mm
Functions:
- Zero setting • Hold mode
- Data output (when the output cable is not connected)
- Inch/metric conversion

Response speed: Approx. 1600mm/s
Power source: SR44 (Button type silver oxide cell), 1pc.
Battery life: approx. 2 years (approx. 1 year in continuous use)
Auto power-off not provided.
Output: SPC output (5-pin connector, 1-bit serial)
Output cable: Optional (1m or 2m)
Operating temperature: 0°C to 40°C
Storage temperature: -10°C to 60°C

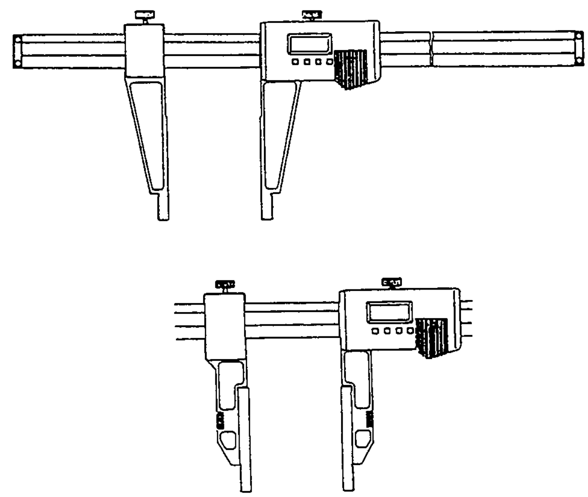


Fig. 11

Table 2 Physical properties of stainless steel (SUS420J2) and CFRP (for 1000mm beams)

	Stainless steel (SUS420J2)	CFRP
Density (g/cm^3)	7.75	1.70
Young's modulus (kgf/mm^2)	29, 000	11, 700
Thermal expansion coefficient (/°C)	10.2×10^{-6}	3.2×10^{-6}
Weight/meter (kg)	1.9	0.4
Unloaded flexure (mm)	0.039	0.020

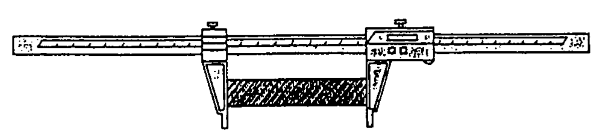


Fig. 12

5.3 Digimatic Height Gage

5.3.1 Digimatic Height Gage HD

The Digimatic Height Gage HD is a popular type, easy-to-use height gage, and is ranked as the top seller of its kind. It has most of the basic functions which include zero setting, hold mode, presetting (uppermost digit only), coarse/fine feeding, battery check, over-speed alarm.

5.3.2 Digimatic Height Gage HDM

In addition to functions of the HD type Height Gage, the Digimatic Height Gage HDM has many other functions to meet wide-ranging measurement requirements.

Resolution: 0.01mm
Detecting method: Photoelectric rotary encoder
Power source: LR6, 3 pcs.
Battery life: approx. 3 months under normal use (approx. 500 hours in continuous use)
Accuracy: Conforms to the JIS B 7517 "Height Gage" for 0.02mm reading, with higher accuracy for up to 450mm range models.
Accuracy of model HDM-30: ± 0.02mm (quantizing error not included)

Functions:
- Origin setting (for ABS mode)
- Zero setting (for INC mode) • Origin restoration
- Presetting (for ABS and INC modes)
- Preset value memory (for ABS mode)
- Hold mode • Coarse/fine feeding
- Error alarm • Data output
- Low battery voltage alarm

A bi-directional touch signal probe can be connected to the Digimatic Height Gage HDM (see **Fig. 13**). This capability greatly improves the accuracy, repeatability and efficiency, because a constant measuring force is maintained, and the data can be held and/or output the moment the probe touches the workpiece. Use of this probe not only improves measuring accuracy, but also offers such advantages as automatic compensation of the probe radius, and non-clutch two-way switching of measuring directions without zero setting. Furthermore, direct measurements of inside width, outside width and step height are available with the following additional functions.
Additional functions:
- Automatic zero setting • Automatic presetting
- Automatic data holding
- Automatic release of data holding
- Automatic data output

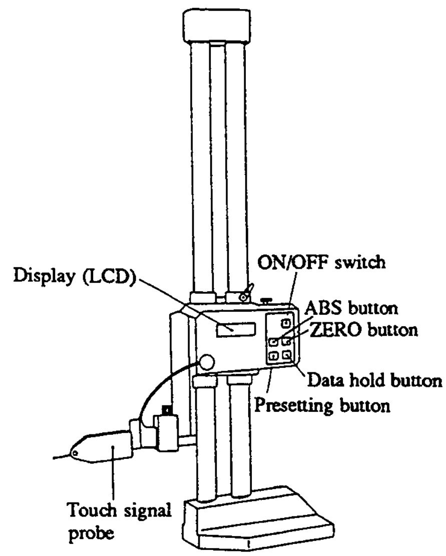


Fig. 13 Digimatic Height Gage HDM

5.3.3 Digimatic Height Gage HDS (Fig. 14)

The Digimatic Height Gage HDS is a popular type, low-price height gage for shop-floor use. It can be used both for measuring and scribing work. Operation is very similar to that of a vernier height gage. For simplicity, the number of switches is limited to a minimum. For instance, simply pressing a switch performs zero setting, instead of moving the main scale as with conventional mechanical height gages. Another advantage is that most of the accessory attachments for mechanical type height gages can be used for the Digimatic Height Gage HDS. There are two types of HDS; the S type popular version and the M type with a data output capability.

Resolution: 0.01mm
Detecting method: Capacitance type linear encoder
Power source: SR44, 1 pc.
Battery life: approx. 1 year under normal use
Auto power-off in approx. 2 hours after last operation
Response speed: 1000mm/s
Accuracy: Conforms to JIS B 7515 "Height Gages" of 0.02mm reading
Functions:
- Zero setting
- Auto power-off
- Error alarm
- Low battery voltage alarm
- Data output (for M type)

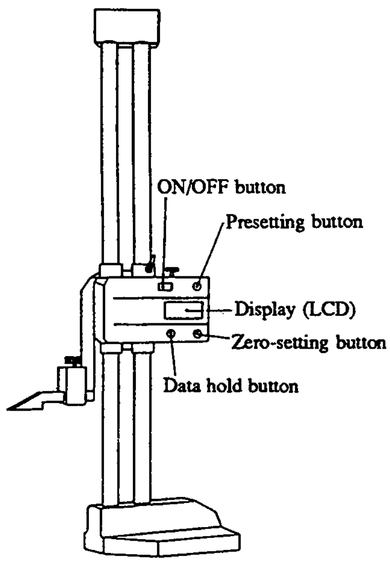


Fig. 14 Digimatic Height Gage HDS

5.3.4 Heightmatic HDF

This is a high-accuracy, high-resolution Digimatic gage for height measurement. The slider incorporates a digital display which can be moved both manually (coarse feed) and with a wheel on the base (fine feed). A touch signal probe can be attached for accurate and repeatable measurement.

Resolution: 0.001mm
Detecting method: Photoelectric linear encoder
Power source: AC outlet via AC adapter
Response speed: 500mm/s
Accuracy: ± 0.004mm for 0 - 450mm range models
± 0.005mm for 0 - 600mm range models
Display: Fluorescent tubes (green)
Functions:
- Zero setting
- Direction changeover
- Presetting
- Go/nogo judgment
- Data output
- Error alarm
- Touch probe measurement

5.4 Digimatic Indicator

As opposed to conventional dial indicators which indicate analog measurements with a dial and pointer, those indicators which digitally display values are called digital indicators or electronic gages.
From the structural point of view, digital indicators are divided into two categories; (a) system that uses a rotary encoder to detect the spindle displacement which is amplified by means of the conventional rack-pinion mechanism, and (b) system that uses a linear encoder to detect the spindle displacement electrically. The Mitutoyo Digimatic Indicators employ the latter system because it needs no mechanical amplification; this ensures high accuracy in a wide measuring range that cannot be achieved by conventional dial indicators. The detecting methods used for Digimatic Indicators include the photoelectric system (models ID and ID-M), the capacitance system (models IDC and IDU), and the differential transforming system, as shown in **Table 1**.

5.4.1 Digimatic Indicator IDF (Fig. 15)

This indicator has a built-in linear encoder using a glass scale and is powered by an AC adapter.
This indicator features optional Infrared Remote Controller which allows various settings to be done by remote control including zero-setting, presetting, and tolerance limit setting.
Resolution: 0.01mm or 0.001mm (depending on the model)
Detecting method: Photoelectric type linear encoder with glass scale
Display: Fluorescent tubes (pale blue)
Power source: AC outlet via AC adapter or DC power supply from a data processing unit
Response speed: 800mm/s
An air damper can be installed to

safeguard against damaging a workpiece by an accidental drop of the spindle, and to prevent the spindle speed from exceeding the response speed.

Functions:
- Zero setting
- Peak value hold mode
- Count direction changeover
- Run-out measurement
- Presetting
- Go/nogo judgment
- Alarm display
- Remote control (by cable or infrared rays)
- Data output

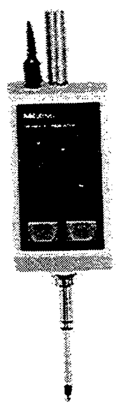


Fig. 15 Digimatic Indicator IDF

5.4.2 Digimatic Indicator IDC (Fig. 16)

The Digimatic Indicator IDC is as compact as the standard Mitutoyo Dial Indicators (series 2), thus allowing a wide range of applications.

Resolution: 0.01mm or 0.001mm (depending on the model)
Detecting method: Capacitance type linear encoder
Display: LCD
Power source: SR44, 2 pcs.
Battery life: Depends on the model (see below).
Response speed: 1000mm/s (for 0.01mm resolution model)
480mm/s (for 0.001mm resolution model)

Functions:
- Origin setting
- Count direction changeover
- Zero setting
- Data output function
- Origin restoration
- Error alarm
- Presetting
- Low battery voltage alarm
- Rotatable display face
- Overflow alarm

Code No.	Resolution	Measuring force	Battery life
543-125	0.01mm	1.0N	1.5 years
543-170	0.001mm	1.5N	2.5 months

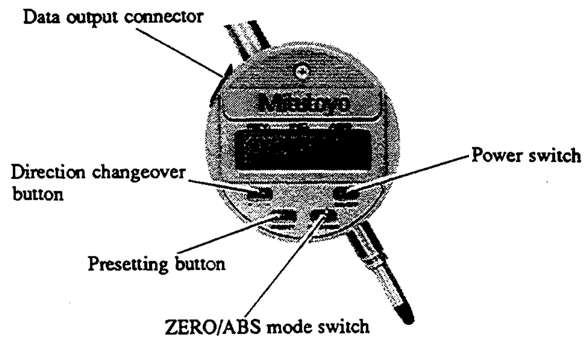


Fig. 16 Digimatic Indicator IDC

5.4.3 Digimatic Indicator IDA (Fig. 17)

The Digimatic Indicator IDA features a dual display; an error-free digital readout and an easy-to-observe analog display (bar graph).

Resolution: 0.01mm or 0.001mm (depending on the model)
Range: 12mm
Detecting method: Capacitance type linear encoder
Display: LCD; Numeric display and bar graph
Power source: SR44, 2 pcs.
Function:
- Zero setting
- Tolerance setting
- Data output
- Bar graph range selection
- Low battery voltage alarm
- Error alarm

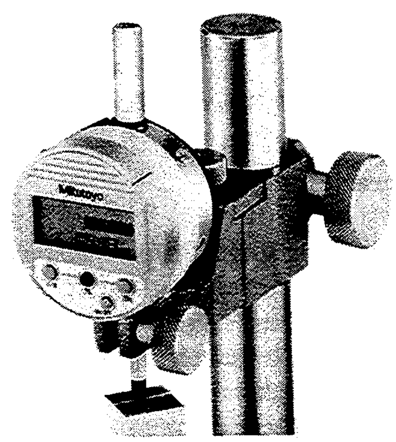


Fig. 17 Digimatic Indicator IDA

5.4.4 Digimatic Indicator IDU (Fig. 18)

This is a compact and slim type at a low price.

Resolution: 0.01mm
Range: 0 - 25mm
Detecting method: Capacitance type linear encoder
Display: LCD
Power source: SR44, 1 pc.
Battery life: 2 years under normal use (1 year in continuous use)
Response speed: 1000mm/s
Functions:
- Zero setting
- Error alarm
- Low battery voltage alarm
- Data output
- Over-speed alarm

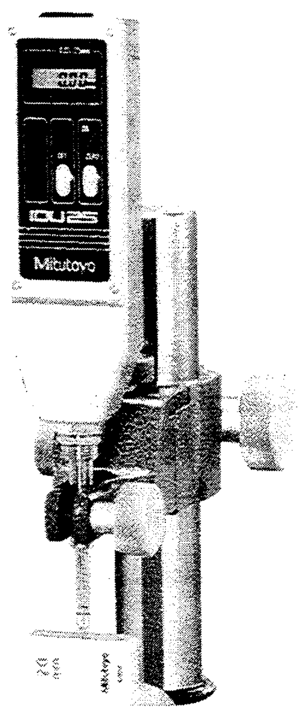


Fig. 18 Digimatic Indicator IDU

5.5 Linear Gage

The detecting principle and the functions of the Linear Gage are almost the same as those of the Digimatic Indicator. The Linear Gage is designed for remote display and control by separating the display unit from the detecting unit, thus allowing it to be incorporated in automated inspection systems, whereas Digimatic Indicators are usually operated manually.

Resolution: 0.01mm or 0.001mm (depending on the model)
Detecting method: Photoelectric type linear encoder with glass scale
Display: Fluorescent tubes (green)
Power source: AC outlet via AC adapter
Response speed: 800mm/s (for 0.01mm resolution model)
400mm/s (for 0.001mm resolution model)
Functions:
- Zero setting
- Run-out measurement
- Count direction changeover
- Go/nogo judgment
- Presetting
- Data output
- Alarm display
- Remote control (by cable or infrared rays)
- Peak value hold mode

The following types of display units are available:
- Difference/sum Unit (connecting with two Linear Gages)
- Display units (counters) for Linear Scales (an LG interface [**No. 938418**, optional] is required for connecting with a linear gage head)
- 0.0001mm resolution display unit (special order)

6. M-SPC SYSTEM

As mentioned in the first part of this textbook, digital measuring instruments or tools were introduced because (1) no expertise is needed for reading measured values, (2) measurement can be carried out even under low light, and (3) errors do not occur in reading the smallest graduations on the micrometer sleeve (0.5mm for metric type). Advantages of digital measuring tools surpassed these, with many additional functions that are not available with conventional analog measuring tools; for example, a go/nogo judgement function, which enables the operator to instantly inspect each product as it comes from the production line. Since the current trend in industry is toward computerized control of the entire production process, the data output function of digital measuring tools has assumed a new, significant role — today not only are the tools used to inspect finished products, but they permit process control through on-line inspection in order to minimize the number of defective products.
SPC (statistical process control) is an integrated sys-

tem of measuring tools and data processing units for statistical control of products' quality through controlling the production process. The Mitutoyo Statistical Process Control system, abbreviated the M-SPC system, is an epoch-making system which integrates a wide variety of measuring tools into a comprehensive process control system. All Mitutoyo Digimatic products use a standard data output format, called the Digimatic code, which allows them to be connected with common data processing units in order to construct an M-SPC system. The sections that follow outline the standard types of data processing, collection and transmission units used in M-SPC systems. For detailed description of the M-SPC system, please refer to the separate textbook titled "M-SPC" (Textbook No. 7024).

6.1 Digimatic Mini-processor (Fig. 19)

This is a stand-alone type data processor which provides statistical processing of measured data on the spot with a simple operation. With its built-in set of programs, operators can perform the required data processing without any special knowledge of programming.

There are four types of Digimatic Mini-processors as follows:
a) DP-1DX
b) DP-2DX
c) DP-3DX
d) DP-30
Refer to the table on the last page for the functions, specifications, etc. of each processor.

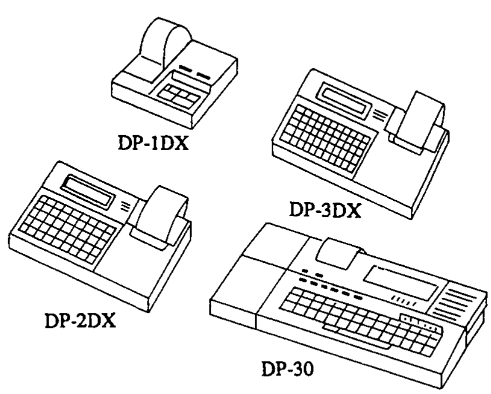


Fig. 19 Digimatic Mini-processor

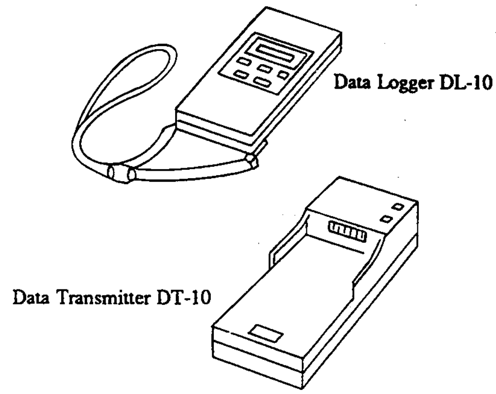


Fig. 20 Batch processing system

6.2 Data Transmission Unit

The following systems are used to transfer measured data from a Digimatic tool to the host computer:

a. Batch processing system (**Fig. 20**)
In this system, data is stored in a data logger as measurements are made, and subsequently uploaded in batch to a computer for data processing. The system consists of a data logger (data storage unit) and a data transmitter (data transmission unit).
• Data Logger DL-10
Maximum number of data items logged: 1000
Number of characteristics*: 1-10
* "The number of characteristics" means the number of measurement items on a workpiece. The characteristics number setting is used when more than one feature is measured on each workpiece.
Display contents: Entry No., Number of characteristics, Measured data
Power source: LR6, 4 pcs.
Battery life: approx. 30 hours in continuous use
Automatic power-down in 10 minutes after last operation (The input data is retained in memory.)
• Data Transmitter DT-10
Output specification: RS-232C interface
Baud rate options (300, 600, 1200, 2400 bps)
Power source: 100VAC, 50/60Hz

b. On-line data processing system (**Fig. 21**)
In this system, the measured data collected on site is

transmitted in real time to the host computer through a cable. A Digimatic Multiplexer MUX-10 or MUX-20 is used for data transmission.

• Multiplexer MUX-10, MUX-20

Output specification: RS-232C interface
  Baud rate options
  MUX-10 (300, 600, 1200 bps)
  MUX-20 (300, 600, 1200, 2400 bps)

Number of input channels: 3

Power source: 100VAC, 50/60Hz

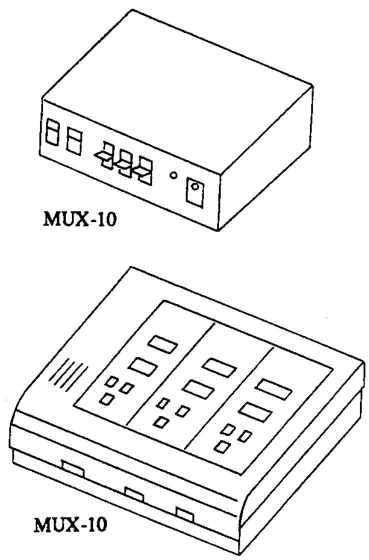


Fig. 21 Digimatic Multiplexer

6.3 M-SPC System Configuration Diagram

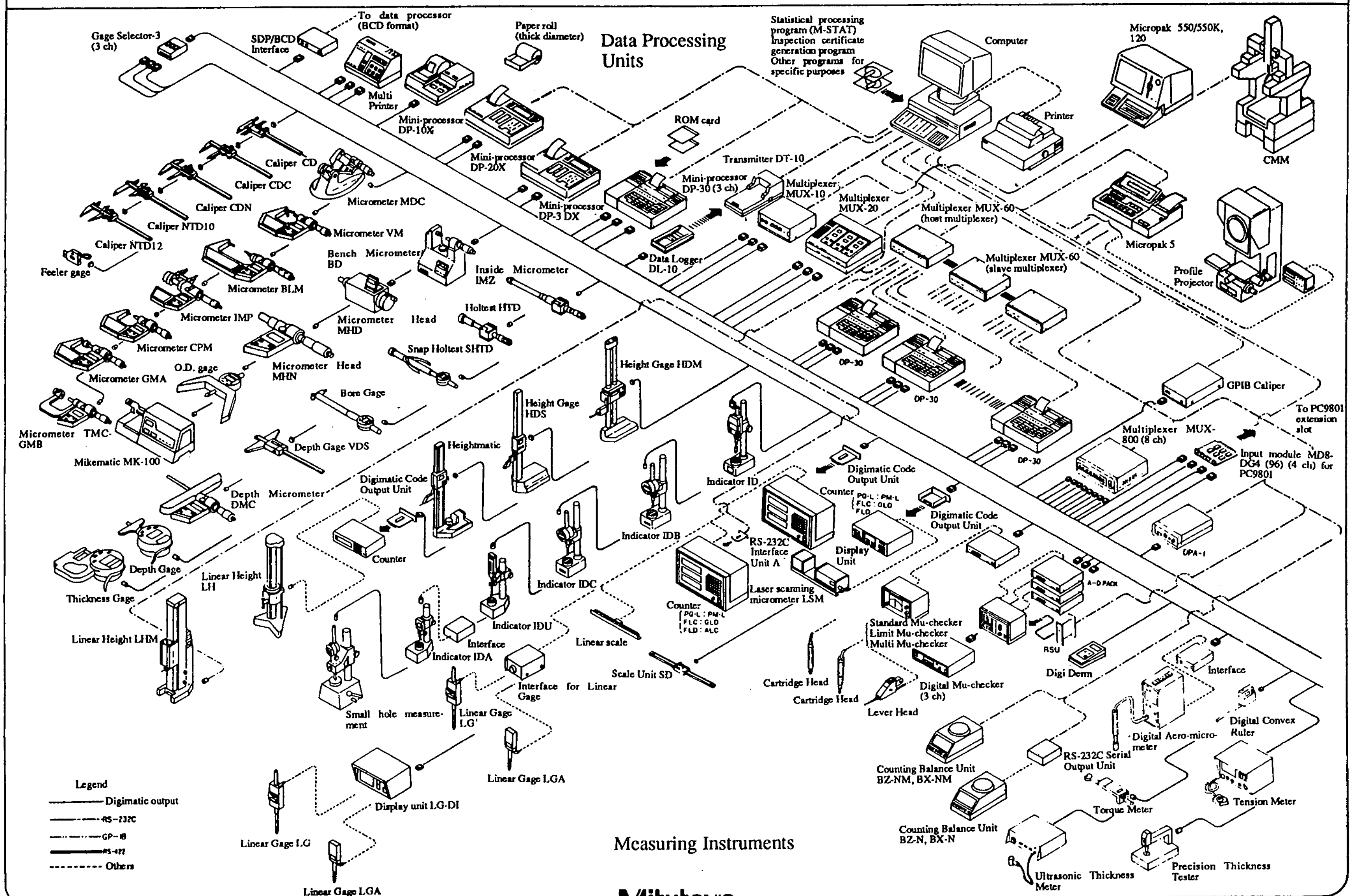
We have introduced the representative models of Digimatic measuring tools and data processing/transmission/collection units. In addition to these, the Digimatic family has many other members to make up the M-SPC system, as shown in the following system diagram, and is expected to further expand in the future.

Digimatic Mini-processor Functions

FUNCTION \ MODEL		DP-1DX	DP-2DX	DP-3DX	DP-20DX
Number of channels		1	1	1	3
Application	Control Chart Mode (SPC)	○	—	○	○
	• Sample size	2 to 10	—	2 to 8	2 to 10
	• Number of subgroups	35 max.	—	35 max.	30 max.
	Inspection Mode (SQC)	○	○	○	—
	• Number of measurement entries	1000 max.	1000 max.	1000 max.	—
Number of dimensional characteristics		1	1	2 max.	8 max.
Preset a data on the measuring tool (ID, LG, LGA)		—	○	○	—
Tolerance setting to the measuring tool (ID, LG, LGA)		—	○	○	—
Calculation of measurements with a constant		—	○	—	*
Compensation of thermal effect on measurements		—	○	—	*
Calculation of difference between two measurements		—	○	—	*
Key-in of measurement data		—	—	○	○
Tolerance limits setting		○	○	○	○
Recording (by a built-in printer) Measurement data		○	○	○	○
Results from above calculations marked with ( )		—	○	—	*
Go/nogo discrimination	▲ (+NG), ▼ (-NG)	○	○	—	*
Number of measurements	N	○	○	○	*
Max. and Min. values	MAX, MIN	○	○	○	*
Range	R	○	○	○	○
Mean value	$\bar{x}$	○	○	○	○
Standard deviation	σn	○	○	—	*
Standard deviation	$\sigma n\text{-}1$	○	—	○	○
Fraction defective	F. D.	○	○	—	○
Estimate fraction defective	Z_{USL}, Z_{LSL}	—	—	○	○
Process capability index	Cp	○	○	○	○
Process capability index	Cpk	○	—	○	○
Process capability index	1/CP	—	—	○	*
Kurtosis		—	—	—	*
Skewness		—	—	—	*
Histogram		○	○	○	○
Control limit values		○	—	○	○
$\bar{x}$-R control charts		UCL, LCL	—	○	○
$\bar{x}$-s control charts		—	—	○	○
File heading		Alphabetical	Numerical	Alphanumeric	Alphanumeric
Date and time		Title only	○	○	○
Part name or No.		Title only	○	○	○
Machine name or No.		—	○	○	○
Inspector name or No.		Title only	○	○	○
Selection of items to be recorded		—	○	—	*
Alarm singnal output (Over UCL, under LCL)		—	○	○	*
Built-in printer		Thermosensitive	X-Y plotter type (4-colors)		Dot printer
Power supply	AC adapter	9VDC, 0.8A	10VDC, 1.2A		6VDC, 0.6A
	Rechargeable batteries	—	—	—	○
	To the measuring tool (ID, LG, LGA)	○	○	○	—

* DP-20 performs (*) marked items with EPSON BASIC.
• You can create your own application program for DP-20 by EPSON BASIC and SPC BASIC.
• Micro-cassette drive or casette tape recorder can be used for storage of measurement data and application program of DP-20.

M-SPC System Diagram



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