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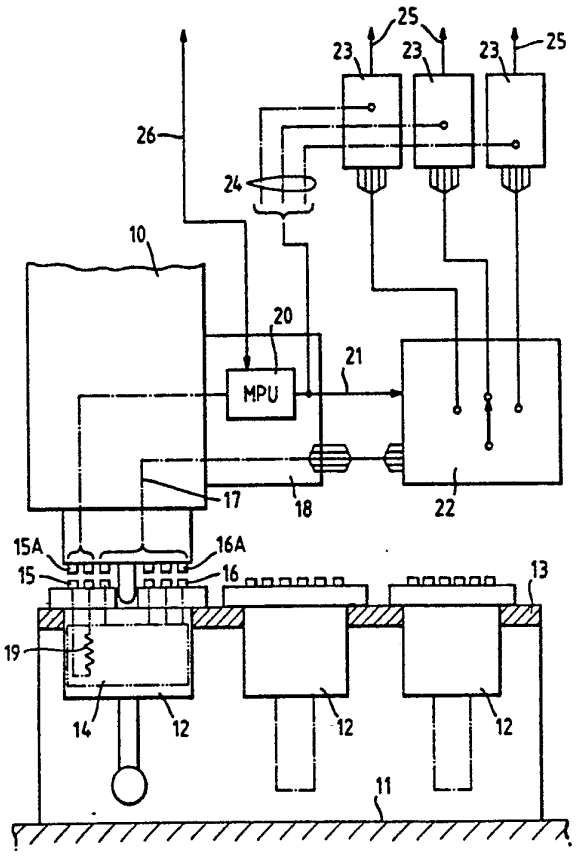
(54) Title: TOOL CHANGE APPARATUS

(57) Abstract

A tool-holding head (10) for changing tools (12) on a co-ordinate measuring machine or machine tool, especially measuring tools such as probes, and also extension bars for use with such tools. To ensure that the correct tool has been picked up and thereby prevent possible damage, each tool is provided with a unique resistor (19) for identification purposes, which is interrogated by a microprocessor (20). If the correct tool is thus identified, the microprocessor (20) then instructs a multiplexer (22) to connect an appropriate computer interface (23) to the tool.



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TOOL CHANGE APPARATUS

Technical Field

This invention relates to tool change apparatus, for example for changing the measuring tools used for inspection of workpieces on a co-ordinate measuring machine, or for a machine tool.

Background Art

An example of such a tool change apparatus is shown in our international patent application published under the number WO85/02138, incorporated herein by reference. The apparatus exemplified by that application comprises a head for releasably supporting one of a plurality of tools. The tool may for example be a probe which generates a signal in response to contact with a workpiece. Such a signal is then

transmitted via confronting electrical contacts on the tool and on the head to a computer (which may be part of the co-ordinate measuring machine or machine tool). In practice, an interface is commonly required to condition the signal before passing it to the computer, and/or also to provide appropriate power and possibly control signals to the tool.

Disclosure of Invention

A problem arises where more than one type of tool is to be connected to the head, if different tools have different requirements for signal conditioning, power supply and/or control signals. The appropriate requirements for the tool currently connected must be met, and for example a tool may be damaged if an incorrect power supply is inadvertently applied to it.

According to this invention we provide tool change apparatus for a co-ordinate measuring machine or a machine tool, comprising:

(a) a tool-holding head having means for releasably supporting (in operation) one of a plurality of tools, the tools to be supported each including a respective identification means unique to the tool, and

(b) means for detecting the identity of a said tool, when supported by the head, from the identification means of the tool, and for producing an output signal indicative of the identity.

Brief Description of the Drawings

An embodiment of the invention will be described by way of example with reference to the accompanying drawings,

in which:

Fig 1 is a diagrammatic layout of a tool change apparatus,

Fig 2 is a more detailed schematic diagram of part of the apparatus,

Fig 3 is a flow chart explaining the operation of the apparatus, and

Fig 4 shows diagrammatically an extension bar for use with the apparatus

Best Mode for Carrying Out the Invention

Referring to Fig 1, a co-ordinate measuring machine (known per se and not described in detail) has a head 10 movable relative to a table 11 on which a plurality of different tools 12 are arranged in respective storage locations of a support 13. The head 10 is adapted to be connected to any one of the tools 12 and to move the tool to a workpiece (not shown) for measuring or inspecting the workpiece all as known in general from our said International Patent Application.

The tools 12 may include a probe, known per se, for sensing contact with a workpiece and opening electrical contacts within the probe when the workpiece is touched. They may also include analogue probes for responding to contact with the workpiece, proximity probes, crack detecting probes, laser and other optical measuring probes, video cameras etc. enabling the co-ordinate measuring machine to be used as a very flexible inspection system for inspecting a wide variety of quality aspects of the workpiece.

Each tool 12 has an electric circuit 14 connected to a plurality of contacts 15,16 co-operating with confronting contacts 15A,16A on the head 10 to connect the tool circuit 14 to a signal conditioning unit ("SCU") 18 provided on the head 10. Certain contacts, 15, are used to enable the SCU to recognise the particular tool being connected to the head 10 while other contacts, 16, are used for transmitting an operational group of signals 17 to and from the tool.

Any parameter or code may be used for said recognition. In this example the tools 12 include respective resistors 19 of different resistance value connected to the contacts 15. The tools 12 could however contain, for example, respective capacitors of different values, or each could transmit a unique digital code on being interrogated. Alternatively, in place of recognition via the electrical contacts 15,15A, each tool could carry an element bearing a unique, optically or magnetically recognisable code, read by an appropriate sensor on the head 10.

The SCU 18 of the present embodiment includes means (described below) for determining the resistance of the resistor of whatever tool 12 is connected to the head thereby to positively identify the tool. In this example a microprocessor system 20 (also described below) is used in the SCU for this purpose and is adapted to produce discrete identifying signals 21 for the respective tools 12. However, the same purpose could obviously be achieved by non-microprocessor circuitry if preferred.

Said other contacts 16 are connected through the SCU 18 to a multiplexer 22 for transmission of the operational signal groups from the tool 12 to a respective

interface unit 23 where the operational signals are processed to appear at 25 in useful form for further processing by computer or for display e.g. in the form of printed characters. The interface 23 may also provide appropriate power and/or control signals to the respective tool 12 via the multiplexer.

The multiplexer 22 is operated by the SCU in response to the identifying signals 21 so that the operational group of signals 17 of any one tool 12 identified by the SCU 18 is connected by the multiplexer 22 to the appropriate interface unit 23. The SCU 18 is also adapted to produce signals 24 responsive to the respective signals 21 and connected to the respective interface units 23 to initiate the processing of the operational signals 17 connected thereto by the multiplexer. Such processing may include the digitisation of analogue values. The SCU itself may include amplifiers for amplifying any such analogue values prior to onward transmission. Furthermore, the microprocessor 20 is in communication via a channel 26 with a host computer of the co-ordinate measuring machine, which has overall control of the machine and governs the picking up, use and setting down of the tools 12 by the head 10.

Fig 2 shows more detail of part of the SCU 18, and Fig 3 shows the sequence of operations performed by the microprocessor 20. At step 30 in Fig 3, the microprocessor is waiting for a signal from the host computer. At 32, a signal is received from the host via the communication channel 26, advising the microprocessor that the host has caused the head 10 to pick up a tool 12 from a given location on the support 13 (in the manner described in the above-mentioned international patent application). The signal includes

a code for identifying the tool concerned. On receipt of this signal, at step 34, the microprocessor interrogates the tool 12 which has been picked up. It does this by switching on a constant current source 27 within the SCU, to pass a known constant current through the resistor 19 of the tool via the contacts 15,15A. It then receives an input value from an analogue-to-digital converter 28, indicating the voltage developed across the resistor 19 by the constant current. This input value, of course, is unique to the tool picked up. Having received the value, the current source 27 is switched off.

Next, at step 36, the microprocessor 20 takes the tool identification code received from the host at step 32 and addresses a table stored in its memory 29. From the table, it obtains a corresponding voltage value, being the value expected to be produced in the converter 28 by the tool which the host intended to be picked up. The microprocessor decides whether the correct tool has in fact been picked up by comparing this expected value with the value actually received in step 34. If the values do not agree (to within a specified tolerance) the microprocessor proceeds to step 38, where it signals a fault condition to the host. The host may then halt operation of the machine, or possibly it may attempt to correct the fault. Such a fault may occur for example, if the machine operator has placed the wrong tool in the chosen location of the support 13, or if the tool has not been successfully picked up for some reason. Signalling the fault in this way prevents the host from continuing its cycle with the wrong tool and possibly causing collision damage between the tool and the workpiece.

Assuming that the correct tool is identified, then the

microprocessor sends the signal 21 to the multiplexer 22 to connect the corresponding interface 23 to the tool 12 (step 40). The signal 24 is also sent to the appropriate interface to activate it. Prior to this time, no interface at all has been connected to the tool. This is important in order to ensure that the tool is not inadvertently connected to an incorrect power supply which could damage it. Having instructed the multiplexer and corresponding interface, the microprocessor confirms this fact to the host.

After this step, the microprocessor then simply waits for a further signal from the host (step 42), during which time the host is controlling a measurement or inspection operation on the workpiece, using the selected tool 12. When this is completed on returning the tool to its storage location on the support 13 and immediately prior to disconnection of the tool from the head 10, the host again signals the microprocessor 20 (step 44). The microprocessor then issues a signal 24 to disable the selected interface 23, and a signal 21 to cause the multiplexer 22 to disconnect the interface from the contacts 16A (step 46). Having done so, it confirms this fact to the host which will proceed to disconnect the tool from the head. The microprocessor can now return directly to step 30 to repeat the whole process for the next selected tool.

Fig.4 illustrates a further type of tool, one or more of which may be present in the support 13. This is an extension bar tool 50 which can be used as an accessory in conjunction with any one of the measuring tools 12. One end 52 of the bar is provided with mechanical and electrical connections identical with the tools 12, in order that it can be picked up by the head 10 (though

the mechanical connections are not shown in the figure). The other end 54 has mechanical and electrical connections identical with the head 10, so that once the bar has been picked up by the head, it can then in turn pick up either a selected tool or another extension bar 50. The use of an extension bar is known per se, and enables the measuring tool 12 to inspect regions of the workpiece which would otherwise be inaccessible, e.g. the internal surfaces of a bore. Often, to provide the greatest flexibility, several extension bars 50 of differing lengths will be stored in the support 13.

To permit identification of the tools 12 in exactly the same manner as above, and to allow for transmission of signals and power to and from the tool, a series of parallel electrical lines 15B, 16B run the length of the extension bar 50, connecting the contacts 15,16 at the end 52 with the respective contacts 15A,16A at the end 54. Additionally, it is desirable to be able to identify the extension bar or combination of bars which has been connected. To this end, each bar is provided with a unique-valued resistor 56 connected between one of the lines 15B and one of the lines 16B. The microprocessor 20 controls a switch 31 to connect the constant current source 27 and analogue-to-digital converter 28 across the corresponding contacts 15A,16A. The identifying resistor 56 is interrogated in exactly the same way as described above for the resistor 19. If two or more extension bars 50 are connected in series, their resistors will appear in parallel to decrease the voltage measured by the analogue-to-digital converter. The combination of bars can be uniquely identified if the respective resistance values are suitable chosen: for example, so that the conductance of each bar is proportional to its length,

or is in a binary sequence such as 100μS, 200μS, 400μS, 800μS etc.

The resistor 56 is connected between a line 15B and a line 16B, rather than across the two lines 15B, in order to facilitate identification of the measurement tools 12 separately from the extension bar tools 50. Since this reduces the number of the electrical connections 16,16A which are available for signal and power purposes, and since it is likely that the number of pins available for these purposes will be limited, it may be desirable to use the two connections 15,15A for both identification functions. This can be done if the extension bars (for example) are each identified with a unique capacitance value instead of a unique resistance value; but this leads to an excessively complicated arrangement and is not preferred.

The tool change apparatus described is particularly useful with measuring and inspection tools on co-ordinate measuring machines, and can also be used with measuring and inspection tools on an automatic machine tool. It enables the correct interface to be selected and prevents electrical and mechanical damage being caused if the wrong tool is picked up. However, it is also useful for confirming the identity of tools not themselves intended for measurement or inspection, including the accessory extension bars already discussed, and even (if desired) the cutting tools of a machine tool, provided an appropriate means of identification can be applied to them.

CLAIMS

1. Tool change apparatus for a co-ordinate measuring machine or a machine tool, comprising:

(a) a tool-holding head (10) having means for releasably supporting (in operation) one of a plurality of tools (12;50), the tools to be supported each including a respective identification means (19;56) unique to the tool, and

(b) means (20,27,28) for detecting the identity of a said tool, when supported by the head, from the identification means of the tool, and for producing an output signal (21;24) indicative of the identity.

2. Apparatus according to claim 1, for use with tools (12;50) in which the identification means is a resistor (19;56), wherein the detecting means includes means (27,28) for producing a value corresponding to the resistance of the resistor (19;56).

3. Apparatus according to claim 2 in which the detecting means includes a constant current source (27) for connection to the resistor (19;56) and means (28) for measuring the voltage developed across the resistor by the constant current to produce said value.

4. Apparatus according to claim 1, for use with tools (12) which have means (14) for transmitting a signal (17) to the apparatus, and including a multiplexer (22) which is acted upon by said output signal (21) and which is arranged to receive said signal (17) transmitted from the tool and pass it to a selected one

of a plurality of processing circuits (23), the processing circuit being selected by the multiplexer in accordance with the output signal.

5. Apparatus according to claim 4 in which said means for detecting the identity of a tool includes means (20) for receiving from a host computer a code representing an expected tool identity, for comparing the received code with the detected tool identity, and for causing the multiplexer (22) to select a said processing circuit (23) only if the detected identity agrees with the received code.

6. Apparatus according to claim 1, including at least one said tool (12;50).

7. Apparatus according to claim 6, in which the identification means within the tool (12;50) is a resistor (19;56).

8. Apparatus according to claim 6, in which the tool is a measuring tool (12).

9. Apparatus according to claim 6, in which the tool is an extension bar (50) adapted to releasably support a further tool (12;50).

10. Apparatus according to claim 9, in which the extension bar (50) has a plurality of electrical lines (15B,16B) running in a parallel arrangement from electrical connections (15,16) at one end of the bar to corresponding electrical connections (15A,16A) at the other end of the bar, thereby to connect the head (10) to a said further tool in operation, and including said identification means in the form of a resistor (56) connected between two of said lines.

Fig.1.

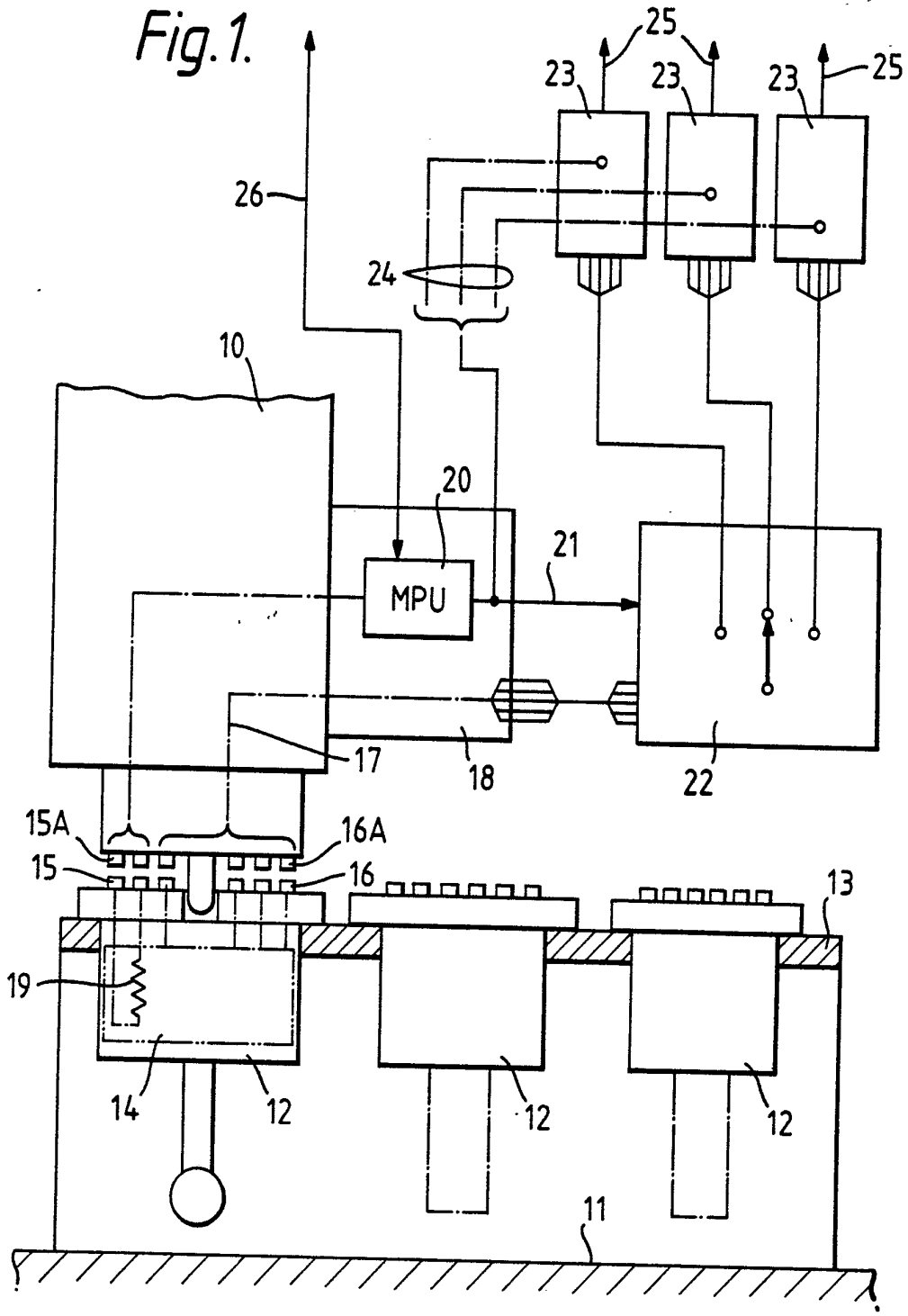

25
23
23
23
25
26
24
10
20
MPU
21
17
18
22
15A
16A
15
16
13
19
14
12
12
12
11

Fig.4.

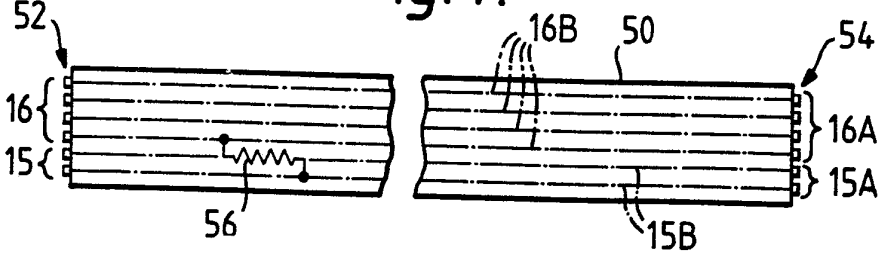

52
16B
50
54
16
15
16A
15A
56
15B

Fig.2.

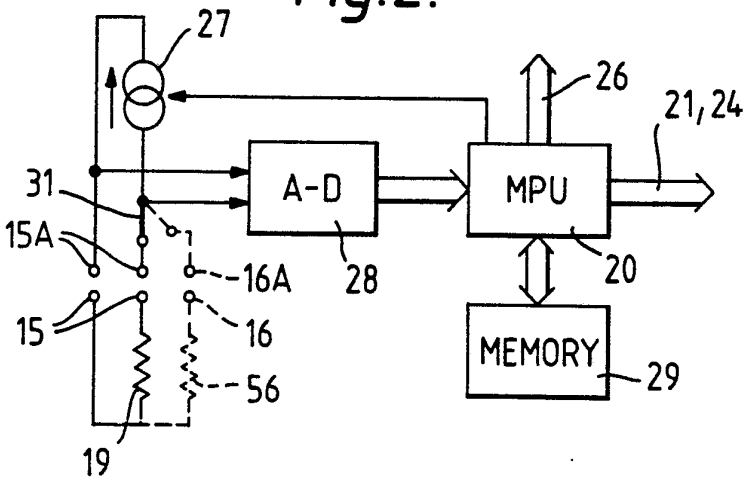
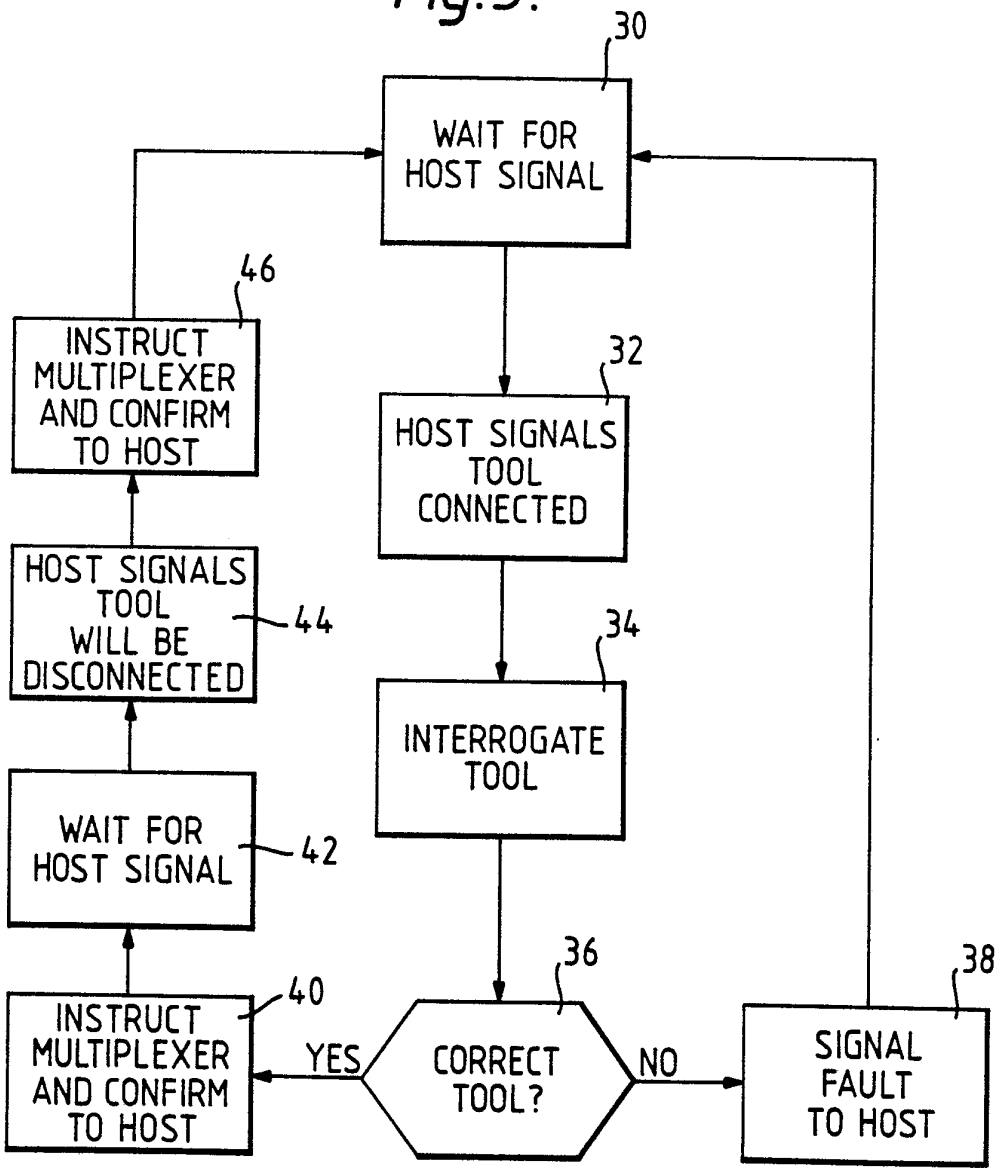

27
26
21,24
31
A-D
MPU
15A
16A
28
20
15
16
MEMORY
29
56
19

Fig.3.


30
WAIT FOR HOST SIGNAL
46
INSTRUCT MULTIPLEXER AND CONFIRM TO HOST
32
HOST SIGNALS TOOL CONNECTED
HOST SIGNALS TOOL WILL BE DISCONNECTED
44
34
INTERROGATE TOOL
WAIT FOR HOST SIGNAL
42
36
38
40
INSTRUCT MULTIPLEXER AND CONFIRM TO HOST
YES
CORRECT TOOL?
NO
SIGNAL FAULT TO HOST

INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 86/00551

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC[4]: G 01 B 7/00; G 05 B 19/12; B 23 Q 3/155

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC[4]	G 01 B 7/00; B 25 J 15/00; B 23 Q 3/00; G 05 B 19/00

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category [10]	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
X Y	EP, A1, 0132528 (OTTO BILZ) 13 February 1985, see the whole document	1,6 4,5,8,9
Y	GB, A, 2141364 (GTE VALERON CORP.) 19 December 1984, see figure 1, page 1, line 39 - page 6, line 103	4,5,8
Y	EP, A3, 0142373 (RENISHAW PLC) 22 May 1985, see the whole document cited in the application	8,9
X	DE, A, 1652694 (H. KOLB) 25 February 1971, see the figure; page 1, line 1 - page 5, line 3	1

* Special categories of cited documents: [10]

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
9th December 1986	22 JAN 1987
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	M. VAN MOL

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON

INTERNATIONAL APPLICATION NO. PCT/GB 86/00551 (SA 14547)

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Patent document cited in search report	Publication date	Patent family member(s)		Publication date
EP-A- 0132528	13/02/85	JP-A-	60025629	08/02/85
		DE-A-	3326615	31/01/85
		US-A-	4588339	13/05/86
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		SE-A-	8403157	15/12/84
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DE-A- 1652694	25/02/71	None		