

Development of a Multifunction Monitor Panel

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Recently we developed a multifunction monitor panel having an easy-to-see color graphic liquid crystal display (LCD) for the new GALEO Series of hydraulic excavators. This multifunction monitor panel has a number of striking features. For example, it permits the operator to check the operating condition of the machine by means of a communication with KOMTRAX and provides the operator with various types of information which make it easier to operate the machine efficiently. These and other features enhance the value of the product that is equipped with the multifunction monitor panel. This paper outlines the multifunction monitor panel and describes the development of an easy-to-see color graphic LCD required of construction equipment and a system that allows for design of various screens in a short time.

Key Words: Color Graphic LCD, Visibility, Machine Condition, KOMTRAX, Application Software.

1. Introduction

The conventional monitor panel of the AVANCE Series of hydraulic excavators and the new multifunction monitor panel of the GALEO Series of hydraulic excavators are shown in **Fig. 1**.

The monitor panel of the AVANCE Series employs a segmented monochrome liquid crystal display (LCD) and LED lamps. In developing a monitor panel for the GALEO Series, we considered several problems with the conventional monitor panel: the contents of items to set are complicated; the

machine information cannot be fully utilized; the contents of data displayed are limited; it takes much time and money to provide additional functions; and so on.

In order to solve those problems, we adopted a color graphic LCD and an interface for communications with KOMTRAX for the monitor panel of the GALEO Series of hydraulic excavators.

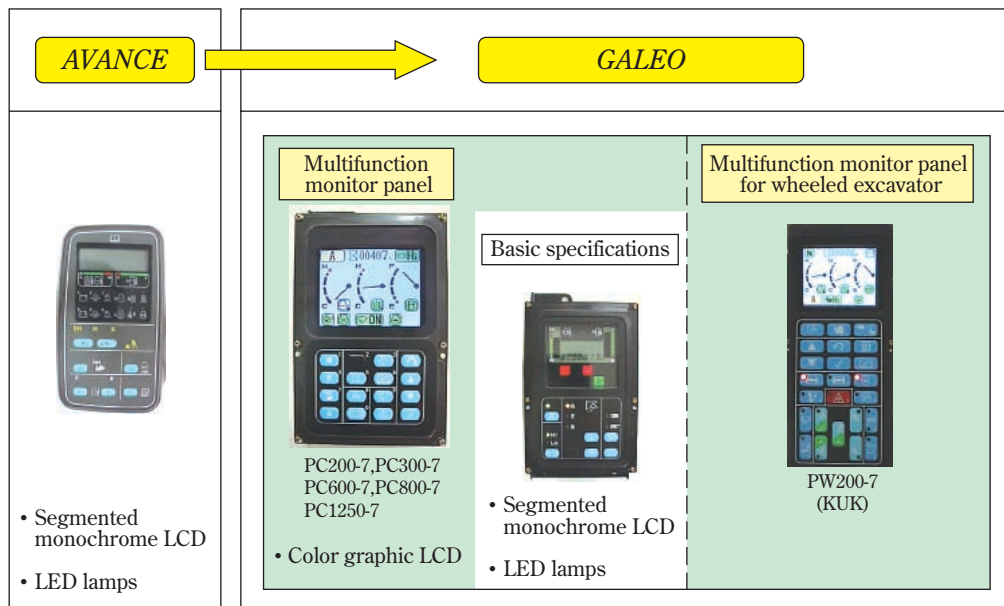


Fig. 1 Monitor panels of hydraulic excavators

2. Background to the development

The monitor panel of the AVANCE Series of hydraulic excavators has segmented monochrome LCD meters and indicator/caution lamps which differ in design from one model to another. Concerning this monitor panel, it was found that there were requests for improvements as shown in **Table 1(1)**. Specifically, they include: easier-to-understand contents of items to set, ease with which machine information can be obtained, capability to display general information, compatibility with new functions, etc.

In developing a new monitor panel for the GALEO Series, we had to consider meeting the above requests. The contents of improvements to be made are summarized in **Table 1(2)**. We considered that the requests shown in Table 1(1) came from inadequate display capacity, limited ability to display general information, and absence of established methods for acquisition and control of machine information. **Table 1(3)** shows the means of making the improvements shown in Table 1(2). We adopted a color graphic LCD to solve the problem of inadequate display capacity and an interface for communications with KOMTRAX^{*1} to permit acquiring and controlling machine information. From the viewpoint of preventing a construction machine to be stolen and used in some other crime, which has become a social problem, we considered it effective to use the monitor panel as an interface for input of the password^{*2}.

*1: The system that permits grasping the position of each construction machine and obtaining various types of data about construction machines in operation by communication networks so as to manage construction machines and improve customer services.

*2: The function that enables the engine to start only when the input password agrees with the password stored in the memory.

Table 1 Tasks to tackle in development of monitor panel for the GALEO Series

(1) Requests for improvements on monitor panel of the AVANCE Series	(2) Contents of improvements to be made	(3) Means of making improvements shown in (2)
[Opinions of customers] • The contents of items to set should be made easier to understand. • There are so many indicators that the operator is at a loss to know which indicator to see.	• Use different shapes and colors to make the display easier to see. • Reduce the number of indicators by adopting multifunction indicators.	Adopting a color graphic LCD
[Opinions of Service Department] • The SERVICE mode is difficult to use. • The contents of references are very difficult to confirm (items, units, error codes, etc.) • Machine information is very difficult to obtain.	• Use characters in the menu and make the SERVICE mode easier to use. • Display the units and errors in words. • Establish methods for acquisition and control of machine information.	Adopting a color graphic LCD Providing an interface for communications with KOMTRAX
[Opinions of Development Department] • Specification changes are very difficult to make (due to time and cost involved). • It is to be desired that general information should be displayed. • Some functions are sacrificed to space.	• Make it easier to respond to a change in color/shape. • Make it possible to switch contents of display. • Make it possible to switch contents of display. • Use the monitor panel as an interface for input of password.	Adopting a color graphic LCD

3. Features

3.1 Features of the multifunction monitor panel

The multifunction monitor panel has the following features.

- (1) Display of easy-to-see machine information by a color graphic LCD
Improvement in efficiency of machine operation by display of many menu screens
- (2) Use of the panel as an interface for input of password
- (3) Monitoring of the machine operating condition by EMMS^{*1} and grasping of machine conditions through communications with KOMTRAX
- (4) Easy preparation of diagrams by use of an AIP^{*2}

*1: Equipment Management Monitoring System.

*2: Advanced Intelligent Panel, a product of Electronics Division (AIP is now produced by Koyo Denshi Co., Ltd.).

In order to attain the above features, it was necessary to meet two important challenges – securing sufficient visibility of displays on the panel as it is installed in a hydraulic excavator and developing a computer program for displaying various screens on the panel. The contents of the measures taken to solve the above problems are described in 3.2 and 3.3.

3.2 Visibility

The cab of a hydraulic excavator is enclosed by glass windows to secure sufficient visibility of its surroundings. Since the hydraulic excavator may be operated bright day and dark night, it is necessary that the monitor panel should always offer good visibility even if the brightness of the surroundings varies markedly. In developing the multifunction monitor panel, we developed the following two items to obtain the required display performance.

- ① Liquid crystal display (LCD) that offers good visibility regardless of the brightness of the surroundings
- ② LCD window and LCD that minimize the reflection of surrounding objects

(1) Development of LCD that offers good visibility regardless of the brightness of the surroundings

In adopting a color graphic LCD for the multifunction monitor panel, it was necessary to choose a light source which provides adequate visibility to the panel to be installed in a hydraulic excavator. There are three types of light sources: transmission, semi-transmission, and reflection (**Table 2**). They differ in visibility according to surrounding conditions (**Fig. 2**).

Table 2 Types and characteristics of LCD classified by light source

LCD type	Light source	Main characteristic
Transmission	Backlight	Used in environments whose light quantity can be controlled effectively (e.g., PC display and LC TV).
Semi-transmission	Combination of backlight and external light (ambient light)	Used in environments which are subject to marked variance in light quantity (e.g., some models of PDA).
Reflection	External light (ambient light)	Used in bright environments.

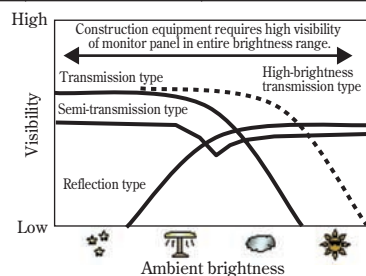


Fig. 2 Relationship between light source and visibility

The transmission type offers good visibility even in dark surroundings, whereas the LCD is difficult to see when the surroundings are very bright (e.g., under direct sunshine). Conversely, the reflection type of LCD is difficult to see when the surroundings are dark (e.g., during nighttime or in the shade). Although these two types have their advantages, they do not meet the required visibility performance. Therefore, we decided to adopt the semi-transmission type that has the advantages of both the transmission type and the reflection type. The semi-transmission layer has the function of reflecting/transmitting light at a certain proportion. By making the reflection characteristic such that good visibility is obtained when the surroundings are bright while maintaining the transmission characteristic that offers good visibility in dark surroundings, we could obtain an LCD which offers satisfactory visibility regardless of the brightness of the surroundings (Fig. 3).

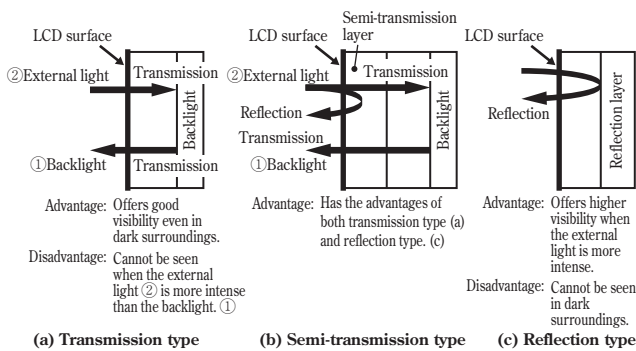


Fig. 3 Mechanisms of LCDs with different light source

(2) Development of LCD window and LCD which minimize the reflection of surrounding objects

It is necessary to secure adequate LCD visibility even when some surrounding object is reflected in the LCD window of the monitor panel.

The mechanism by which some surrounding object is reflected in the LCD window is as follows. Light is divided into the part that is transmitted through the LCD window and the part that is reflected by it (Fig. 4). The reflected light forms an image of some surrounding object on the surface of the LCD window. We took the following two measures to reduce the reflection of surrounding objects in the LCD window of the multifunction monitor panel.

- ① Improving the LCD window transmittance to reduce the quantity of light reflected and thereby reduce the reflection of surrounding objects in the LCD window
- ② Applying the same treatment as shown above to the LCD surface to reduce the reflection of surrounding objects.

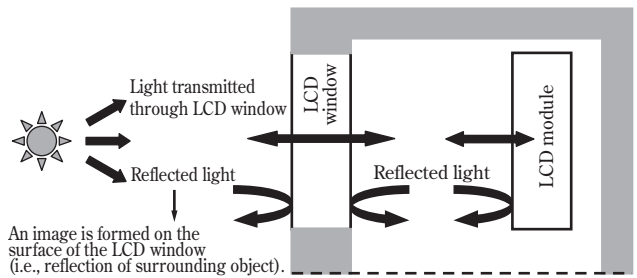
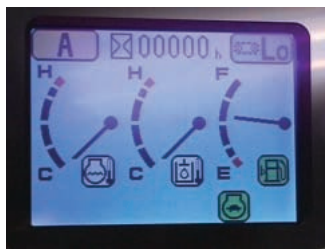
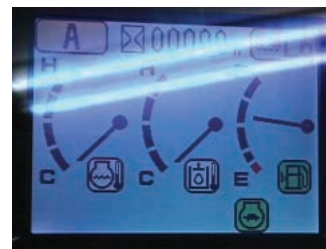


Fig. 4 Relationships between LCD window/LCD and light

The effect of the measures taken to reduce the reflection of surrounding objects can be seen in Fig. 5. Fig. 5 (a) and (c) show LCD windows which have been subjected to the reflection-reducing treatment, and Fig. 5 (b) and (d) show non-treated LCD windows. In Fig. 5, the object reflected is a fluorescent lamp. If a bright object is reflected in the LCD window, the display on the LCD cannot be seen at all in the cases shown in Fig. 5 (b) and (d). On the other hand, in the cases shown in Fig. 5 (a) and (c), the display can be seen well, although the portion in which the object is reflected is slightly whitened.



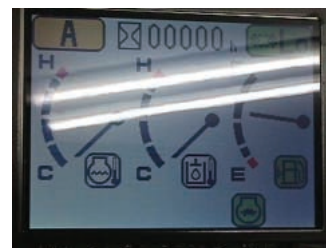
(a) LCD window subjected to reflection-reducing treatment
 There is no problem in visibility of display, although the portion in which the fluorescent lamp is reflected is somewhat whitened.



(b) LCD window not subjected to reflection-reducing treatment
 The portion in which the fluorescent lamp is reflected cannot be seen.



(c) LCD subjected to reflection-reducing treatment
 There is no problem in visibility of display, although the portion in which the fluorescent lamp is reflected is somewhat whitened.



(d) LCD not subjected to reflection-reducing treatment
 The portion in which the fluorescent lamp is reflected cannot be seen.

Fig. 5 Effect of reflection-reducing treatment (when fluorescent lamp is made reflected)

3.3 Software

As the software for the multifunction monitor panel, we adopted the AIP system which was developed within the company and which facilitates drawing diagrams.

Although there were two other software systems (Table 3) that were applicable to the multifunction monitor panel as well, we decided to adopt the AIP system because of the following advantages.

- ① By using the existing system, it is possible to reduce the number of points to be modified and the time required for modification when installing the software in the multifunction monitor panel.
- ② The system offers easy-to-use software for drawing.

The screen configuration in the AIP system is described below.

As the screens of the multifunction monitor panel, there are a screen which performs some processing at all times but which does not display anything (global screen) and multiple screens (local screens) which display different types of information (Fig. 6). Namely, the multifunction monitor panel screen which the operator sees at any time is one of the local screens. Each of the local screens consists of a required number of parts laid out in the background.

Take an ordinary screen as an example (Fig. 7). The

aqua-colored portion is the background, and each item enclosed in broken lines is a part. Thus, an ordinary screen is made up of a collection of parts.

Each part can be divided into three elements – background, control, and operating program. We shall explain below the three elements using the part displayed in the WORK mode as an example (Fig. 8). In this case, the three elements are as shown in Fig. 8 (a) – (c). The control in Fig. 8 (b) is the element that displays a work mode (A, E, L, B, etc.). The operating program in Fig. 8 (c) is the element that determines when to display which work mode and issues a suitable command to the control. For example, consider that the B switch is pushed in the A mode to enter the B mode. In this case, the fact that the B switch has been pushed is transmitted to the operating program (Fig. 8 (c)), which in turn issues a command to change the display from A to B to the control (Fig. 8 (b)).

The individual parts enclosed by broken lines are independent of one another. Therefore, even when changing the positions of display of work mode and running speed, it is only necessary to alter the layout of the parts on the drawing tool. Thanks to the AIP system and drawing tool which can flexibly respond to minor to major changes, we could develop the software for the multifunction monitor panel and deploy it to other models in a short time.

Table 3 Comparison of AIP system with other software systems ○ Superior △ Equal × Inferior

OS	Drawing software	Features	Cost	Development lead time	
				OS	Screen
AIP system	K-Basic	<ul style="list-style-type: none"> • Can be applied to multifunction monitor panel relatively easily. • Amounts of resources required (CPU processing speed, memory capacity, etc.) are reasonable relative to monitor panel cost. • Easy-to-use drawing software is available. • Assets accumulated through sales business (functions, qualities, etc.) can be fully utilized. 	○	○	○
Windows CE ¹⁾	JAVA Visual Basic ¹⁾ etc.	<ul style="list-style-type: none"> • Amounts of required resources have considerable cost burden on multifunction monitor panel. • Installing the system in multifunction monitor panel requires extensive software modification. 	×	×	△
Linux	JAVA Visual Basic ¹⁾ etc.	<ul style="list-style-type: none"> • Amounts of required resources have considerable cost burden on multifunction monitor panel. • OS is suitable for communications and data collection. 	△	△	△

¹⁾: Windows and Visual Basic are registered trade names of Microsoft Corporation.

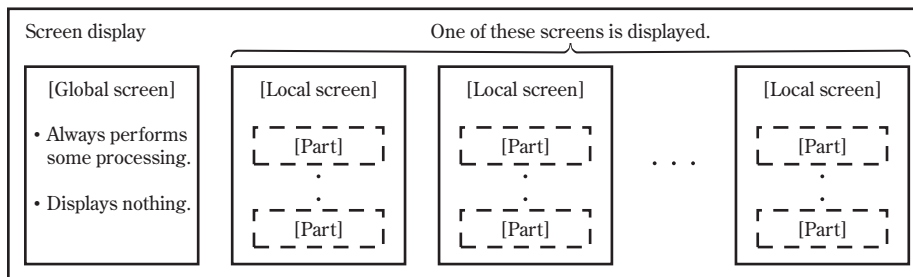


Fig. 6 Multifunction monitor panel screen configuration

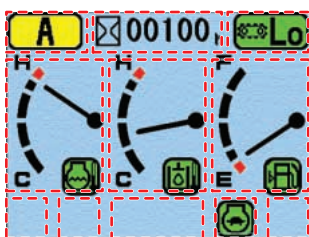


Fig. 7 Ordinary screen configuration

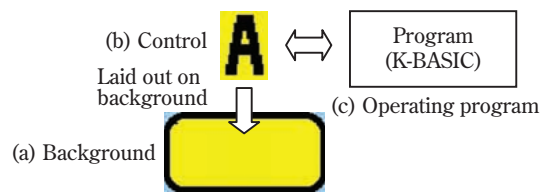


Fig. 8 Part configuration (in display of work mode)

4. Specifications and major functions

4.1 Specifications of multifunction monitor panel

The appearance of the multifunction monitor panel is shown in Fig. 9. The panel consists of a color graphic LCD and switches for input of a desired mode, etc. The content of information displayed shall be explained in 4.2.

The connectors for connecting the monitor panel to the wiring of the machine body are provided at the back of the panel.

The principal specifications of the interface for communication with the monitor panel, LCD, and multifunction monitor panel are shown in Table 4.

4.2 Content of display on multifunction monitor panel

The ordinary screen of the multifunction monitor panel displays a work mode, travel speed, fuel level, water temperature, etc. (Fig. 10). The use of a color graphic LCD has made it possible to change the color combination of display by the nighttime illumination switch (Fig. 10 (a)), display cautions by modifying a part of the ordinary screen (Fig. 10 (b)), display maintenance information (Fig. 10 (c), (d)), etc. ¹⁾

For arm crane specifications, when the Lift (L) mode is selected, the LCD also displays the actual and rated loads in large characters (Fig. 10 (e)).

In addition, a screen for input of a password is provided. Thus, the multifunction monitor panel also serves as an interface for password input.

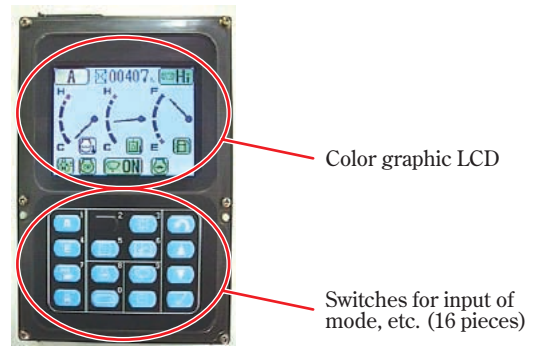
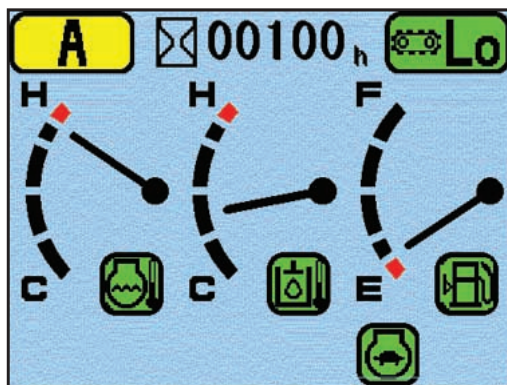


Fig. 9 Appearance of multifunction monitor panel (front view)

Table 4 Principal specifications of multifunction monitor panel

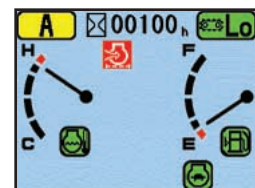
Dimensions (including fixture)		120 × 219 × 68 (W × H × D)
Dimensions (as installed in machine)		100 × 157 (W × H)
Supply voltage		20 – 30V (DC)
Interface	Pushbutton switch	16 pieces (Ten-key function provided)
	Digital input	Radiator water level sensor, etc.
	Analog input	Water temperature, fuel level, etc.
	Output	Windshield wiper, washer
	CAN communication	Available
	SNET communication	Available (Komatsu exclusive half-duplex serial communication)
LCD	Display method	Color graphic dot matrix
	Number of pixels	320 × 240 RGB (W × H)
	Number of colors	16
	Display area	77 × 58 (W × H)



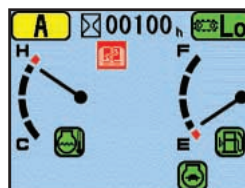
Ordinary screen display



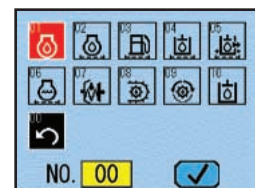
(a) Display during nighttime



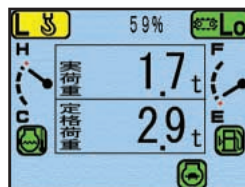
(b) Display of cautions



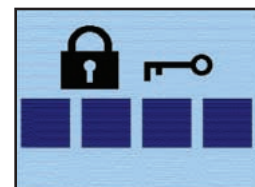
(c) Display indicating need of maintenance



(d) Listing of maintenance items



(e) Screen for arm crane specifications



(f) Screen for password input

Fig. 10 Multifunction monitor panel display screens

4.3 Management of machine information by means of communication with KOMTRAX

The linkage of the multifunction monitor panel with KOMTRAX has made it possible to promptly grasp the content of monitoring of machine conditions implemented by EMMS.

In KOMTRAX Step 2²⁾ with which the multifunction monitor panel is compatible, it is possible to refer to the information shown in **Table 5** through communications with KOMTRAX.

Table 5 Monitor information that can be referred to in KOMTRAX Step 2

Item	Content
Service meter	Display of information every 0.1 hour
Engine cooling water temperature	Displayed in 16 steps
Remaining fuel level	Fuel: Current level Engine cooling water temperature: Maximum value
Caution information	Content of caution; time belt in which caution occurs
Error information	Type of error; time at which error occurs; frequency of error
Maintenance information	Time to change various oils and greases

4.4 Application of multifunction monitor panel to various models

Since the multifunction monitor panel was installed for the first time in PC200-7 GALEO, it has been applied to a good number of models as shown in **Table 6**. Concerning hydraulic excavators, almost all models of 15-ton to 120-ton class are equipped with the multifunction monitor panel. Application of the panel to wheel type excavators manufactured by KUK (Komatsu UK) and to mobile crusher / mobile soil recycler has already been started.

Table 6 Models equipped with multifunction monitor panel (as of May 2003)

(a) GALEO Series of hydraulic excavators

Class (ton)	5	10	20	30	40	60	80	120	180
Hydraulic excavator			↔				↔		
Wheel type excavator			↔						

(b) Mobile crusher / mobile soil recycler

Class (ton)	5	10	20	30	40	60	80	100
Mobile crusher						●BR480RG-1		
Mobile soil recycler			●BZ210-1					
Other								

5. Future plans

We could demonstrate that the multifunction monitor panel which features a highly flexible display capability and a communication interface with KOMTRAX will open a new aspect of product planning for hydraulic excavators. In the future, we intend to continue expanding the scope of application of the multifunction monitor panel to increase the value of every product equipped with it. This is considered especially important to mobile crusher / mobile soil recycler that offers many different specifications.

References

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Introduction of the writers



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[A few words from the writers]

After a long series of and trial & error, we could finally make our multifunction monitor panel mass-produced successfully. By the way, we consider that employing the AIP system for our system was meaningful from the viewpoint of promoting the collaboration between the Komatsu's technology incorporated in its sales products and the monitors installed in construction equipment.