Latest Expansion of Command Switch Product Line and its Technology

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1. Introduction

Operating switches and indicator lamps used in various machines and equipment must be able to communicate information between humans and machines quickly and accurately. Fuji Electric continues to sell various types of operation switches and indicator lamps under the commercial product name of “command switches,” and these products have been well received by Fuji’s customers. Standard cutouts in a command switch panel range from ϕ8 to ϕ30. In recent years, control panels and operation panels have become smaller in size, and together with the growing popularity of teaching pendants, the demand for ϕ16 panel cutouts is increasing remarkably.

This paper describes the features and relevant technology of Fuji Electric’s new products, as typified by the new ϕ16 command switch.

2. Specifications and Features of New ϕ16 Command Switch

The command switch product series is as shown in Table 1 for ϕ8 to ϕ30 panel cutouts. In terms of functions, the command switches are classified as operating switches (having a model number beginning with the letter “A”) and indicator lamps (having a model number beginning with the letter “D”). Additionally, the cutout shapes are classified as round-hole type (symbol R) and rectangular-hole types (symbol F). Accordingly, there is a large variety of command switch products. In particular, the operating switches have the emergency stop pushbutton function of high-end products, and an operating shape that satisfies the needs of many customers.

Figure 1 shows the appearance of representative models of the new ϕ16 command switches. Figure 1(a) shows a comparison of the installed condition of the AH165 series, AR16 series and the AF16 series, respectively from top to bottom, as viewed from the side of the panel. In response to customers’ requests for reduced wiring space, the AR16 series (known as the “minico series”) was developed. The AR16 series adopted an integrated contact structure, and its depth dimension is much smaller than the existing AH165 series. The AF16 series was developed in response to requests for a more elegant design of the control panel surface. Figure 1(b) shows the external appearance, as viewed from the panel surface, of the AR16 series and

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Table 1 Types of command switches

Nominal size	Panel cutout	Model		Comments	Use
		Present	New		
ϕ30	ϕ30.5	AR30 model DR30 model		–	Switch-board, machine tool, industrial machinery, etc.
ϕ22	ϕ22.3	AR22 model DR22 model AM22 model DM22 model		–	
ϕ16	ϕ16.2	AH165 model AH164 model	AR16 model DR16 model	–	
	24.2 × 19.2	–	AF16 model DF16 model	Flush rectangular thing type	
	□19.2			Flush square thin type	
	ϕ19.2			Flush round thin type	
ϕ12	ϕ12.1	AH125 model AH124 model		–	Small equipment such as measuring instruments
ϕ10	ϕ10.1	AH10 model		–	
ϕ8	ϕ8.1	AH08 model		–	

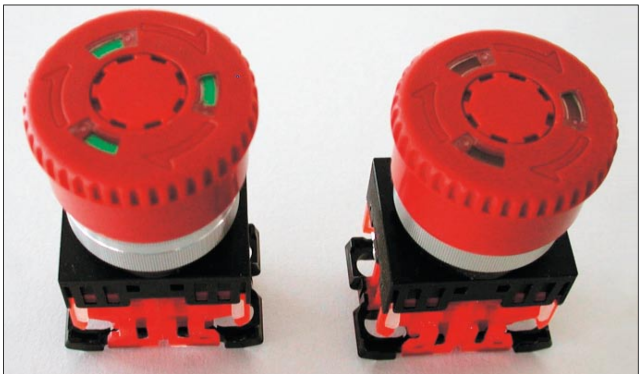
Fig.1 New ϕ16 command switch model series

(a) Panel side (b) Panel surface

Table 2 Main ratings, performance and specifications of the new ϕ 16 command switch

Item		(Illuminated) pushbutton switch	Selector switch	Indicator lamp
Rated insulation voltage		250 V AC/DC		
Endurance	Mechanical	Momentary action: At least 1 million times Alternate action: At least 250,000 times	Manual return: At least 250,000 times Auto return: At least 250,000 times	–
	Electrical	At 220 V AC and 0.7 A: At least 100,000 times		–
Open/close frequency		1,200 times/hr (utilization rate: 40%)		–
Withstand voltage	Between live part and ground	2,000 V AC, 1 minute		
	Between live parts of different polarity	2,000 V AC, 1 minute		–
Insulation resistance		At least 100 MΩ (with 500 V DC dielectric tester)		
Resistance to vibration		Resonance test: amplitude width 0.1 mm, frequency 10 to 55 Hz Steady state oscillation endurance test: amplitude width 3 mm, frequency 16.7 Hz		
Resistance to impact		Mis-operation: 100 m/s^2 Durability: 500 m/s^2		
Ambient environment for usage		− 10 to + 55 °C, (no freezing, no condensation)		
Protective structure		IP65 oil resistance protection (dust proof type, jet proof type)		
Depth dimension	AR16 series	28.4 mm		
	AF16 series	35.9 mm		

Fig.2 Emergency stop switch with mechanical indicator



(a) Normal state (b) When switch has moved

the AF16 series.

The new ϕ16 command switches can be selected from various illuminated pushbutton switches, pushbutton switches, knob selector switches, key selector switches, and indicator lamps. Additionally, the shape of the operating portion (round, square, rectangular), switching action (momentary, alternate), button color (green, red, orange, yellow, blue, milk-white, black) and number of contacts (1c, 2c) may be combined with these types of command switches. Table 2 lists the main ratings, performance and specifications.

The ϕ22 panel cutout-size AM22VME, an emergency stop switch having a mechanical indication mechanism has been developed, by adding variations of the front-mounting type AM22 series were expanded. In its normal state, this switch displays the color green at three window locations (see Fig. 2(a)). However, in the state where the emergency stop switch has been operated, the color displayed from the three window locations changes from green to red (see Fig. 2(b)). Thus, the characteristic feature of this switch is improved visibility.

Details of the new ϕ16 command switch are described below.

2.1 Reduction of panel-mounting depth with integrated contact structure

The existing AH165 series has a depth of 42.5 mm from the panel to the tip of the contact terminals and the lamp terminals. On the other hand, the new AR16 series has a similar depth dimension of 28.4 mm for all products (pushbutton switch, selector switch, indicator lamp). This reduction in depth was realized with the following two achievements: the realization of an integrated contact structure and the elimination of unnecessary strokes for parts coupled to the operating part.

2.2 High brightness LED

A high brightness LED was newly developed as the power source for the illuminated pushbutton switch and the indicator lamp. The AR16 series and the AF16 series consume approximately 25% less power than the existing AH165 series. Brightness was increased by approximately 30%, however, so that visibility was improved for the illuminated pushbutton switch and the indicator lamp. Table 3 compares the specifications between the new high brightness LED and the existing LED.

2.3 IP65 oil resistant protective structure

By increasing the air tightness of the internal structure of the AR16 series and the AF16 series, the requirements for an IP65 protective structure have been met. Accordingly, the AR16 and the AF16 series are usable in environments where oil is used for machine tools and the like. To realize this IP65 oil resistant protective structure, the following internal struc-

Table 3 LED comparison between new series and existing series

Specification item		New product	Existing product
LED type (24 V rated product, green color)		DR6L695-EG	AHX695-24G
Command switch type	Illuminated pushbutton switch	AR16FON, etc. AF16FON, etc.	AH165-TL, etc.
	Indicator lamp	DR16FON, etc. DF16FON, etc.	AH165-ZT, etc.
Rated voltage		6, 12, 24 V AC/DC	5, 6, 12, 24 V DC
Power consumption (24 VDC product)		0.28 W	0.37 W
Brightness peak on surface of color cap (green)		1,800 cd/m^2	1,340 cd/m^2
LED color varieties		Green, red, orange, yellow, blue, milk-white	Green, red, orange, yellow, blue, milk-white

tures were developed. In a pushbutton switch, a packing ring structure that ensures a 3 mm stroke, and the fixed shape thereof, were developed. Additionally, in a selector switch, a packing ring structure having good durability against rotational operation was developed.

2.4 Support of internationalization

In the AR16 series and the AF16 series, IEC and C-UL certification were acquired for standard products. Additionally, in order to expand into China whose market has been growing rapidly in recent years, GB certification was also acquired for those standard products.

2.5 Socket lineup

Sockets and protectors usable in both the AR16 series and the AF16 series were developed as accessories. As a result, handling by the customer and wiring work have been simplified.

3. Development of New ϕ16 Command Switch

3.1 Development of contact element by using simulation technology

In reducing the depth of the command switch, the following three technical challenges were identified for realizing a contact element having a small snap action structure.

(1) Snap action structure that provides a sufficient operating feel

Figure 3 shows the change in force when the color cap of the pushbutton switch is moved. The snap action creates points of force change in both the push and the return operations. An operator senses this change as the operating feel. The operating feel is an important property for providing optimum operability and preventing mis-operation.

The new contact element has external dimensions of 4.4(W) × 12.8(D) × 16.6(H) (mm) and is extremely small. Accordingly, the structure was realized with a detailed study using 3D-CAD. (See Fig. 4(a).)

Fig.3 Change of operating force on pushbutton switch (momentary action)

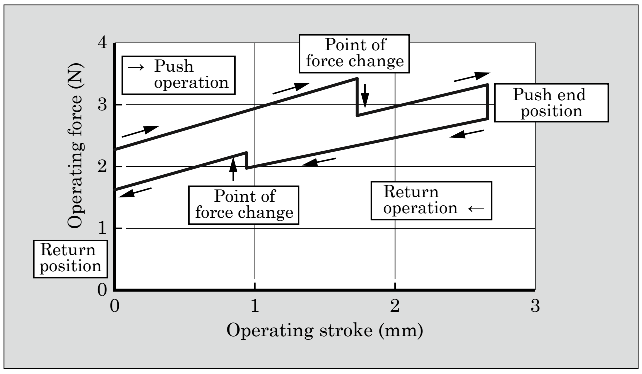
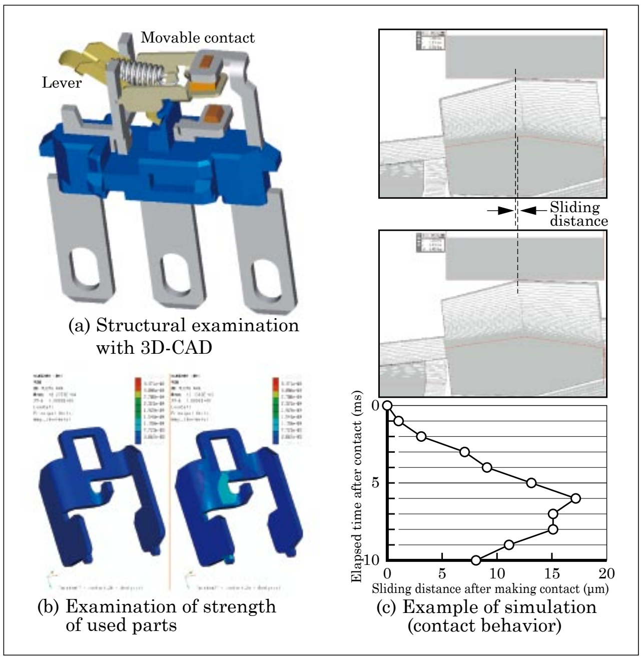


Fig.4 Design considerations for snap action structure



(2) Mechanical durability more than 1 million operations

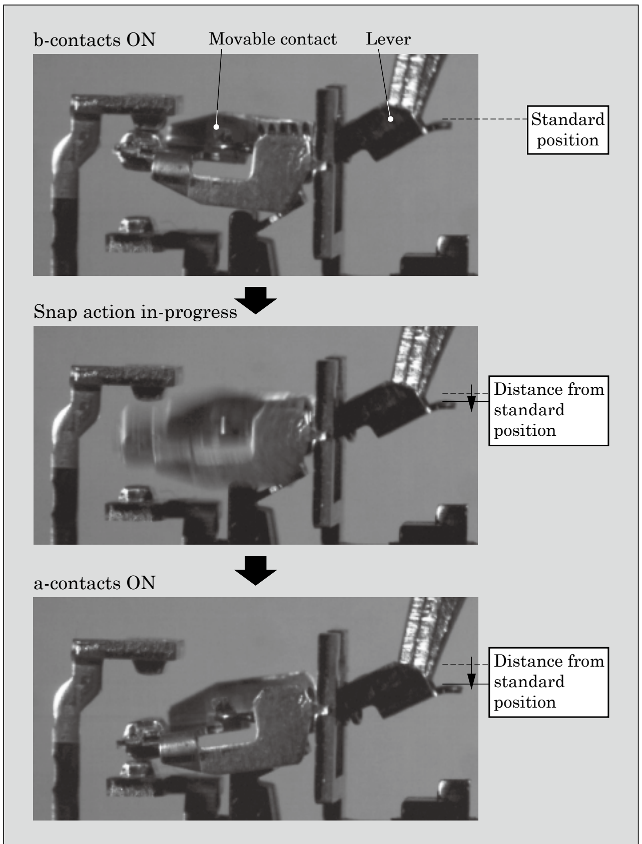
As is shown in Fig. 4(a), the new contact element uses an extension spring to obtain the required contact force. This extension spring attaches to a hook provided on a lever component and to a hook provided on a movable contact, and expands and contracts according to the snap action. In order to satisfy the switch specification requirement for mechanical durability more than 1 million operations, the structure was designed using 3D-CAD and stress analysis was performed for the coupled lever and the movable contact. Figure 4(b) is an example of a contour diagram that examines the reduction of stress in the hook part of the movable contact.

(3) Realization of high contact reliability

In the field of small switches, such as ϕ16 command switches, the realization of high contact reliability with a minimum switching capacity of 5 V 1 mA is an important performance. Accordingly, a structure capable of ensuring the sliding distance of the contact was sought. By ensuring a large sliding distance of the contact, the oxidation film and sulfuration film generated on the contact surface are destroyed, and stable contact resistance is obtained. Similarly, a control relay having high contact reliability uses the elasticity of a leaf spring so that after making contact, the contact angle changes, and such a relay typically exhibits a sliding distance of 5 μm or more. In this structure, the movable contact is a rigid body, and the common terminal supporting the hinge of the movable contact is designed to be an elastic structure so that the desired amount of contact sliding is obtained. Figure 4(c) shows an example simulation of the horizontal distance traveled by a pointed contact tip moving from the contact start to the contact end. Moreover, the figure shows a graph of the transition in sliding distance up to 10 ms after the start of contact.

Figure 5 shows the behavior observed using a high-speed camera of the sliding distance of a movable contact in a snap action operation. As a result, it was determined that the movable contact was sliding in an actual device. When the lever in the upper right-hand corner of this figure is moved in the vertical direction, the distance of motion of this operation corresponds to the operating stroke of Fig. 3. Figure 5 shows a series of processes of the inversion from the initial ON state of the b-contact initial to the ON state of the a-contact,

Fig.5 Observation of behavior of snap action structure



wherein as a result of operation of this lever, the movable contact performs a snap action at the point where the force of the pushing operation changes.

Additionally, the extension spring, which is an essential component of the snap action mechanism, not only provides simple expansion and contraction, but is also coupled to the inverting operation of the movable contact, and its orientation changes. By observing the above behavior, we were able to determine that there is no obstruction due to impact with the coil part or the like.

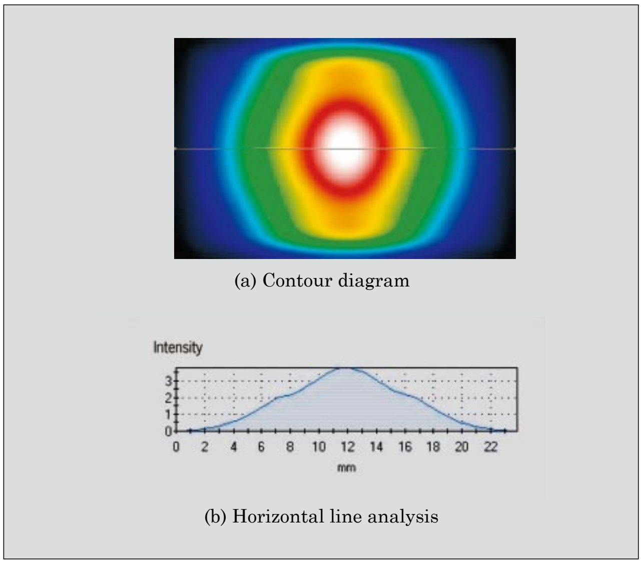
3.2 Illuminated structure developed by using simulation technology

One development challenge for the new ϕ16 command switch was how to illuminate the "OFF", "ON" and other lettering printed on the inside of the color cap so as to be clearly visible to the operator. In order to overcome this challenge, we established the goal of developing an illuminated state with no light unevenness when viewed from the front face of the color cap on the panel surface. In particular, a light transmitting reflector and scattering plate structure were added to disperse light smoothly from the center to the tip of the color cap which receives light emitted from the newly developed high brightness LED.

(1) Design of reflector and scattering plate by simulation

We set about to quantify the illuminated state. Several proposed shapes of the reflector and scattering plate were analyzed using optical simulation. Figure 6 is an example analysis that shows a contour diagram of the intensity of light emitted from the LED as seen from the front face of the color cap. A diagram of the intensity along a horizontal line passing through the center of the color cap is also shown. In this diagram, the combination of the reflector and scattering plate has not been optimized and "light unevenness" can be

Fig.6 Analysis of illumination intensity by optical simulation



seen. Characteristics of the case when "light unevenness" exists can be understood as follows.

(a) There is a large difference in illumination between the center part and the tip.

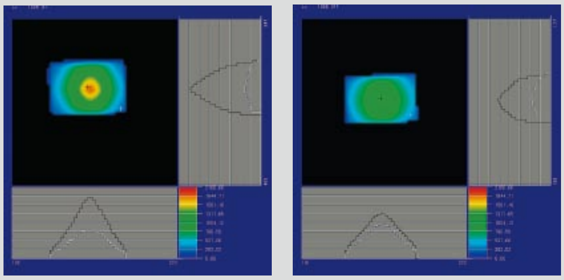
(b) There is a large change in intensity between the −3 mm and + 3 mm positions of the graph's horizontal axis (corresponding to the outer periphery of the internal LED).

From the proposed shapes of the reflector and scattering plate, a shape that results in no light unevenness was selected. Additionally, the illuminated state was quantified, partially based on the results of spectral ray tracing analysis that resolved the light into many light rays and analyzed the trajectory of the individual light rays. Based on these analyses, the shapes of the reflector and scattering plate were determined.

(2) Measurement to verify effectiveness of reflector and scattering plate combination

To evaluate the developed products, brightness at the color cap surface for each of the six colors was measured using the latest brightness meter. The results showed that the new product achieved high brightness, with peak brightness values of 110 to 130% compared to those of the existing AH165 series. Figure 7 shows brightness measurement results for the new command switch and the existing AH165 series as viewed from the front face of the color cap (green). As in the case of the simulation, the brightness along horizontal and vertical lines passing through the center of the color cap is shown graphically. As a result, the appropriateness of the illuminated state determined by simulation and the shapes of the reflector and scattering plate were verified. Also, energy savings was achieved with an approximate 25% reduction in power consumption compared to the existing AH165 series.

Fig.7 Example of measurement with brightness meter (green color cap)



(a) New ϕ16 command switch (b) Existing AH165 series

4. Postscript

With the new ϕ16 command switches, Fuji Electric has developed a new series having such characteristics as small size, high brightness and wire savings, and has used the latest analysis software and measuring instruments to realize an improved operating feel for the contact element and improved visibility for the LED. Fuji Electric intends to continue to develop human-machine interface products that support new customer needs and that seek the appeal of such sensations as operability and visibility.