UDC 62-503. 5

NEW-TYPE PROGRAM CONTROLLER AND PROGRAMMER

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I. INTRODUCTION

Fuji Electric has manufactured a universal program controller consisting of a mechanical programmer (ESTPC) and a TRANZET controller (TZ III), as well as a photoelectric programmer (KLP–118) and programmer for sequence control (KZP).

This universal program controller has been used in comparatively simple applications such as temperature control of dye pots, etc., while the KLP and KZP used in plants where high reliability and accuracy are required. Good results have been obtained in practical applications of all of these controllers. Recently, however, there have been greater demand for more compact program controller and programmer with more complete specifications which can be used in a wider range of control applications.

This newly developed instrument is designed to meet the requirement above mentioned. It is compact and also easy to use. Further, it is also capable to be attached with six-sequence program switches, so that it makes automatic plant operation possible and should contribute considerably to reductions in manpower.

As the programmer contains a highly reliable output potentiometer, it will be able to provide highly accurate and reliable control in combination with an aporopriate controller.

The surface design is a completely new concept and dimensions are 240 mm (height) × 192 mm (width) and conform with DIN (German Industrial standards).

II. FEATURES

1. Common Features of Program Controller and Programmer

1) The program sheet is made up of rectilinear scale, so the program curve making is easy. Correction is also simple.
2) The curve trace mechanism operates stably since it contains a servo-mechanism and a non-contact detector.
3) Six sequence program switches can be attached.
4) The present programmed value is shown on a scale and its future value can easily be monitored.

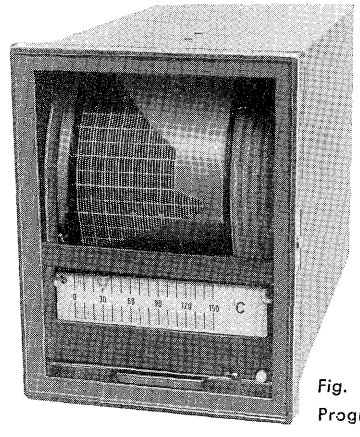


Fig. 1
Program controller

5) When the predetermined program is finished, the program sheet can be stepped automatically to the start point.

Completely automatic operation is possible since the start, stop and quick drive operations can be performed by means of external switches.

2. Features of Program Controller

1) There is a considerable savings in space and wiring cost.
2) The small indicator mounted on the set pointer carriage shows the present value of process variable.
3) The plug-in type amplifiers facilitate maintenance.

3. Features of Programmer

The output potentiometer is very reliable and accurate. The similar ones have been being used for the self-balancing recorder (K–ERS) for many years with good results.

III. PRINCIPLES

1. Curve Trace Mechanism

The principle of the curve trace mechanism is shown in *Fig. 2*. The program curve is prepared on the program sheet by means of boundary lines between a light and opaque area. These boundary lines are detected by means of two photo conductors (CDS1 and CDS2). The reference head (CDS1) is fixed

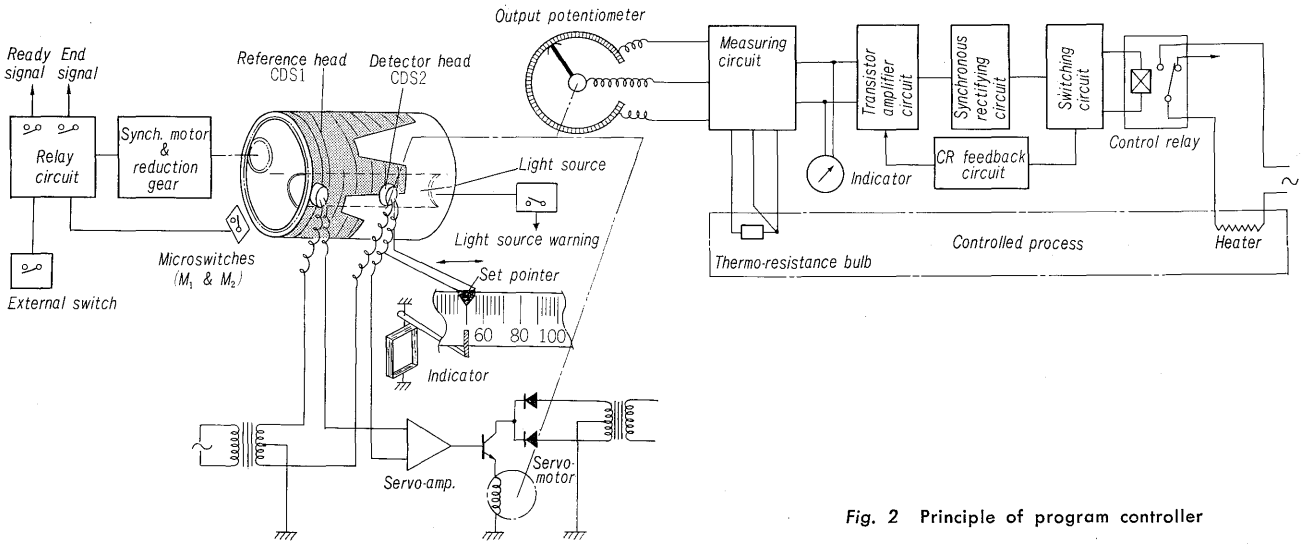


Fig. 2 Principle of program controller

outside the scale range on the program sheet and generally receives constant light. The detector head (CDS2) has its position controlled by the servo-motor so that it is usually over the program curves.

When the program sheet moves, the amount of light striking the detector (CDS2) changes and this causes a change in the resistance value of CDS2. The resistance values of CDS1 and CDS2 are compared by the servo-amplifier and the deviation between them is amplified into an AC voltage of commercial frequency. This AC voltage is applied to a servomotor and the servomotor moves the position of the detector head so that this deviation becomes zero. The output potentiometer is mechanically coupled with the detector head.

2. Controller

The set value determined by the output potentiometer and the signal from the controlled process (for example, the thermo-electromotive force of a thermocouple or the resistance value of a thermoresistance bulb are compared in the measuring circuits). The deviation voltage between them is supplied to the indicator. As the indicator is attached to the detector head and is adjusted to be aligned to the set pointer with zero deviation, so the present value of process variable can be read on the scale.

The deviation voltage is also supplied to a control amplifier to drive a control relay. This control relay has a time proportional action which is proportional to the deviation between the measured value and the set value. The proportional band and cycle time are approximately 2% and 15 sec respectively.

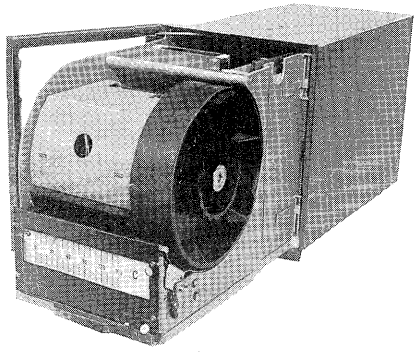


Fig. 3 Internal view of program controller

IV. CONSTRUCTION

This instrument consists of a program sheet drive mechanism, curve trace mechanism, controller and a case. The chassis is of the pull-out type for easy maintenance, and can also be swung around.

1. Program Sheet Drive Mechanism

The program sheet drive mechanism consists of a synchronous motor and reduction gear trains as well as a quick drive circuit.

1) Gear trains

The synchronous motor (M) drives two gear trains. One train moves for the normal drive of the program sheet (0.5 h/rev to 144 h/rev), and the other train is for quick drive. As the preselected speed of the program sheet should differ according to the process, 10 stages of preselective speed are provided.

The principle of the gear trains is shown in *Fig. 4*. Rotation of the synchronous motor (M) is gradually reduced through the reduction gear train G_2 to G_{30} via the gear G_1. The desired speed can be selected by appropriate engagement of G_{31} gear with one of 10 even numbered gears from G_{12} to G_{30}. Gear G_{31} is fixed to the shaft S_3. Shaft S_3 rotates bushing B_1 clockwise and further bushing B_2, which is connected to gear G_{32}, by coil spring C_1. The rotation is further reduced through the gear train G_{33} to G_{40}, and drives a drum G_{42} via gear G_{41} and slip mechanism.

During, quick drive the synchronous motor (M) is turned counterclockwise and the speed is reduced by the reduction gear train. Gear G_{51} fixed on the shaft S_4 is driven by gear G_6. Gear G_{52} drives the gear G_{53} and bushing B_3 clockwise. Coil spring C_2 connects

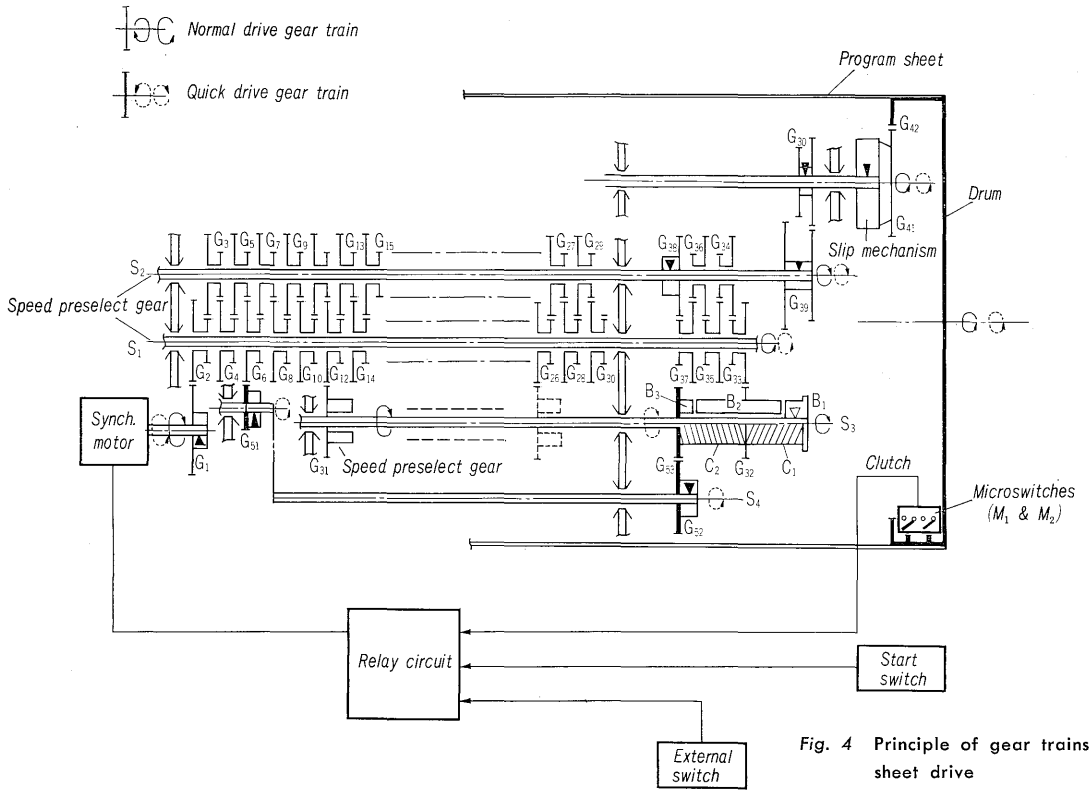


Fig. 4 **Principle of gear trains for program sheet drive**

the bushing B_3 and B_2. Gear G_{32} connected to the bushing B_2 drives the Gear train G_{33} to G_{40} and finally drum G_{42} via G_{41} and slip mechanism.

2) Quick drive circuit

The microswitches M_1 and M_2 are actuated just at the end of the program sheet and keep to be actuated until the program steps to its start point. The relay circuit is controlled by these signals and the start push-button switch SW_1 on the bottom right front surface or the external switches SW_2 to SW_4, and start, stop or quick drive control of the program sheet is achieved. These operations can be explained as follows. When the start push-button SW_1 is pressed or the external start switch SW_2 is closed relay A is operated and then self-maintained by contact A_1. The contact A_3 makes the synchronous motor continue to rotate for start and normal drive.

When the program has finished, relay B is operated by microswitch M_2 or else by external fast feed start switch SW_3 and the self-maintaining condition in relay A is released by contact B_2. (Relay B can be self-maintained by contact B_1) and the synchronous motor is rotated in the reverse direction by transfer of contact B_3. When the program sheet steps forward just to the start point, microswitches M_1 and M_2 are released, then relay C and relay B is released and the motor stops. Stop is possible during the program by opening external stop switch SW_4.

2. Curve Trace Mechanism

This mechanism consists of a photoelectric system, a servo-motor and a servo-amplifier.

1) Photoelectric system

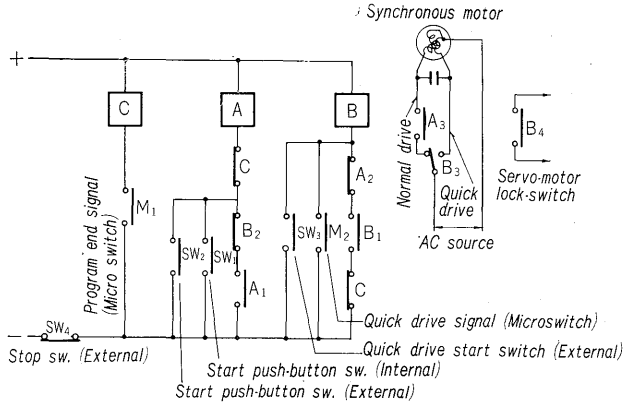


Fig. 5 **Schematic diagram of relay circuits**

The system consists of the program sheet, light source and detection head. The program sheet is slowly passed between a light source containing incandescent lamps and two photo-conductors (one for detection and one for reference) at a preselected speed. The program curve on the sheet is traced by the detector.

(1) Program sheet

The transparent program sheet (thickness : 0.2 mm) has a scale-imprinted opaque plastic film (thickness : 0.05 mm) on top. The edge line of the transparent and opaque parts form the program curve which is cut with a knife in only the scale-imprinted plastic film. After line is cut, right side of film is peeled away. When there is an error in preparing the program, it can be repaired easily by attaching a piece cut from the removed plastic film to the sheet or drawing the edge with black ink.

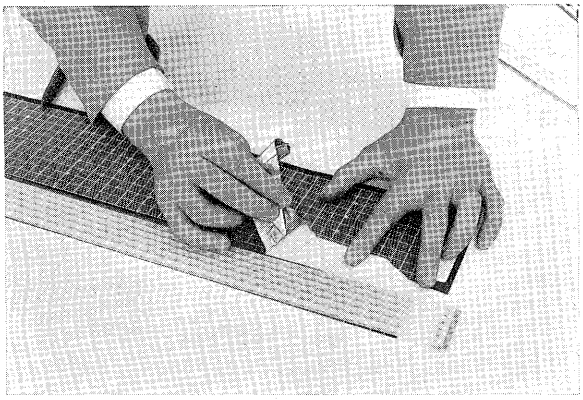


Fig. 6 Program sheet preparation

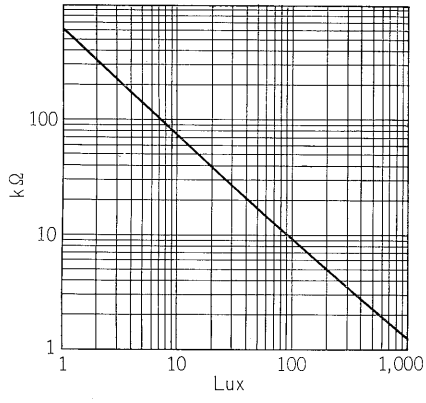


Fig. 7 Characteristics of photo-conductor

(2) Photo-conductors

The two photo-conductors, one for detection and one for reference, are fitted in plastic heads. The light strikes them through a 2 mmϕ focusing hole. The reference head has a light adjuster for balancing with that of the detector photo-conductor. *Fig. 7* shows the characteristics of photo-conductor.

(3) Light source

The light which strikes the two photo-conductors is supplied by two 6.3 V incandescent lamps. A special prism is used to insure that the light strikes the scale slit uniformly. When one of the lamps goes out, the light from the remaining lamp is increased to keep a normal operation and at the same time an alarm relay is actuated (refer to *Fig. 8*).

(4) Special prism

As can be seen in *Fig. 9,* it is the semi-conic shaped transparent plastic (acryl resin) prism and its surface is plated with aluminum except the light

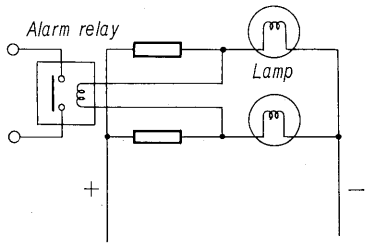


Fig. 8 Lamp circuit

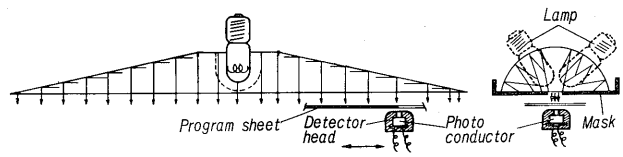


Fig. 9 Special prism

slit. The lamps are inserted into the holes cut in the thick part of the prism. The light flux emitted from the lamps is reflected off at the semi-conic mirror surface and concentrated at the light slit. The light flux density along the slit in nearly uniform.

2) Servo-amplifier

The deviation in the resistance values of the reference and detector photo-conductors is amplified by the servo-amplifier and used to turn the servomotor. This amplifier is mounted on a plug-in type printed circuit board with the relay circuit for controlling the program sheet.

3) Servomechanism

The servomotor, reduction gear trains and output potentiometer are attached to two end plates. The servomotor is a two-phase squirrel-cage type induction motor. The gear trains are inserted between two end plates. They reduce the speed by approximately 1/300, drive the detector head by means of pulleys and drive cable and also rotate the wiper of output potentiometer.

3. Control Part

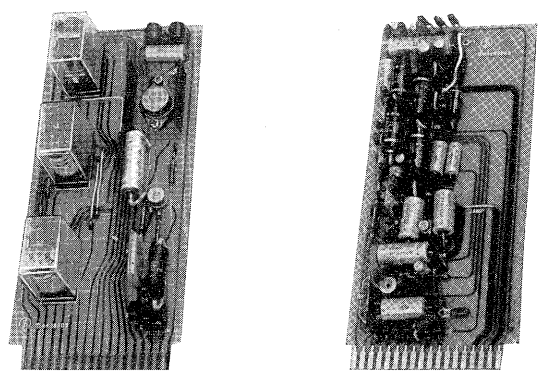
This part consists of a measuring circuit which compares the value of process variable with the programmed value, a control amplifier, an indicator and a control relay.

1) Measuring circuit

This circuit consists of a printed board containing a constant voltage power supply using Zener diodes and the wire wound resistors and the variable resistors for zero and span adjustment. The board is located beneath the chassis. The varaible resistors for zero and span adjustment are located on the front board.

2) Amplifier

The control amplifier circuit consists of FET chopper circuit, an AC amplifier circuit, a synchronous rectifying circuit, a switching circuit and a CR feedback



(a) Servo-amplifier (b) Control amplifier

Fig. 10 Servo-amplifier and control amplifier

Table 1 **Specifications**

Programmer	
Program trace system:	Photoelectric edge trace
Scale length:	100 mm
Setting accuracy:	±1% of full scale
Full scale travel time:	Approx. 20 sec
Program sheet length:	480 mm
Output:	10 Ω—100 Ω—10 Ω Max. supply voltage 12 V 5 Ω—50 Ω—5 Ω Max. supply voltage 7 V
Program sheet drive speed:	0.5, 1, 2, 4, 8, 12, 24, 48, 96, 144 h/full stroke
Quick drive speed:	Approx. 10 min./drum full stroke (total length 520 mm)
Drive motor:	Synchronous motor
Program end signal contact:	Single pole normally open (closed in "End") Contact capacity AC 100 V 0.3 A
Ready signal contact:	Single pole normally open Contact capacity AC 100 V 0.3 A
Remote control terminals:	Start, stop and quick drive
Lamp burn out alarm:	Normally open (closed in "Burn out") Contact capacity AC 100 V 0.3 A
Sequence program switch:	6 switches Single pole normally open Contact capacity AC 100 V 0.3 A
Power supply:	AC 100 V/200 V, 50 Hz or 60 Hz.
Power Consumption:	Approx. 16 VA
Ambient temperature:	0~50°C
Ambient humidity:	Less than 90% RH
Dimensions (H×W×D):	240×192×320 mm
Case color:	Munsell, 7.5 BG 3.2/0.8

Program controller	
Program trace system:	Photoelectric edge trace
Scale length:	100 mm
Setting accuracy:	±1% of full scale
Full scale travel time:	Approx. 20 sec
Program sheet length:	480 mm
Program sheet drive speed:	0.5, 1, 2, 4, 8, 12, 24, 48, 96, 144 h/full stroke
Quick drive speed:	Approx. 10 mm./drum full stroke (total length 520 mm)
Drive motor:	Synchronous motor
Program end signal contact:	Single pole normally open (closed in "End") Contact capacity AC 100 V 0.3 A
Ready signal contact:	Single pole normally open (closed in "Ready") Contact capacity AC 100 V 0.3 A
Remote control terminals:	Start, stop and quick drive
Lamp burn out alarm:	Normally open (Closed in "Burnout") Contact capacity AC 100 V 0.3 A
Sequence program switch:	6 switches single pole normally open Contact capacity AC 100 V 0.3 A

Controller	
Input:	Voltage pver 20 mV DC span Resistance over 50°C span of thermo-resistance bulb Pt 100 Ω
Proportional cycle time:	Approx. 15 sec
Proportional band:	Approx. 2% Full scale
Out put relay:	Contact capacity AC 200 V 3 A

Indicator	
Indicating span:	±10% of full scale
Indicating accuracy:	±1% of full scale
Power supply:	AC 100 V/200 V, 50 Hz or 60 Hz
Power consumption:	Approx. 16 VA
Ambient temperature:	0~50°C
Ambient humidity:	Less than 90% RH
Dimensions (H×W×D):	240×192×320 mm
Case color:	Munsell, 7.5 BG 3.2/0.8

circuit and they are mounted on a plug-in type printed board. Zener diode is used to stabilize DC power supply for AC amplifier circuit.

The CR feedback circuit contains resistors and capacitor. It determines the proportional cycle time.

3) Control relay

The control relay is a miniature high power relay (DPDT). One pole is used for output and the other for switching the indicator lamps on front surface.

4) Indicator

This is a moving coil type indicator with a permanent core magnet. Since a moving coil is suspended by taut bands, the indicator has no part to be worn and is resistant against vibrations and shocks. The indicator shows a present value of process variable with an accuracy of ±1% within ±10% range of full scale from the set value.

5) Sequence program switches

On the right side of the program sheet, there are

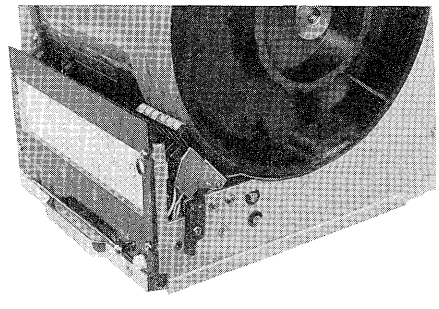


Fig. 11 Time signal switches

six semi-transparent plastic cams. These cams have indentations which operate microswitches and produce six independent signals. Because the actuators for operating the microswitches are usually pressing the cams, the sequence program switches must be shifted out of position by operating a lever for the program sheet exchange. There is a fool proof mechanism

to automatically reset the sequence program switches when the chassis is inserted in the case.

4. Case

The case is dust-proof and is made of steel plate. The front door contains a large transparent glass window. Zero and span adjustment, a gain adjustment for the servo amplifier, a power switch and start switch can be operated just opening the front door.

5. Programmer

The programmer has the output potentiometer. The output potentiometer has the 300° full stroke rotation and its resistance value is either 10 Ω–100 Ω–10 Ω or 5 Ω–50 Ω–5 Ω.

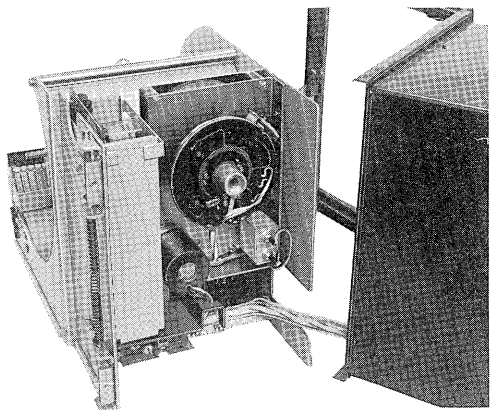


Fig. 12 Transmitting potentiometer for programmer

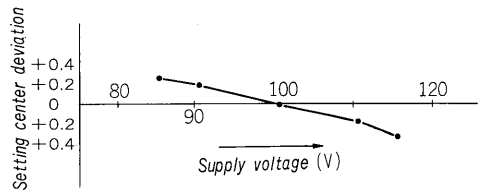


Fig. 13 Supply voltage characteristics of program controller

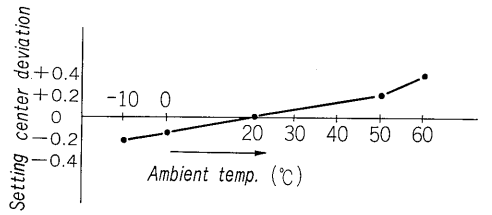


Fig. 14 Temperature characteristics of program controller

V. SPECIFICATIONS

The specifications of the grogram controller and the programmer are shown in *Table 1.* Typical voltage and temperature characteristics are shown for the program controller in *Figs. 13* and *14* respectively.

VI. CONCLUSION

This article has described the principle, construction and features of the new Fuji program controller and programmer. In the future, work will concentrate on the development of completely contactless programmer for voltage and current output.