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TRANSIDYN C SYSTEM CONTROL DEVICE (Part I)

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I. INTRODUCTION

With the rapid development of applications for semiconductors in recent years, the range of use in all fields of power control has widened greatly. Based on the technology used in the TRANSIDYN A and the TRANSIDYN B system control devices as well as new techniques, Fuji Electric has developed a new series of TRANSIDYN C system control devices which have higher functions and greater reliability in respect to more complex and larger equipment, but are also more compact and denser which makes then maintenance free. This article will introduce this equipment and examples of its applications.

II. FEATURES AND CONSTRUCTION

1. Features

This equipment has the following features in respect to the greater complexity, compactness, higher withstand voltage and greater reliability as well as excellent design, maintenance and adjustment characteristics.

1) The main parts of the equipment are in the form of plug-in units of standardized and unified size separated according to functional units. An outerview is shown in *Fig. 1*.
2) The units are designed for convenient maintenance and adjustment and are of the plug-in type. All of the adjustable parts and check terminals for checking the waveforms of the operating voltage are located on the front panel.
3) Each of the units contain IC's in a high density mounting because of the greater complexity and compactness of the control equipment. High performance linear IC's are used in the analog circuits and digital IC's with good noise characteristics are used in the logic circuits. In order to improve the noise characteristics, each unit is provided with sufficient protection, and is greater reliability.
4) These standard functional units are accommodated in a rack of the draw-out frame type which is constructed for standardized component equipments in respect to the various functions. Standardized and unified size type plug-in units are used, and the entire equipment is of the front panel system for operation and maintenance (*Fig. 4*).
5) The standard system checkers are inserted in the frame type equipment divided into component equipments and maintenance is greatly simplified since the inputs and outputs of all units can be checked. If some defect should occur, the faulty unit can be immediately removed (*Fig. 16*).
6) The control panel employs a systematic construction convenient for manufacture and application in accordance with the standard frame system.
7) The control panel is matched to each part of the equipment and is connected by a plug-in system. The front panel system for adjustment

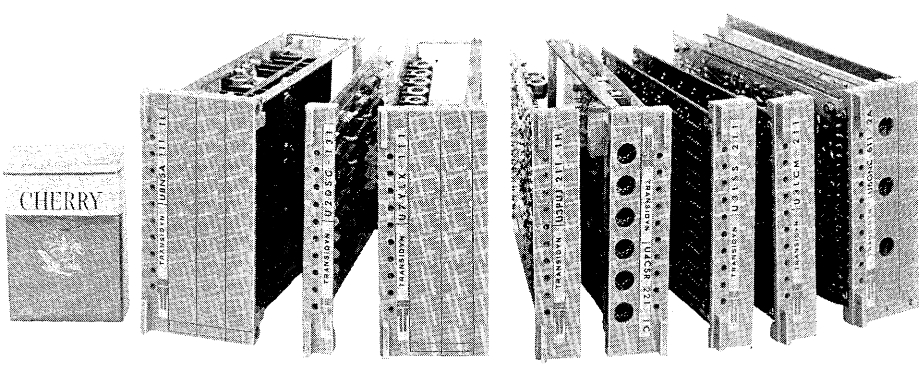

Fig. 1 Outerview of unit type

and maintenance is used in all cases (*Fig. 2*).

8) By combining the standardized functional units, the frame type equipment and the various parts, each type of control equipment can be planned optionally in accordance with the control object so that a wide range of application is possible.
9) Greater compactness has been assured by accommodating everything from an AC protective NFB to DC protective equipment in the control panel for medium and small capacity thyristor Leonard control equipment as well as the inclusion of sequence circuits and control equipment.

2. Construction and System

The TRANSIDYN control equipment can be adapted to the control object by combining elements with various functions.

1) Control panel

The control panel has unified dimensions employing a standard frame so that a systematic construction in accordance with manufacturing and adaptation of the parts and frame type equipment with functional operation and standardized dimensions can be achieved. The elements of frame type equipments can all be accommodated rationally because the four corner columns of the panel contain attachment holes which facilitate attachment of various types of control devices in optional positions.

The various control elements inside the panel are arranged so that each section is a functional equipment as shown in *Fig. 2*. The control panel is constructed by combining these units which are connected by a plug-in system. There is also complete front panel adjustment and maintenance.

2) Stack devices (Type S)

This equipment is composed of stacks of control panels. The panels are attached by means of module holes of unified dimensions. *Fig. 3* shows a thyristor-Leonard type stack device with circulating current-free. It is mono-functional equipment including the thyristor peripheral devices and the control devices. A complete front panel adjustment, checking and exchange system is used to facilitate maintenance and adjustment. Also to simplify maintenance, all external parts are connected by means of a plug-in system except for the AC input and DC output terminal which have a large current capacity.

3) Frame type equipments (Type F)

As shown in *Fig. 4*, the frame type equipment employs the draw-out system with unified dimensions.

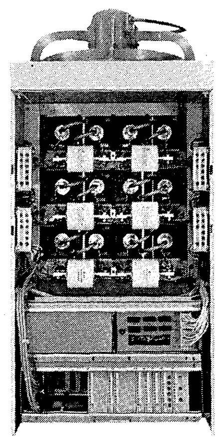

Fig. 3 Outerview of a partial standardization of device

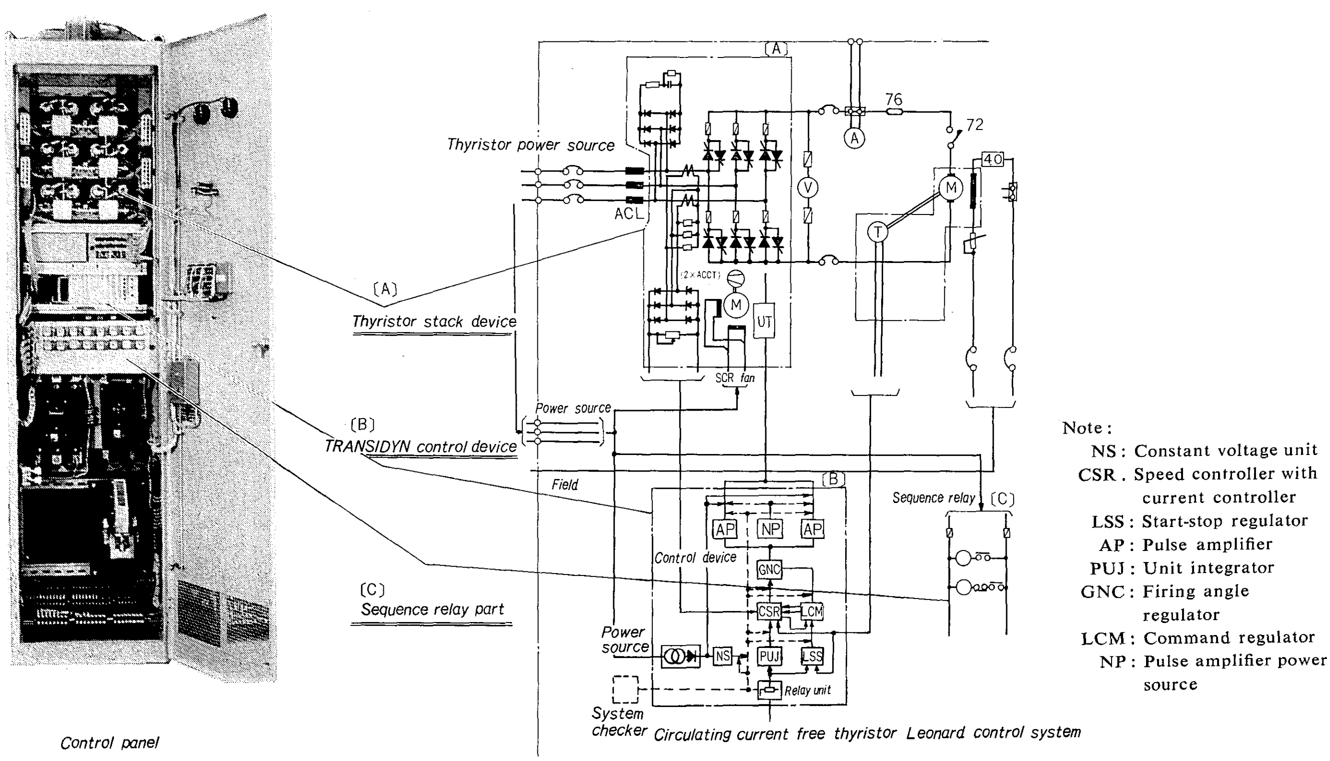

Fig. 2 Control cubicle and block diagram of control system

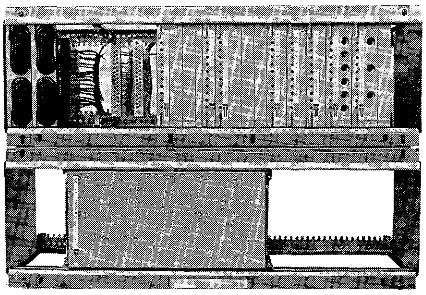

Fig. 4 Outerview of frame type control equipment

The control equipment can be constructed in the form of functional units using one, two or three shelves. Module holes are provided every 7.5 mm on the shelves so that the standardized printed board type units and block units can be inserted optionally as plug-in types according to the equipment plans. Therefore, it is very easy to construct any desired equipment by combining the various types of standardized units. The front surface of the frame type equipment has lock mechanisms for fixing the draw-out type units in place. The external connectors are of the plug-in type which can be operated from the left part of the front surface of the frame type equipment. Because of the compactness and the high density mounting, it is possible to optionally attach plugs with 32 terminals. A filter can also be attached to the bottom part of the frame type equipment to remove dust.

4) Units (Type U)

The printed board units all have standardized dimensions of 100 mm × 160 mm. They are of the plug-in type and have multi-connectors with 31 terminals. The panel on the front surface of the unit contains the check terminals ($J_1 \sim J_{10}$) for checking the operation waveforms inside the unit and the adjustable parts which ensure excellent maintenance characteristics. The volume of the adjustable parts

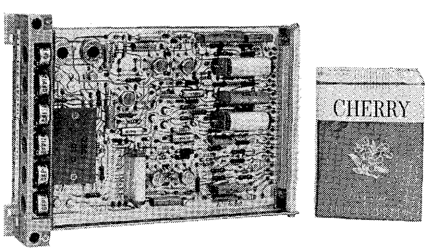

Fig. 5 Outerview of controller (U4CSR-22□/□C)

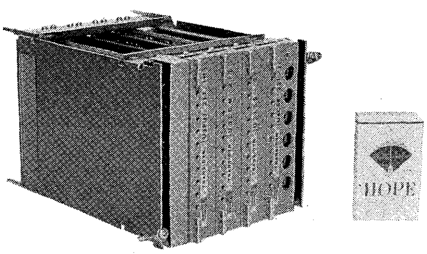

Fig. 6 Outerview of block unit type

can be adjusted on a scale or with a screwdriver from the exterior. The set values can not be altered just by touch, vibrations or shock. The front panel of the unit can be a combination of these basic panels so that the degree of pitch of the unit can be adjusted optionally. These standardized units can also be fitted optionally into frame type equipment or block units. An outerview is shown in *Fig. 5*.

5) Block units (Type B)

As can be seen in *Fig. 6*, the block units are for standardization of multifunction units, relays, etc. or serve as a means for the incorporation of heavy equipment such as transformers in frame type equipment. Module type grooves and holes are provided so that each unit can be inserted optionally and the components can be attached optionally. In this way, the equipment is very easy to construct.

With the above construction methods, the control equipment and control panels can be combined to form the most suitable electronic equipment. This revolutionary method is a systematic, rational block building system from the smallest functional unit to frame type equipment, parts and panels. These standardized units, trays and parts can be systematically combined, connected by a plug-in system and arranged so that each unit is a functional unit. Therefore, this means that the equipment has excellent features in respect to planning, ordering, manufacture and maintenance.

III. COMMON RATINGS

The components and construction of the TRANSIDYN control equipments are not only standardized but the equipment is also standardized in respect to electrical specifications.

1. Control Power Supply

1) DC supply voltage

Except for special cases, the control power supply is generally a 3-wire common source system with ±24 V. The guaranteed range of supply voltage variations is as shown in *Fig. 7*. There is an internal

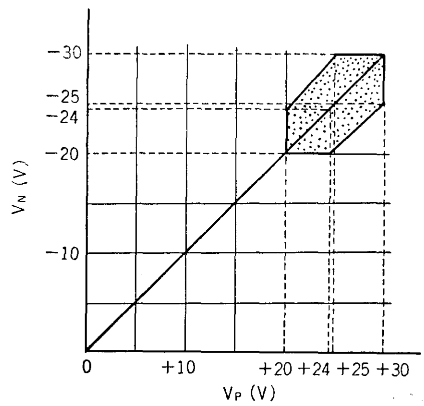

Fig. 7 Tolerance of supply voltage V_P and V_N

stabilized power supply for the analog and logic IC circuits with ±15 V. The pulse transmitter power supply is +48 V with a guaranteed variation range of +40 V∼+60 V.

2) AC supply voltage

The AC supply voltage has a rated value of 200 V/220 V with a guaranteed range of +10%∼−15%. In the above-mentioned DC supply voltage, the AC supply voltage variation has also been considered. Instantaneous variation is also permitted within this variation range.

3) AC power supply frequency

The AC supply frequency has a rated value of 50 Hz/60 Hz with a guaranteed range of +2 Hz∼−3 Hz.

2. Control Signal

Except in special cases, the control signal is DC ±10 V signal intended to improve signal transmission, quality, ease of operation and noise characteristics.

3. Allowable Ambient Temperature

The allowable ambient temperature range is −10°C ∼+65°C for the units of printed boards and various elements, and −10°C∼+40°C for the control panels. These ranges guarantee stable operation and characteristics.

4. Uniform Terminal and Jack Numbers

The following are standard for each unit and frame type equipment:

Terminal 1	−15 V
Termihal 2	+15 V
Terminal 3	0 V
Terminal 31	ground (only when required)
Jack J1 of units	0 V

IV. STANDARD FUNCTIONAL EQUIPMENT

Generally, control equipment possesses setting, detecting and operating functions. The TRANSIDYN C system control equipment has basic functional units which consider ease of design, adjustment and maintenance. The control equipment is constructed by systematically combining such elements. *Table 1* shows the basic control elements. These basic elements are explained below.

1. Controller

The controller of the TRANSIDYN system have proportional (P), integrating (I) and differential (D) functions which are ideal in accordance with TRANSIDYN control theory (*Fig. 8*). They consist of operational amplifier of IC with a high amplification factor and stability, input-circuit for addition and subtraction of set values and actual values, and limiter circuit to control outputs. The following is a typical example.

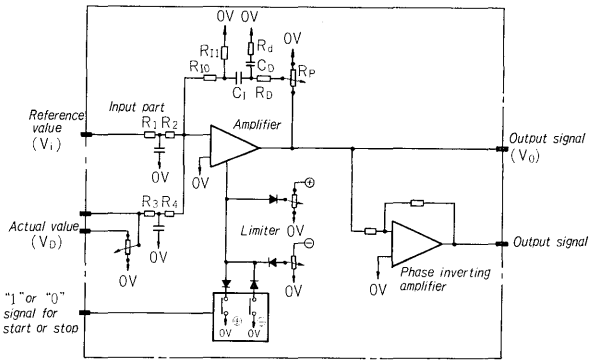

Fig. 8 Circuit diagram of controller

1) Speed controller with current controller (U4CSR-22□/□C)

This controller is used mainly for armature voltage control, counter emf control and motor speed control with armature current control systems as a minor loop. It is composed of two regulators with P and I functions. An outerview of this controller is shown in *Fig. 5*. For example, the two regulators in a motor speed control system consist of a speed control part (ASR) and a current control part (ACR). The ACR part has an armature time constant which is the largest individual time constant according to the TRANSIDYN control theory, and this time constant decides the PI characteristics. The operation of this controller changes the output signals of the PI characteristics in accordance with the difference between the current setting value and the actual value of the armature current. This output signal is the control input signal for the firing angle regulator. The negative output signal becomes the firing instruction value for the α-region and the positive output signal the value for the γ-region. Therefore, the set value has positive polarity and the detected value negative polarity. If a suitable voltage is applied from the exterior, a limiter terminal (for $\alpha_{min.}$, $\gamma_{min.}$ setting) is provided which can freely limit the firing angle instruction value to the value of the applied voltage. The ASR part has a mechanical time constant of the motor which is the largest individual time constant according to the TRANSIDYN control theory and this time constant decides the PI characteristics. The operation of the this controller changes the output signal in accordance with the difference between the actual and setting value of the speed and this becomes the current setting value of the ACR part. The negative ASR output voltage is inverted by a phase inverting amplifier so that a positive setting voltage is normally applied to the ACR. This controller can be easily started or stopped by applying the " 1 " or " 0 " signals respectively from the exterior. The logic signal generally employs the " 1 " or " 0 " binary code but this is electrically uniform as follows in the TRANSIDYN system.

The "1" signal is 0 V and the "0" signal, +15 V (or open). The output limited voltage can easily be set

Table 1 **Standard family of control equipment**

Name		Type	Form	Application and specifications
Controller	Speed controller with current controller	U 4 CSR–22□/□C	U	Used for three-phase pure bridge circulating current-free thyristor Leonard control. Speed controller: Input ∓10 V/100%, output ±10 V/100%, detecting value ±10 V/100% Current controller: Input +10 V/100%, output ∓10 V/100%
	Current controller	U 4 CCR–22□/2	U	Used to control motor armature current which is consisted by three-phase pure bridege reversible circulating current thyristor Leonard control. Circulating current: 0∼10%, Input +10 V/100%, output ∓10 V/100% Two current control part included.
	Field current controller	U 4 CFL–22□/□G	U	Used for field current control or back EMF control of motors. Also contains firing angle regulator for single-phase pure bridge and hybrid bridge connections. Input: +10 V/100% Output: D, E, G, H and N type thyristor firing
Computer	Unit integrator	U 3 PUJ–21□/□H	U	Used as command regulator for acceleration and deceleration of motors. Continuously variable accel. and decel. time up to 0.5∼6 sec. or 5∼60 sec.
	Way regulator	U 5 PWS–11□	U	Rotating angle commaud generator containing integrator. Characteristics: $V_{out}=\sqrt{K \cdot V_{in}}$, $K=20\sim200$
	Start-stop regulator	U 3 LSS–21□	U	Provides start-stop command for thyristor Leonard control equipment.
	Command regulator	U 3 LCM–21□	U	Used as forward-reverse switching regurator for circulating current-free thyristor Leonard control.
	Aux. command regulator	U 3 LCM–21□/M	U	Used as auxiliary regurator of U 3 LCM–21□ for circulating current-free thyristor Leonard control with mechanical tie connection.
	Armature command regulator	U 3 LCM–22□	U	Used as forward-reverse switching regulator for reversible thyristor Leonard control with switching armature circuit.
	EMF computer	U 4 PEM–22□	U	Used to compute back EMF of motor
	Multiplier	U 3 PMD–21□	U	Multiplier for four quadrants with Z=X•Y/10 relation. Input X: ±10V, Y=±10 V Output: Z=X. Y/10 V
	Comparator	U 3 ALL–21□	U	Detects analog levels and converts to logic signals. Two element included and output is possible to drive control relay.
Firing angle regulator	Firing angle regulator	U 6 GNC–61□/1 A, 1 B	U	For three-phase pure bridge (with circulating current thyristor Leonard).
	Firing angle regulator	U 6 GNC–61□/2 A, 2 B	U	For three-phase pure bridge (with circulating current-free thyristor Leonard).
	Firng angle limited regulator	U 4 BGR–21□	U	Used as overcurrent limiter unit in thyristors converter.
Pulse amplifier	Transistor type pulse amplifier	U 5 APR–63□/2 U 5 APR–63□/3	U	Applied N and P type thyristors firing.
	Pulse amplifier	T 1 APR–31□	T	Applied 4P or over firing of N and P type thyristors.
Setter	Motor driven setting block unit	B 30 SAM	B	Operation time: 3.3∼600 sec. Setting resistor: multi-turn and single potentiometer (4∼6 trains)
DC power supply	Constant voltage unit	U 8 NSA–11□	U	Stabilized voltage unit for analog and logic circuit. Input: DC ±24 V Output: DC ±15 V
	Power source block	B 3 NAL	B	Power supply block unit with built in synchronous power supply circuit. Output for analog ±24 V, for logic ±24 V, for relay ±24 V, for pulse transmission circuit +48 V
		B 4 NAL B 3 NPR	B	Power supply block unit with built-in two synchronous power supply circuits for the circulating current system. Output for analog ±24 V, for logic ±24 V, for relay ±24 V, for pulse transmission circuit +48 V
	Pulse amplifier power source	T 1 NP–11□ T 2 NP–12□	T	Power supply for pulse amplifier Output: ±24 V, +48 V
Maintenance unit	Check unit	U 1 MCL–11□	U	Used for maintenance and inspection of thyristor Leonard control equipment.

Note: Letters in Form column indicate the following.
U: unit, B: block unit, T: tray unit, □: the design mumber is shown in brackets.

by means of the volume unit on the front surface and the armature current value can be limited optionally. The amplifier parts of both controller employ linear IC's with high amplification factor and stability. One of the main features of this controller is that the input stage of the amplifier can be controlled smoothly without saturation by means of the special feedback circuit even when there is a large deviation in the input.

2) Field current controller (U4CFL–21□/□G)

This controller is applied in the weak field control of motors. It consists of a field current controller part which performs PI operations and a firing angle regulator which receives the current controller output and generates a firing pulse. The field current controller has a field time constant which is the largest individual time constant according to the TRANSIDYN control theory and this constant decides the PI characteristics. The operation of the field current controller changes the output signals in accordance with the difference between the field current setting value and the detecting value. This signal becomes the input of the firing angle regulator. This regulator is applied for single phase pure bridge connection at 1S1P4A or single phase hybrid bridge connection.

2. Computer

As control systems become more complex, control equipment with higher functions is required, and PID controllers alone are not sufficient to meet the control requirements. Various types of computers become necessary when these computers are classified according to function. They can be divided into analog type computers and contactless semiconductor logic computers which give systematic starting and stopping commands such as controllers and firing angle regulators in order to improve the performance of the control equipment.

1) Unit integrator (U3PUJ–21□/□H)

In motor acceleration and deceleration control, a speed (voltage) controller is used as a setting instruction device. The unit integrator has computing and integrating functions. It changes the output signal without relation to the size of the input signal until it becomes equal to the input signal at a constant time gradient. This time gradient is of two types continuously variable between 0.5 and 6 sec. or 5 and 60 sec. The acceleration time and the deceleration time can be set independently, and also signals during acceleration and deceleration can be obtained. An analog switch is built in so that the output signal can be made zero without any relation to the input signal.

2) Start-stop regulator (U3LSS–21□)

This regulator is a control device for the TRANSIDYN C system, and establishes conditions for sending a zero holding command (forcing the output signal to 0 V) and auxiliary setting command to controllers and computers.

The input signals are whether there are set voltages, detecting voltages and fault conditions. The output signals are the brake command, unit integrator zero hold and zero release command, the drive-stop command of the command regulator described later and the auxiliary setting of the current controller (the negative voltage is applied without relation to the control signal to the input of the current controller and the signal for shifting the pulse forcibly to $\gamma_{min.}$ position is fed in or cut off). *Fig. 9* shows the operation principles.

(1) Stopping state

If there are no setting, detecting or fault conditions after closing the control power source, the following output signals are given and the motor is stopped. The output signals are the brake throttle signal, the zero hold signal of the unit integrator, the zero hold signal of the speed controller, the stop command of the command regulator (only when required) and the auxiliary " on " setting to the current controller.

(2) Operating state

When a setting is applied after the conditions in (1) above, the brake release command, the zero hold release command of the unit integrator, the zero hold release command of the speed controller, the operating command for the command regulator and the "off" command of the auxiliary setting to the current controller are given. Operation begins and normal operation starts.

(3) Fault stop

When a fault signal is received during normal operation, the zero hold signals of the controllers

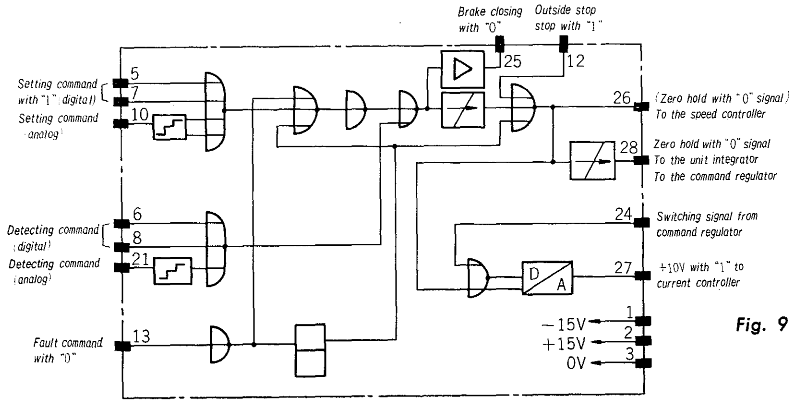

Fig. 9 **Circuit diagram of start-stop regulator (U3LSS–21□)**

and computers, the auxiliary setting " on " signal and the signal closing brake are given and the motor is stopped. In this case, the motor can not be started again until the fault is completely eliminated. In the case of thyristor Leonard systems with circulating current-free, the various command signals are given by combining this computer with the command regulator described next.

3) Command regulator (U3LCM–21□, U3LCM–21□/M and U3LCM–22□)

The U3LCM–21□ is used for current switching between an inverter and a converter connected in anti-parallel in a thyristor Leonard control system with circulating current-free. The U3LCM–21□/M is used in a mechanical tie in combination with the above computer. The U3LCM–22□ is used as a command regulator for contactor switching in an armature switching control system. *Fig. 10* shows the principles of the U3LCM–21□ and *Fig. 11* is an outerview.

(1) U3LCM–21□

The input signal of this regulator is a start-stop signal from the start-stop regulator as well as a torque polarity and armature current signal. The output signals are signals which gives an inverter and a converter pulse off command, speed regulator zero hold, and the " on " and " off " auxiliary setting signals the aforementioned start-stop regulator. The firing angle regulator (or pulse amplifier) connected to the thyristor converter on the side in accordance with the torque polarity is activated and a current flows (for example, in the case of forward polarity torque, the torque polarity causes a positive voltage, the forward polarity side of the speed controller is activated, a pulse-on command is given to the firing angle regulator on the forward side and current flows into the forward converter). When the torque polarity is reversed from this condition, the auxiliary setting signal is applied to the current controller, the pulse of firing angle regulator is shifted to $\gamma_{min.}$ position and the current is decreased in a main circuits.

When it is detected and confirmed that the current which has been flowing has become zero, the pulse of the firing angle regulator on the side which has been firing is turned off and after a constant time, the firing pulse is activated on the side depending on the new torque polarity and current flows in the line circuit. This is exactly the same operation are the reverse switching.

(2) U3LCM–22□

The input signals of this regulator are a torque polarity signal and a start-stop signal from the start-stop regulator. The output signals are contactor "on" and "off" commands of the forward and reverse sides, zero hold and zero release commands of the speed

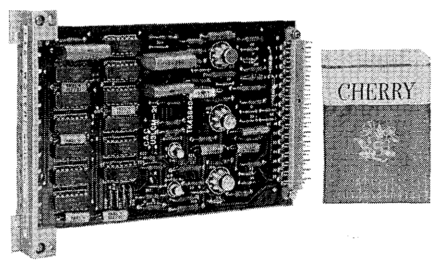

Fig. 11 Outerview of logic regulator (U3LCM–21□)

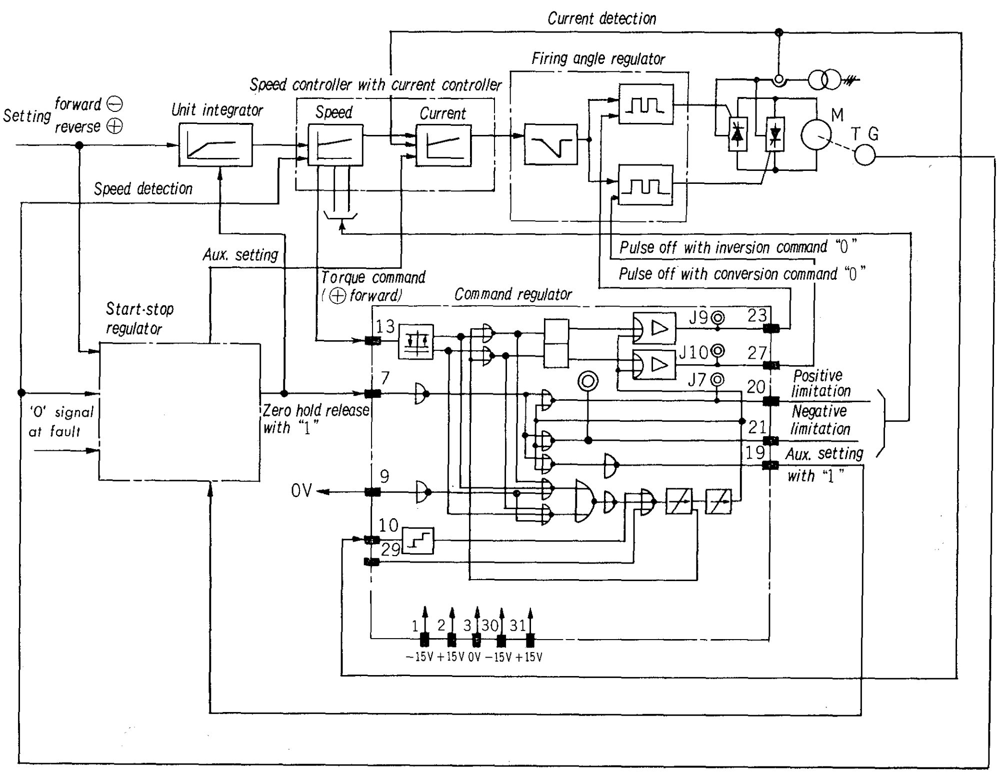

Fig. 10 Block diagram of command computer (U3LCM–21□)

controller and the auxiliary setting signal. When the torque is reversed, the firing pulse is shifted to $\gamma_{min.}$ position and after a constant time, the contactor which has been connected is disconnected and the contactor on the side in accordance with the torque polarity is connected. This principle is shown in *Fig. 12*.

3. Firing Angle Regulator (U6GNC–61□/2A, 2B, U6GNC–61□/1A, 1B)

The firing angle regulator generates a pulse in phase with the related input control signal and the thyristor gate is controlled by this phase-controlled pulse. IC's are used in the TRANSIDYN C in general. An outer-view is shown in *Fig. 13* and a block diagram in *Fig. 14*. The U6GNC–61□/1A is for the 1S1P6A, can be connected to two sets of pulse amplifiers (T1APR–31□) and can perform simultaneously firing of a number of thyristors from 1S4P6A up to 1S9P6A.

The U6CNC–61□/1B is connected to the transistor type pulse amplifier (U5APR–63□) mentioned later, and can be used as a thyristor converter for 1S2P6A or 1S3P6A. The type 2A and 2B are for 12 phases. Since the relation between the control angle and the input control signal is linear, the control angle can easily be limited by limiting the input control signal.

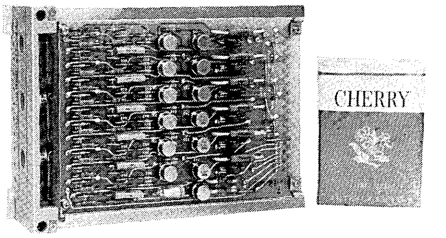

Fig. 13 Outerview of firing angle regulator (U6GNC)

The AC voltage synchronized with the thyristor power source is given as the synchronizing signal in the firing angle regulator and this signal is changed into a saw-tooth waveform of constant gradient in a saw-tooth generator circuit. Since a zero point synchronizing method in which there is synchronization at the zero point which shifts the synchronizing signal from negative to positive is used, in principle, there can be no effect from voltage variations in the synchronizing signal or waveform distortion. The output signal of the saw-tooth waveform signal level and the input control signal after the amplified parts are compared with the signal current by a comparator containing IC's. A constant width pulse is generated

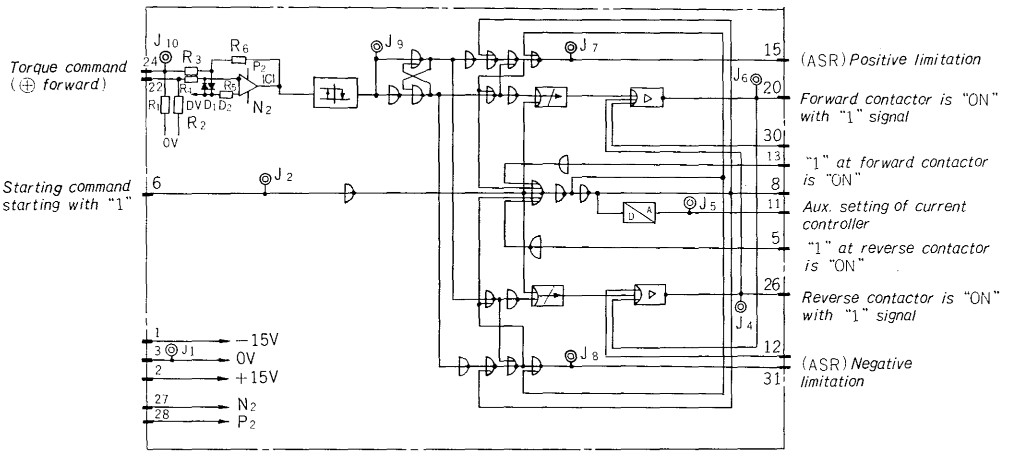

Fig. 12 Circuit diagram of command regulator (U3LCM–22□)

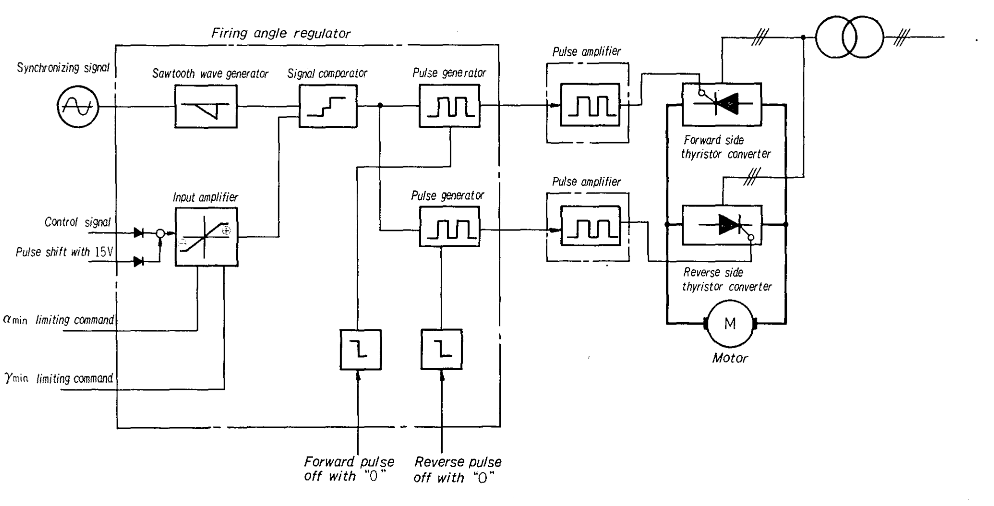

Fig. 14 Block diagram of firing angle regulator

when the saw-tooth wave signal level is larger than the input control signal. When this regulator is used for the thyristor converter of 3 phase pure bridge connection, this pulse and the pulse delayed by 60° el. (double pulse) are amplified and the firing pulse is applied to the thyristor gate. By limiting the input control signal on the input amplifier part, the control firing angle can be limited. By adding the firing angle limited regulator (U4BGR–21□), flip-flop operation takes place when an over-current flows in the thyristor, the firing angle pulse is shifted to $\gamma_{min.}$ position without any relation to the control input, this condition is self-hold and an alarm signal is given to the exterior. After the fault is removed, the original condition will be recovered if a reset signal is applied. When the stop command is given, the pulse shifts to $\gamma_{min.}$ position and the thyristor converter is actually stopped but there is no self-hold at such a time.

4. Pulse Amplifiers

The pulse amplifiers are used mainly to fire simultaneously a number of thyristors (applicable thyristors types: GTL, GTN and KGP) connected in parallel or in series with the main circuits. Therefore, they are connected after the firing angle regulator and the phase controlled pulse output is amplified directly, and passes to the line thyristor gates through the pulse transmission circuits, to provide firing gate current.

1) Transistor type pulse amplifier (U5APR–63□)

This pulse amplifier has 6-phase pulse amplifier functions and uses a large capacity transistor in the output stage. Since a transistor " Darlington " connection is applied, 2P or 3P line circuit thyristors can be fired simultaneously by using U6GNC–61□/1B, 2B in the firing angle regulator on the previous stage.

2) Pulse amplifier (T1APR–31□)

This pulse amplifier has three-phase pulse amplifier functions and is contained a pulse amplifier unit for each phase. By combining with a firing angle regulator (U6GNC–61□1A, 2A), simultaneous firing of 4P or over line circuit thyristors is possible. For example, when the line circuit converter has the 3 phase pure bridge connection, two pulse amplifiers are connected to the output of the firing angle regulator (U6GNC–61□/1A).

5. Setter (B30SAM)

The setter is used in cases when there is to be a time coefficient of the command value or the command values at the remote operation in the automatic control system or the control value are to be stored.

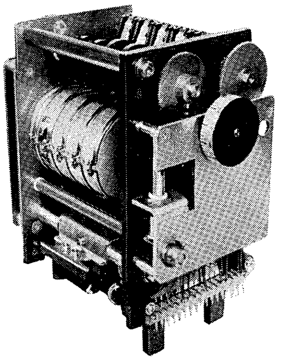

Fig. 15 Outerview of setter (B30SAM)

Single or multi-rotation slide resistors is driven by a two-phase servomotor and the driving time can be altered from 3.3∼60 sec by the voltage or the gear ratio. There are two limit switches provided for end terminals and three for control. A slip mechanism is used for protection and the sliding parts are totally enclosed. The indicator is attached so that the rotation position can be checked from the front. This block is combined with a drive power supply block with voltage switching and voltage polarity switching relays. An outerview of the setter is shown in *Fig. 15.*

6. Checker (U1MCL–11□)

This unit performs checking of the operation of thyristor Leonard equipment. There are meter, lamp, rotary switch for changing check point, check terminal, manual voltage setter and terminal on the front panel. It can perform simultaneous checks of the input and output of the analog computers and controllers by meter and the output signals of logic computers and the output pulses of firing angle regulator by lamp. Manual terminals are provided for the logic and analog signals of external circuits can be checked individually. Since a setting voltage of 0∼±12 V can be obtained from a terminal on the front panel, it can be utilized to provide setting signals to external circuits. *Fig. 16* shows an outerview and *Fig. 2* an example of application.

(To be continued)

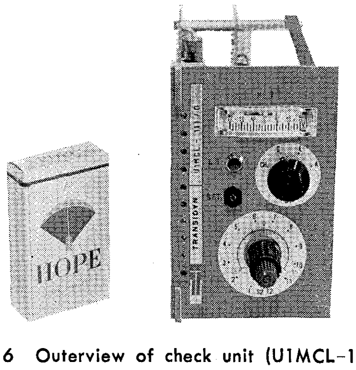

Fig. 16 Outerview of check unit (U1MCL–11□)