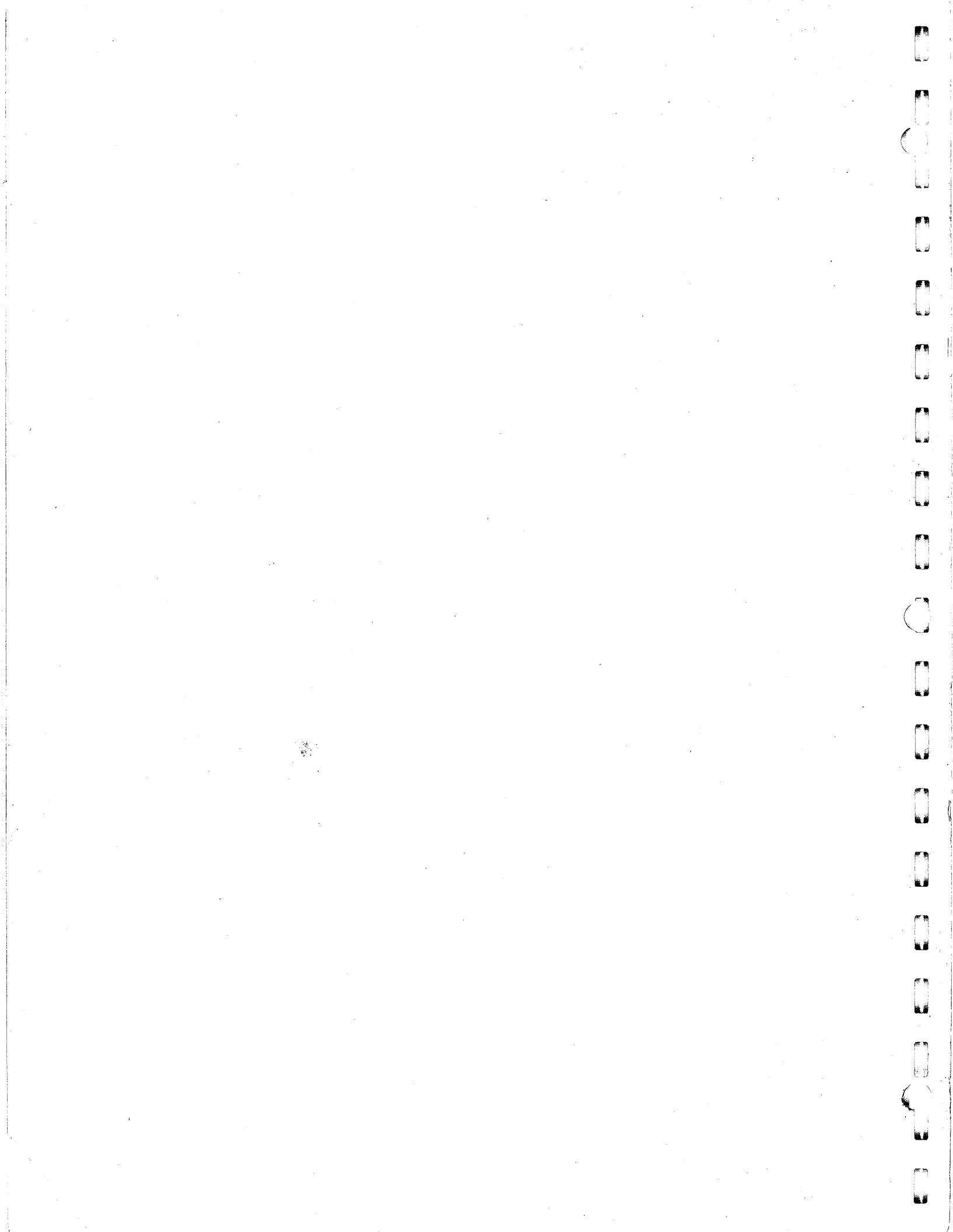
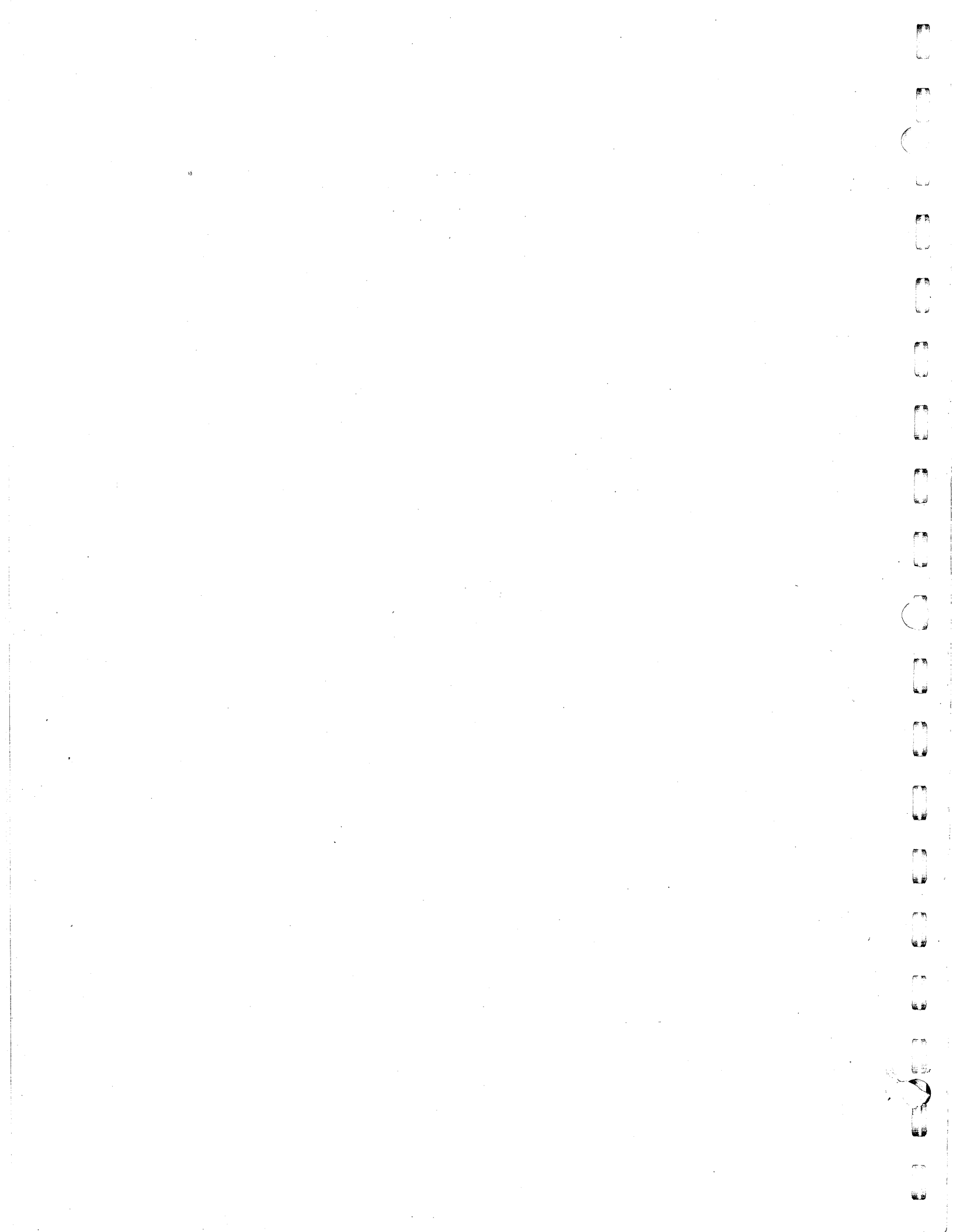


INSTRUCTION
MANUAL
ANALOG COMPUTER
HITACHI 303



Instruction Manual

for Analogue Computer HITACHI - 303



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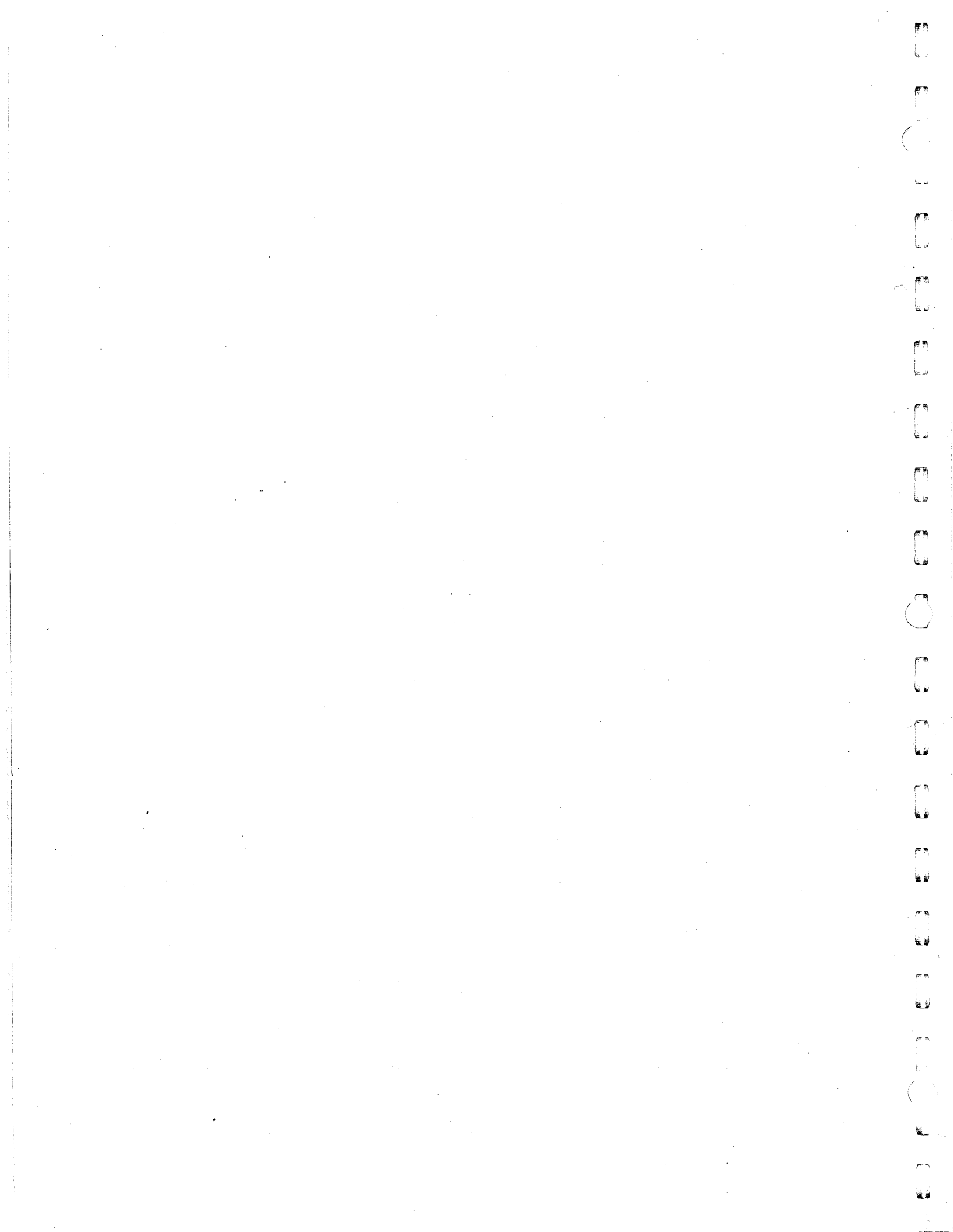
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Observe in strict accordance with the suggestions noted in the text.

The instruction for the synchroscope is separated.



1. Introduction

1.1 General

The present analog computer is a small size, desk type computer utilizing the vacuum tubes. It is designed to have almost as excellent functions as a large computer in its auxiliary mechanisms such as the control panel which permits very easy operation.

The components are roughly classified as the linear panels, non-linear panels, and control board. Since each panel is constructed in the building-block (principle), addition of panels is very easy.

The programing for this computer is based on an unique pre-patch system. For operational speed, this computer permits the selection between slow operation and repeating operation by a single action of the control switch, in order that the operational speed is easily obtained.

By use of the newly designed AB changing mechanism, it is possible to automatically display the two of the solution variables, both in slow and repeating operations by cycling between them.

In addition to the mechanisms mentioned above, this analog computer is provided with several other auxiliary mechanisms to enhance it's use.

The maximum signal voltage of this computer is ± 50 volt, and the maximum output current of operational amplifiers is ± 3 mA.

1.2 General specifications

Type	HITACHI-303
Purpose	Solution of differential equations, analysis of automatic control systems.

Performance	Computing voltate	within $\pm 50V$
	Computing impedance precision	$\pm 0.5\%$
	Drift of amplifier	within 10m V/H
	Connecting system	Pre-patch system
	Ambient temperature	$5^{\circ}C$ -- $30^{\circ}C$
	Ambient relative humidity	50%--80%
	Power source	115V \pm 5V, 50 c/s~60 c/s. 1 ϕ

Power consumption and dimensions

These values depend upon the number of panels being mounted, which are shown below.

(The number of panels is a total number of linear panel LA-121's and nonlinear panel NA-122's, mounted.)

	Composition (Number of panels)	Power consumption	Dimensions (Height)
1.	Panel	Approx. 100 VA	Approx. 410 mm
2.	Panel	150	480
3.	" (half mounted)	200	550
4.	"	300	620
5.	"	350	690
6.	" (fully mounted)	400	760

Approx. 550 mm, in width and approx. 410 mm in depth

(note) These values show the ambient temperature and humidity conditions necessary to meet the specifications.

The specification will be almost met even if the above-mentioned ambient temperature and humidity exceed the parameter given.

1.3 Composition

1.3.1 General

This equipment employs a building block system with operation panels. According to the panels selected, many combinations are available. There are 4 type of panels;

1. Linear panel LA-121
2. Non-linear panel NA-122 (or NA-121)
3. Control board CT-121
4. Additional power unit PS-021

The control board is indispensable. But, linear panels and non-linear panels can be combined arbitrarily within the limits described below;

Linear panel	LA-121	1 to 6 panels
Non-linear panel	NA-122 (NA-121)	1 to 3 panels

The total number of linear panels and non-linear panels must be not more than 6, because of the limits of height and power source capacity. (Excluding NA-121)

When the total number of panels is more than 3, the additional power unit is always needed. (It is equipped inside the control board).

Fig. 1-1 shows an outside view of the computer in full-equipped condition.

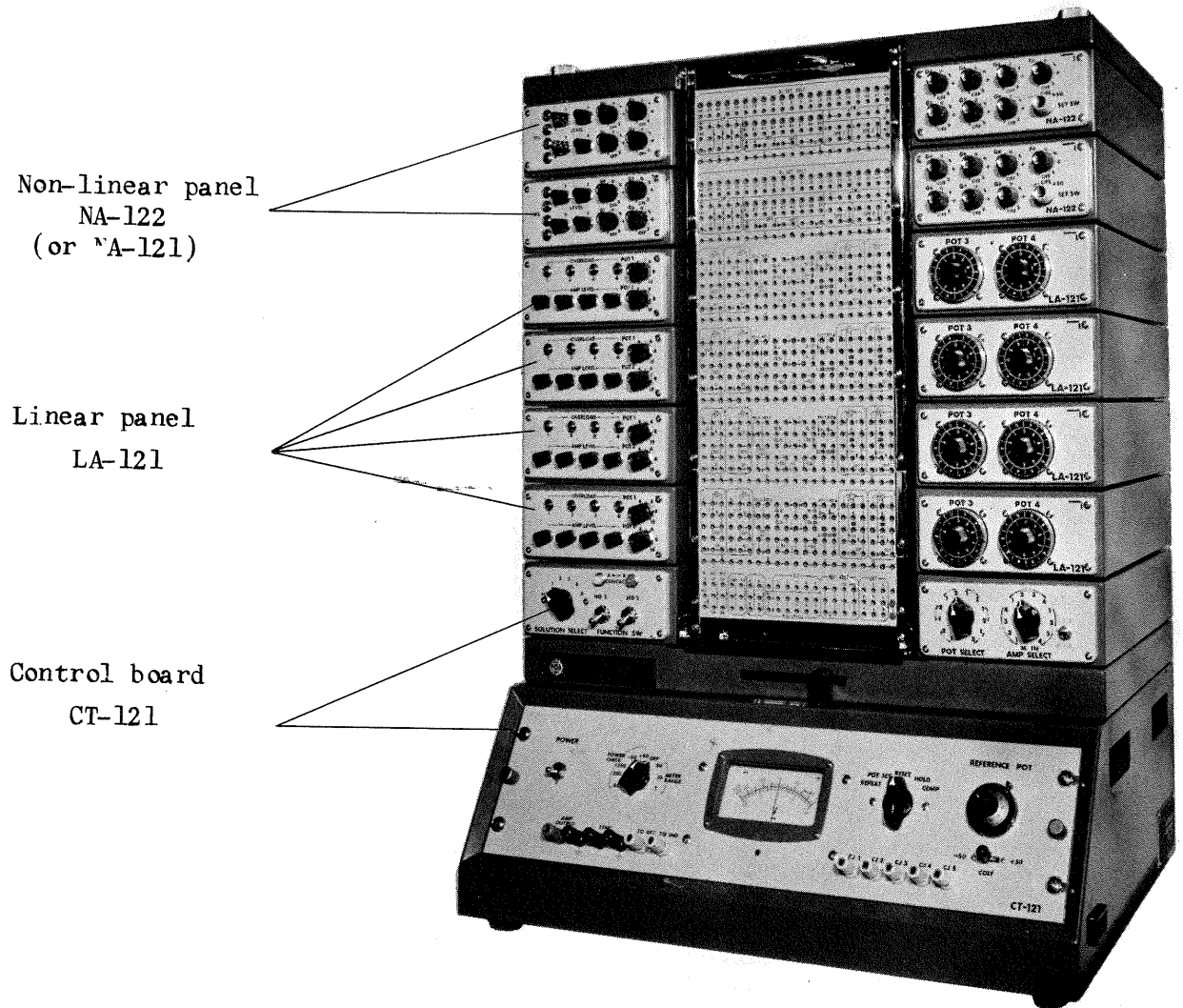


Fig. 1-1 Outside view in full-equipped condition

1.3.2 Composition of the main equipment

		[	Summer or universal operational	
			amplifier	2	
		[	Integrator or summer or universal operational	
			amplifier	2	
HITACHI-303	Linear panel (LA-121)	[	10 turning type potentiometer	2
			1 turning type potentiometer	2	
			[Auxiliary operational impedance	1 group
			[Free diode	4
			[Diode function generating component	1
			[Multiplier/divider (with amplifier equipped inside)	1
			[Voltage comparator (with amplifier equipped inside).....	1
			[Inverter or universal operational amplifier	2
			[Control unit	1
			[Selector unit	1
		[	Indication unit	1
		[	Patch unit	1
		[	Power unit	1
		[	Attached unit	1
		[	Pre-patch board	1 group
		[	Additional power unit (PS-021)	1 group
		[	Diode function generating component	1
		[	Multiplier-divider component	1
		[	Voltage comparator component	1
		[	Non-linear panel (NA-121)	

1.3.3 List of accessories

HITACHI-303 Accessories	Patch cord	length 20 cm	1 group
		" 40 cm	1 group
		" 70 cm	1 group
		" 100 cm	1 group
	Short circuiting plug		
	Maintenance tool	soldering iron	1
		nipper	1
		cutting pliers	1
		screwdriver ⊕	1 group
		" ⊖	
	Spare parts		1 group

2. Linear panel LA-121

2.1 General

In the linear panel LA-121, four (4) DC amplifiers are equipped. The panel is composed of the following elements. Furthermore, this panel is provided with four (4) potentiometers and a group of auxiliary operational impedances. The auxiliary operational impedances can also be used as circuit elements for saturation or dead space.

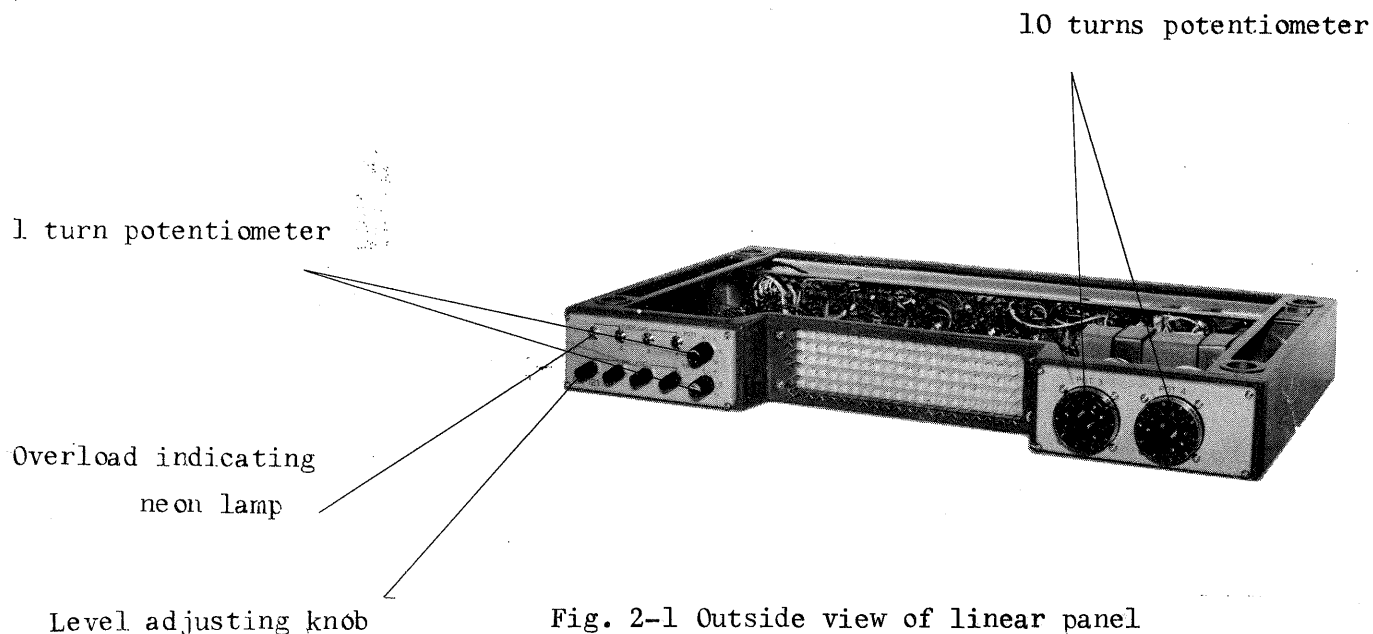


Fig. 2-1 Outside view of linear panel

Linear Panel LA-121	Summer or universal operational amplifier		2
	Integrator or summer or universal operational amplifier		2
	10 turning type potentiometer		2
	1 turning type potentiometer		2
	Auxiliary operational impedances		
		1 M ohm + 1 M ohm $\pm 0.5\%$	2
		100 K ohm $\pm 0.5\%$	2
		0.1 μF $\pm 0.5\%$	1
		0.001 μF $\pm 0.5\%$	1
		Free diode	

2.2 Summer or universal operational amplifier (ADD or OPE AMP)

The ADD or OPE AMP is composed of amplifiers No. 1 and No. 2. The functional operation is selected by patch control (insertion or removal of short circuit plug).

o In case of summer

Put a short circuit plug in $\bigcirc \overset{A}{\text{---}} \bigcirc$ on the prepatch board as shown in Fig. 2.2, and the amplifier will operate as a summer.

o In case of operational amplifier

The ADD or OPE AMP operates as an operational amplifier without patching the short circuit plug in Fig. 2.2. Therefore, any transfer function can be patched as described.

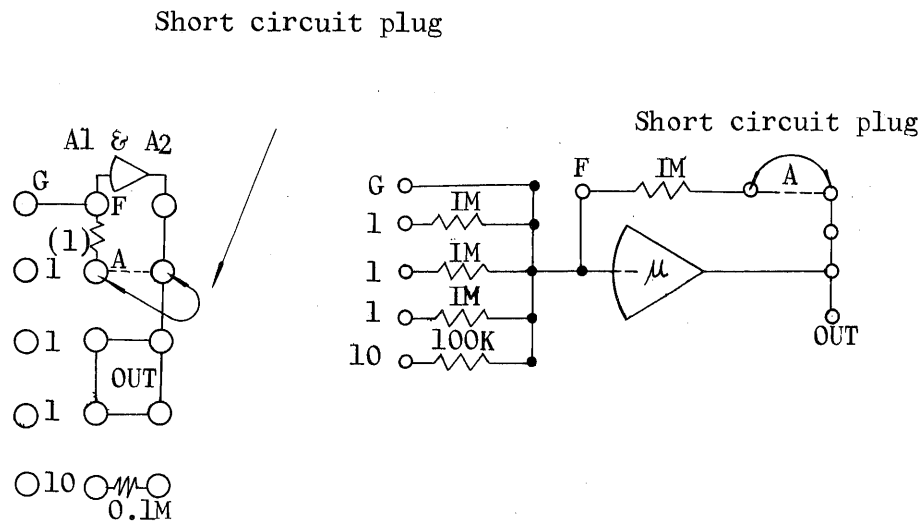


Fig. 2-2

2.3 Integrator or summer or universal operational amplifier (INT or ADD or or OPE AMP)

This amplifier is composed of amplifiers No.3 and 4. It operates as a linear component having any one of the above mentioned three functions by the patch control (by means of short-circuiting plugs).

o In the case of integrator

Link $\text{O} \overset{\text{I}}{\text{---}} \text{O}$ by means of short-circuiting plug as shown in Fig. 2-3, then this amplifier will operate as an integrator. IC is the input terminals to give initial value to the integrator. Apply a fixed voltage at the terminals IC when the initial integrator output voltage is needed at the beginning of computation.

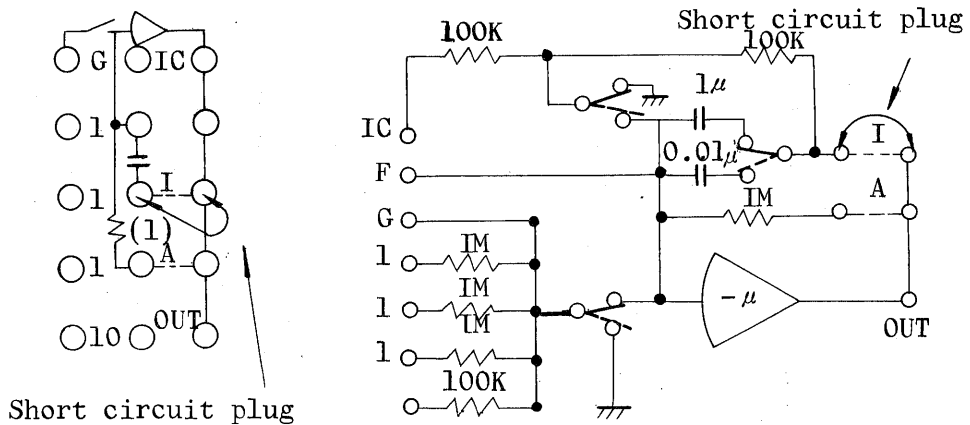


Fig. 2-3

o In case of summer

With a short circuit plug inserted in $\text{O} \text{---} \overset{\text{A}}{\text{O}}$ as shown in Fig.

2-4, it will operate as a summer.

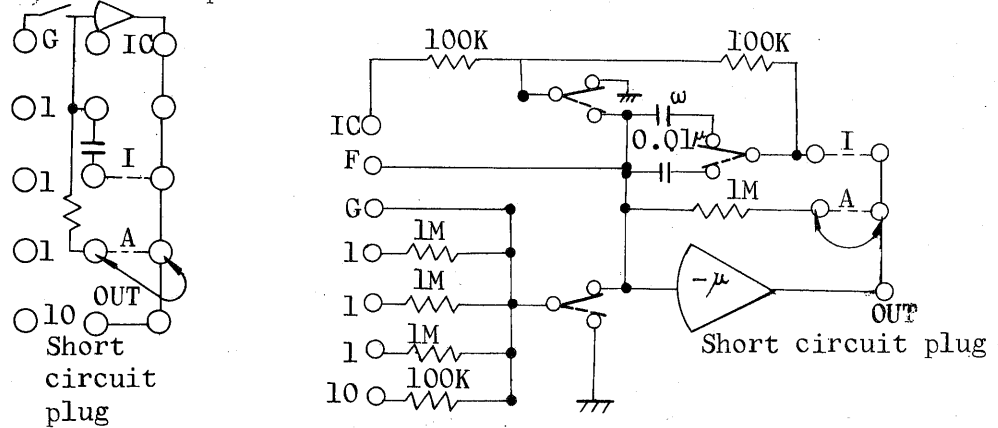


Fig. 2-4

o In the case of operational amplifier

It will work as an operational amplifier when no short circuit plug is patched in A nor I. Therefore, any optional transfer function can be patched.

o Level adjustment of operational amplifier

This adjustment is to adjust the offset voltage of operational amplifier and, with it the output level can be changed. "LEVEL" on the left side panel of LA-121 is the adjusting knobs. The numbers 1-4 correspond to those of amplifiers.

Procedure for adjustments

1. Prepare all the operational amplifiers as summers or integrator by inserting short circuit plugs.

2. Place the operation control switch on the control board to "RESET".
3. Place the prepatch board to "SET"
4. Select an amplifier on AMP SELECT. Then, turn the corresponding "LEVEL" adjusting knob to get 0 volt reading on the voltmeter of the control board. In this process, make fine adjustments in a properly selected METER RANGE.

As a simplified adjustment, the LEVEL knob is so adjusted that the neon lamp above the knob will extinguish with the prepatch board down.

Note that the computer should be adjusted before it is used. This adjustment is to be made after 10 minutes after the application of power (warm-up).

Overload indication lamp

OVERLOAD lamps on the left panel are to indicate overloaded condition of amplifiers. Therefore, when a lamp illuminates, stop the computation and remove the cause.

Great errors will result if the computation be continued with the lamp illuminating.

Amplifier overload may occur due to improper patching; amplifier malfunction; demand of voltage higher than rated or current.

2.4 Potentiometer

2.4.1 10 turning type potentiometer.

POT3 and 4 are 10 turn potentiometers. One end of each potentiometer is grounded. They are used for setting multiplication constants or for setting initial values. Their resistance value is 50 K Ω and their linearity is $\pm 0.4\%$. The corresponding patch board is shown in Fig. 2-5.

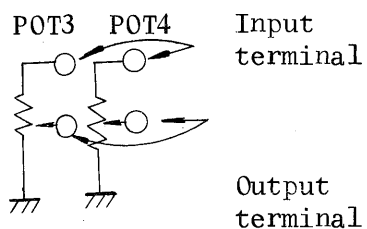


Fig. 2-5

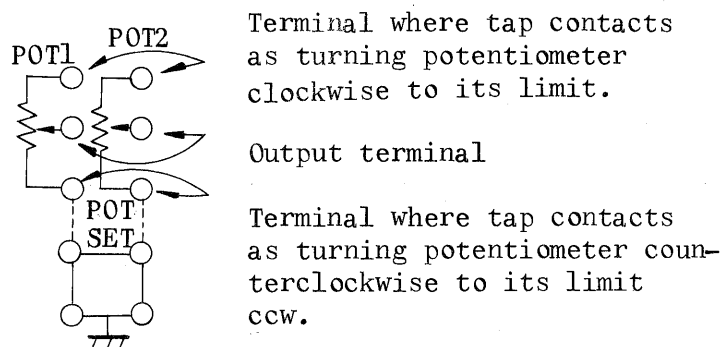


Fig. 2-6

2.4.2 1 turning type potentiometer

POT1 and 2 are 1 turn potentiometers and are free at both ends. They are used for setting multiplication constants or for setting initial values, or used as a variable free impedance.

Resistance is 100 K Ω .

Setting precision $\pm 0.4\%$.

The corresponding patch board is shown in Fig. 2-6.

o In the case of setting multiplication constant or initial value

Put a short circuit plug in the part indicated with dotted lines in Fig. 2-6. Thus, one end will be grounded and it can be used for setting multiplication constant or initial value.

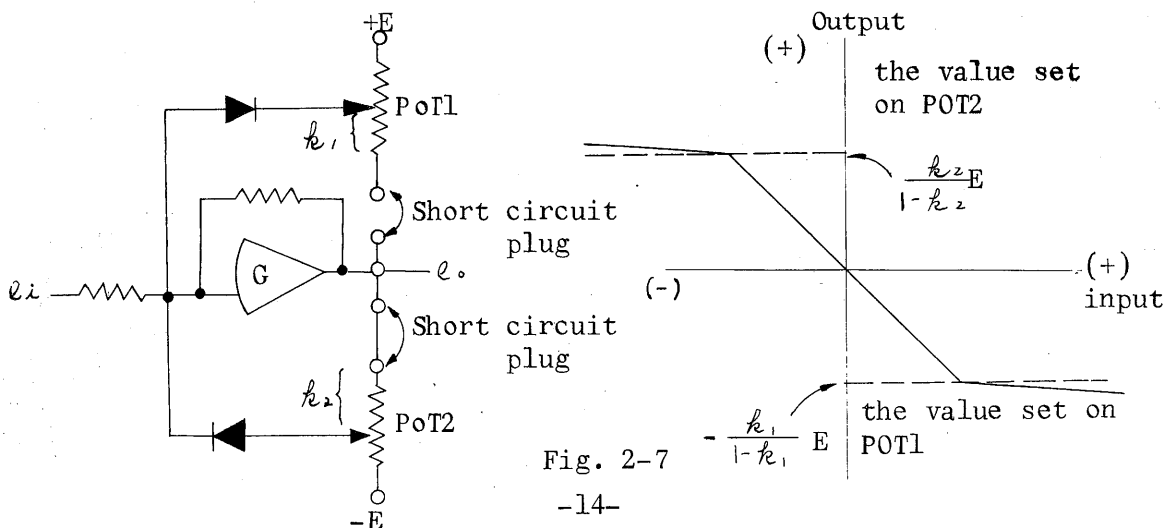
Since no dial is provided on the 1 turning potentiometer, a fine setting shall be made in combination with the reference potentiometer of the control board.

o Setting procedure (Refer to Fig. 2-7)

1. Insert the short circuiting plug (with patchboard down.).
 2. Set the patch plate at "SET" condition (with patch board up).
 3. Select the POT No. with "POT SELECT" on the output selecting panel.
 4. Place the control switch on the control panel to "POT SET".
 5. Set the reference potentiometer (REFERENCE POT) on the control panel to a desired value.
 6. Watching the meter at the center of control panel, turn the POT to be set and get zero indication (at center).
- (The setting described above can be carried out with the others left patched).

In case of variable free impedance

It can be used as a 0-100 K Ω variable operational resistor between the moving contact and the other terminal with both ends left free. The figure below illustrates an example of use.



1 turn potentiometer setting principle

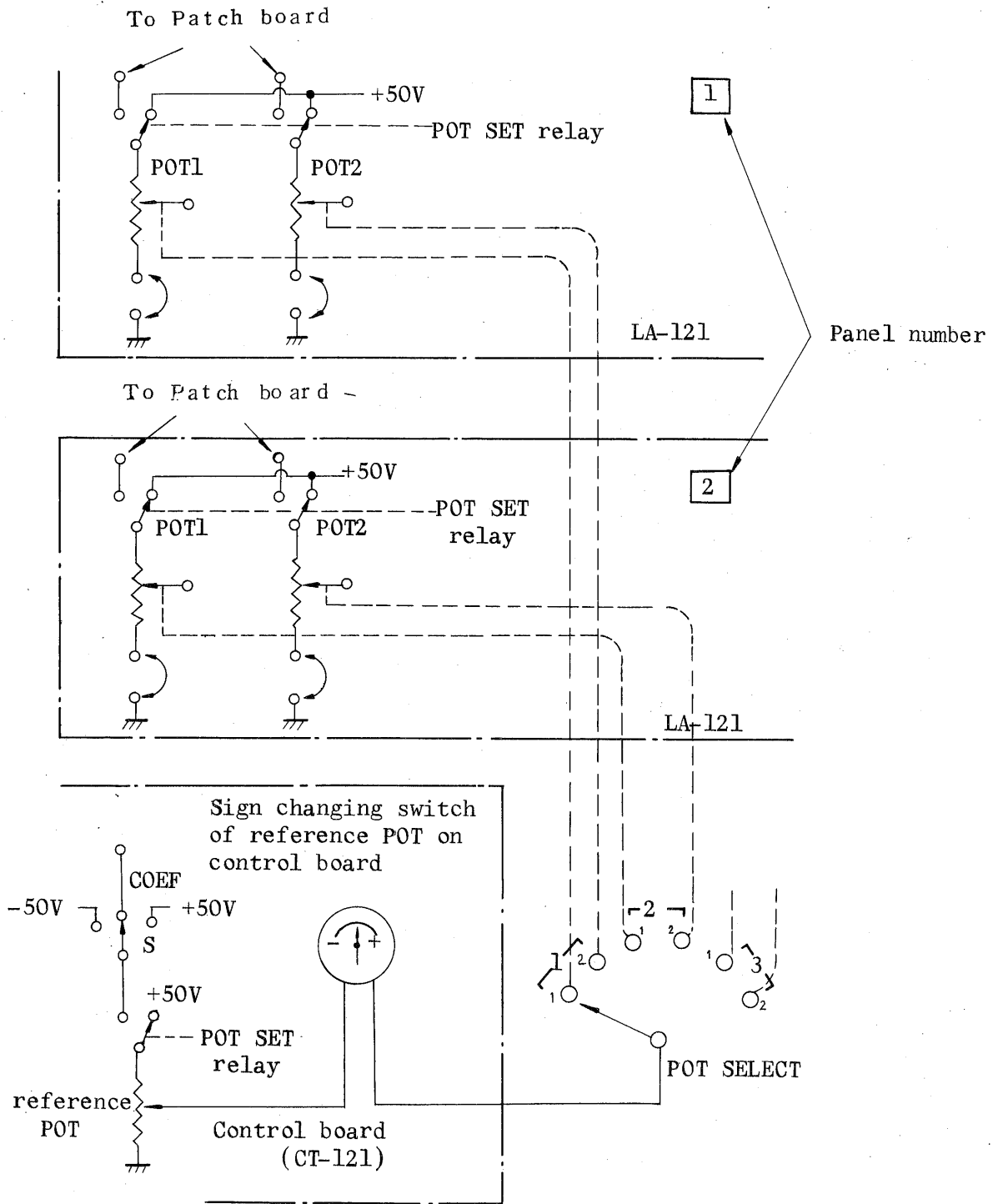
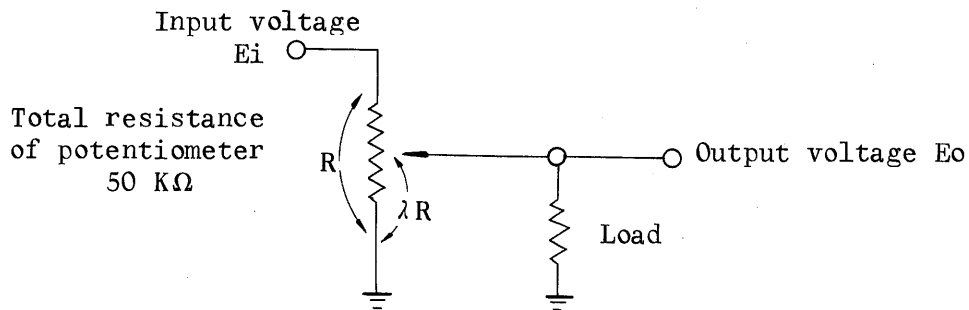


Fig. 2-7

- o Positioning the MODE switch of the control board to POT SET, +50V is automatically applied to POT 1 and POT 2 on the linear panel.
- o Follow the procedure described below in setting POT 1 at 0.15.
 - (i) By POT SELECT switch, select POT 1 now desired.
 - (ii) Set the desired value 0.15 on REFERENCE POT of the control board.
 - (iii) Turn POT 1 to get the zero indication on the volt meter on the control board.

2.4.3 Compensation for the effect of 10 turning potentiometer loading

Always when used with impedance load at the output terminals, a potentiometer is, in general, affected by the effect of loading. Therefore, this loading effect must be considered on setting a value on a potentiometer. Illustration below shows an example of setting a certain voltage. How to get the division ratio K with the load R_L left connected is as follows:



λ is an apparent division ratio;
 i.e. the dial setting value to
 get the desired value K with R_L
 left connected.

R_L is 100 K Ω when the potentiometer concerned is connected to be initial value setting terminal of integrator.

R_L is 100 K Ω when it is connected to the ten input terminals of various kinds of amplifiers of 1 M Ω when it is connected to one input terminal of an amplifier.

Referring to the above illustration, a desired division ratio K will be expressed as follows.

$$K = \frac{E_o}{E_i} = \frac{\lambda}{1 + \lambda (1 - \lambda) \frac{R}{R_L}} \text{ --- (1)}$$

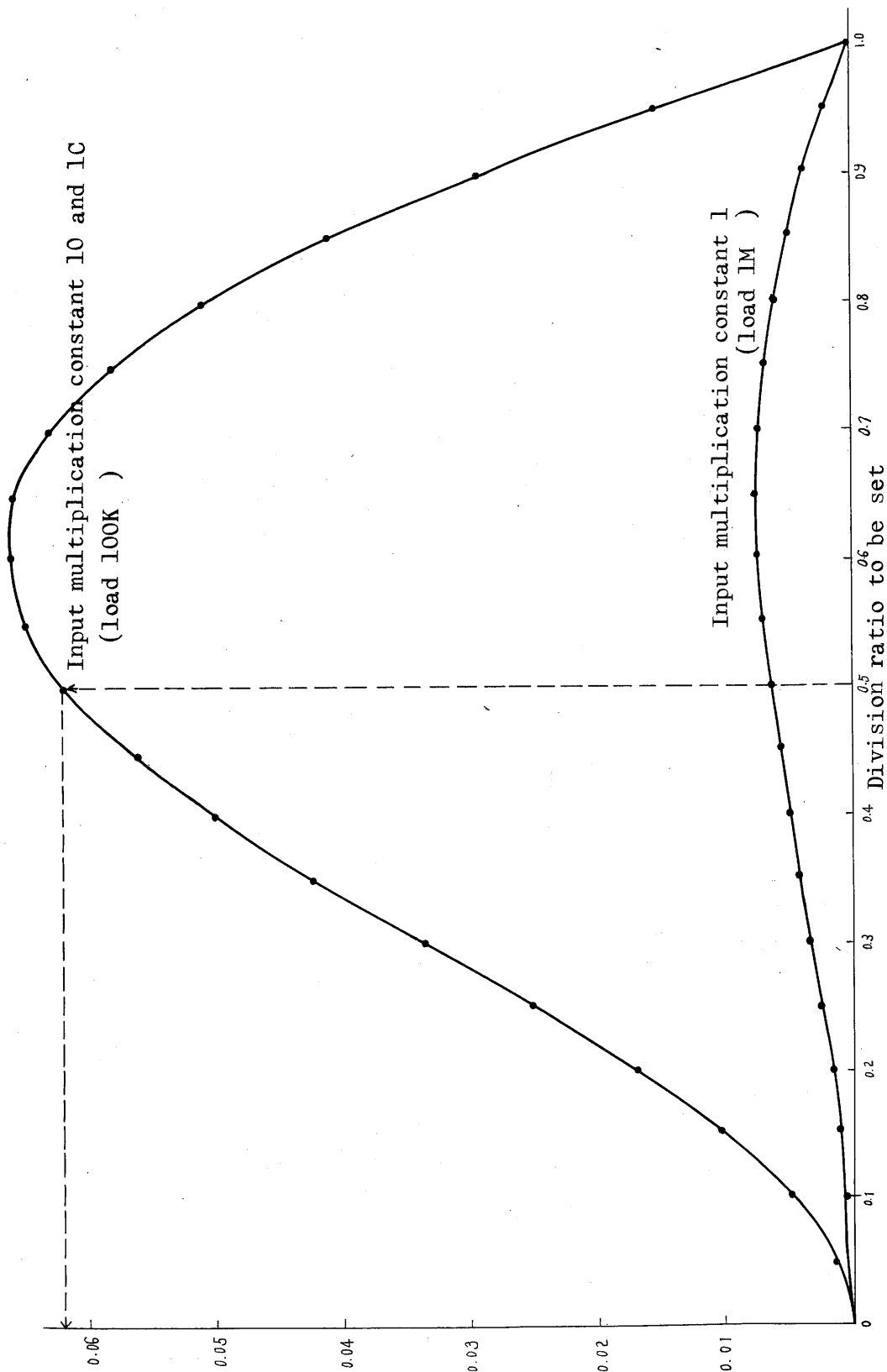
From equation (1), the apparent division ratio λ , that is, the value to be set on a dial which includes compensation to get K , will be

$$\lambda = \frac{-(1-aK) + (1-aK)^2 + 4aK^2}{2aK} \text{ --- (2)}$$

where, $a = \frac{R}{R_L}$

Fig. 2-8 shows the relation of the difference between the desired division ratio K and the apparent division ratio on the vertical axis and the desired division ratio K on horizontal axis for $R = 50 \text{ K}\Omega$ and $R_L = 100 \text{ K}\Omega$, $R_L = 1 \text{ M}\Omega$ in equation (2).

Thus, the value $(\lambda - K)$ should be set on the dial for compensation.



(Value to be set on potentiometer dial) = (Division ratio to be set) + (Compensation value got from this chart)

Example of compensation:
 Now, assume to get division of 0.5 with load 100 K . Compensation value 0.062 is obtained from the curve as is shown with dotted lines. So set the potentiometer dial to

$$0.5 + 0.062 = 0.562$$

← Value to be compensated
 (Value to be set on dial for compensation)

Fig. 2-8. Compensation curve for potentiometer

2.5 Auxiliary operational impedance

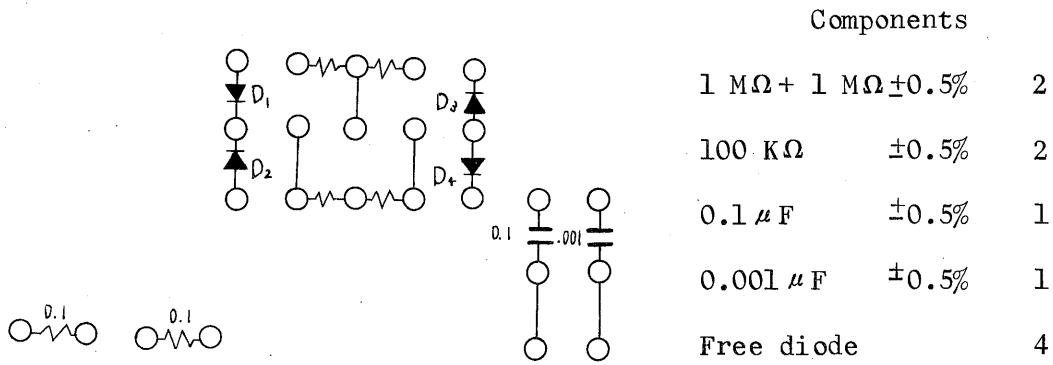


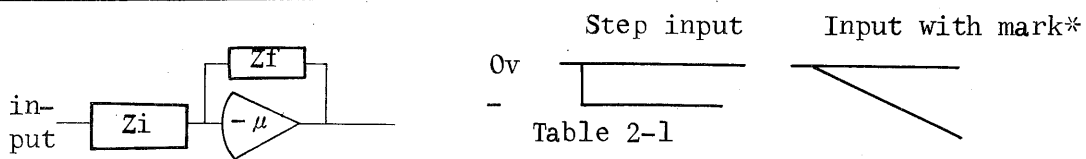
Fig. 2-9

The auxiliary operational impedance is employed as an auxiliary impedance for linear components and can be also employed as a component for saturation or dead space (special nonlinear component). As for the special nonlinear component, an explanation will be made in section 2.6.

Transfer functions are shown in Table 2-1, with some impedances used as their elements.

Table of transfer functions

	Zi	Zf	Transfer function	Indicial response	Remarks
1			$-\frac{1}{TP}$ $T = CR$		Integration
2			$-\frac{K}{1+TP}$ $K = \frac{R2}{R1}$ $T = CR2$		Incomplete integration
3			$-K(1 + \frac{1}{TP})$ $K = \frac{R2}{R1}$ $T = CR2$		Proportion integration
4			$-TR$ $T = CR$		Differentiation
5			$-\frac{KTP}{1+TP}$ $K = \frac{R2}{R1}$ $T = CR1$		Incomplete differentiation
6			$K = \frac{R2}{R1}$ $T = CR1$		
7			$\left(\frac{1+T2P}{1+T1P}\right)$ $K = \frac{C}{C}$ $T1 = C1R1$ $T2 = C2R2$		
8			$-\frac{T2P}{(1+T2P)(1+T1P)}$ $K = \frac{R2}{R1}$ $T1 = C1R1$ $T2 = C2R2$		
9			$-K(1 + \frac{1}{T2P})(1+T1P)$ $K = \frac{R2}{R1}$ $T2 = C2R2$ $T1 = C1R1$		



2.6 Special nonlinear component

Circuit elements to be used with this component are equipped in the linear panel LA-121. For the operational amplifier, the universal operation amplifier on the linear panel should be applied as a rule.

2.6.1 Dead space characteristics

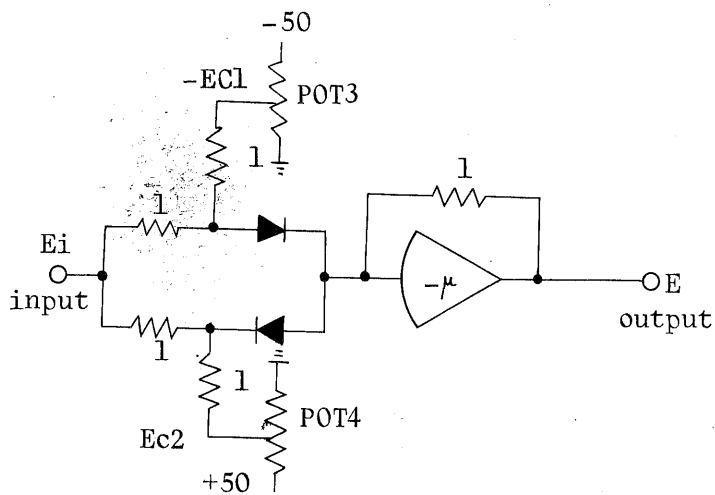
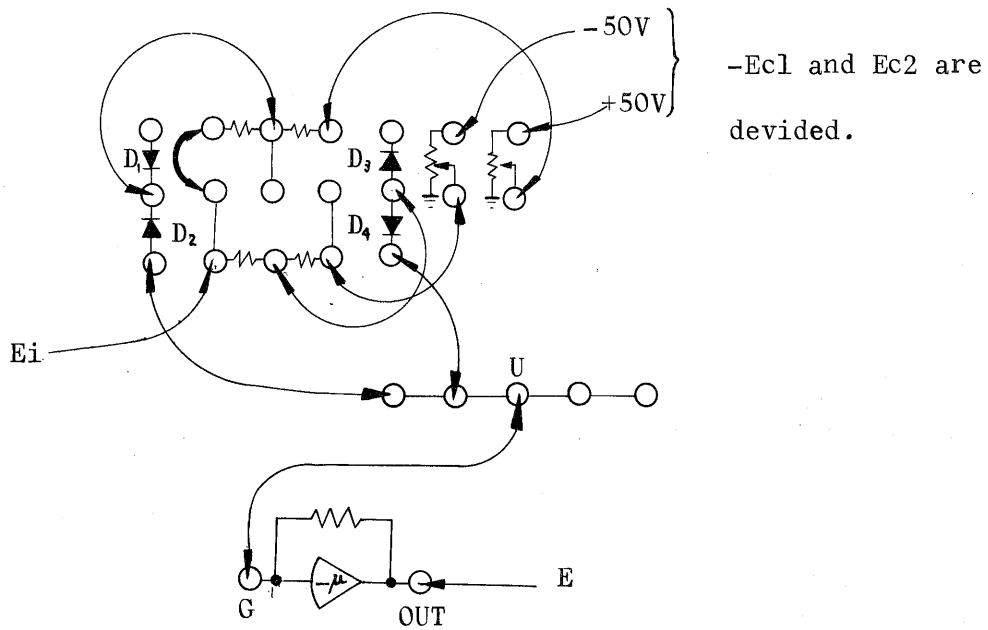


Fig. 2-11

Input signal	Output signal
$(E_i - E_{c1}) > 0$	exist
$(E_i - E_{c1}) < 0$	non exist
$(E_{c2} - E_i) > 0$	non exist
$(E_{c2} - E_i) < 0$	exist

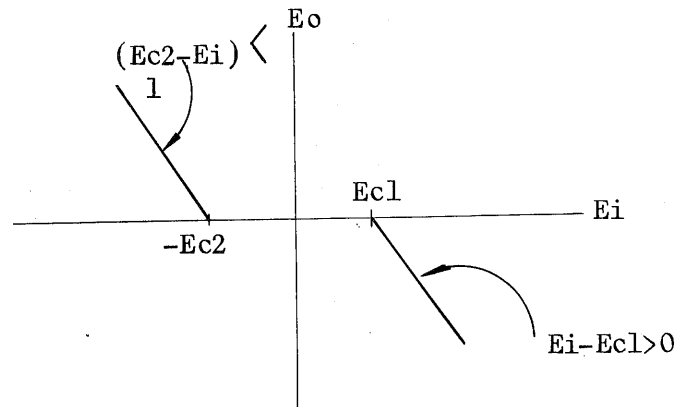


Fig. 2-12

2.6.2 Saturation characteristics

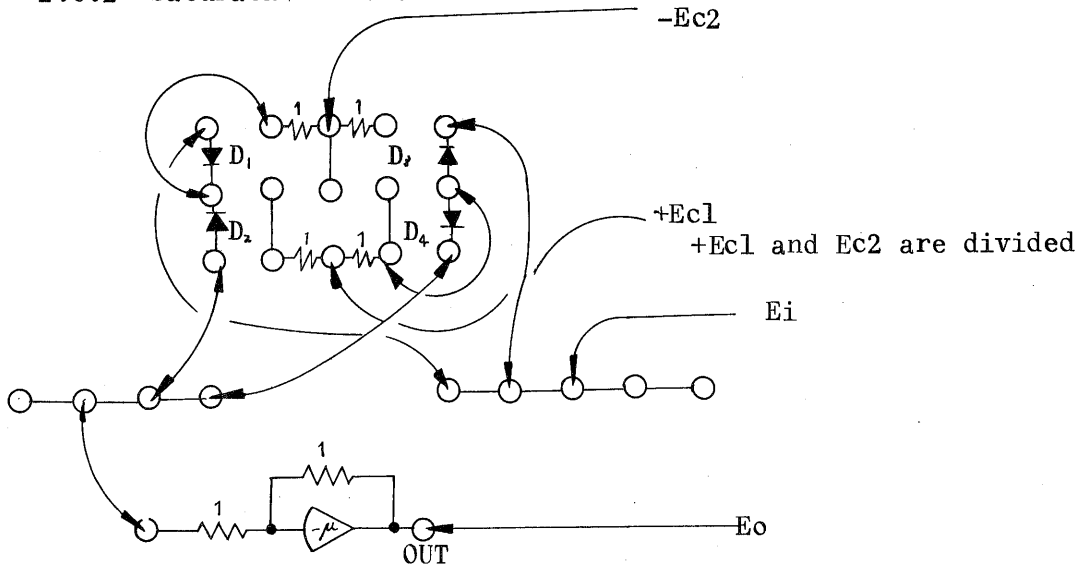


Fig. 2-13

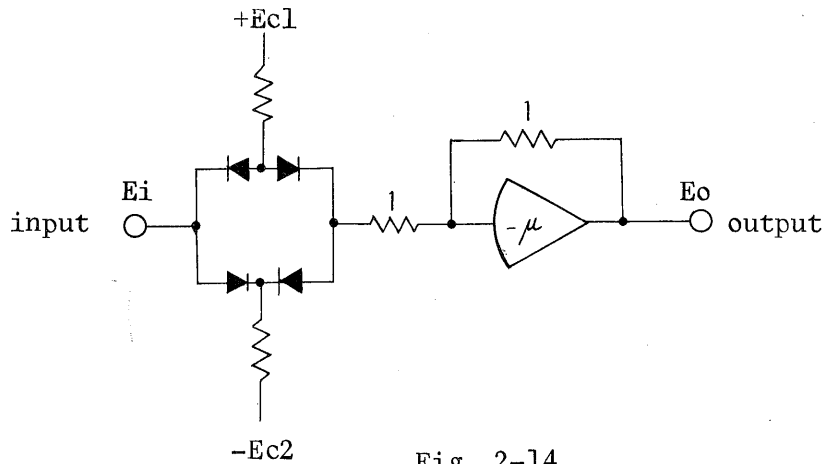


Fig. 2-14

Input signal Output signal

$$E_i > \frac{E_{c1}}{2}$$

Constant

$$-\frac{1}{2}E_{c2} < E_i < \frac{1}{2}E_{c1}$$

Variable

$$E_i < -\frac{1}{2}E_{c2}$$

Constant

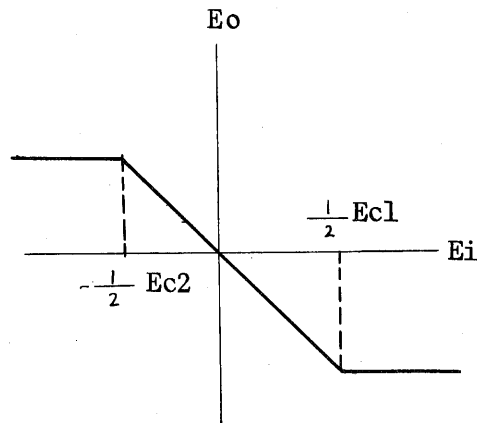
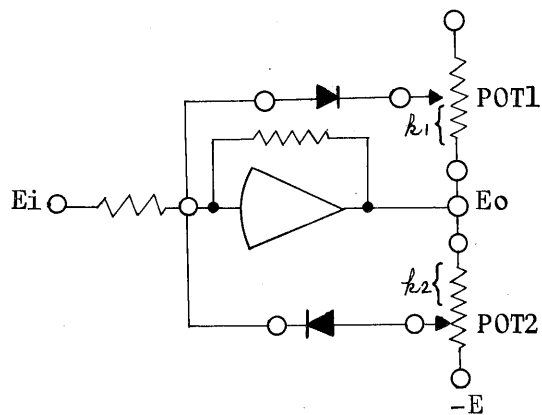
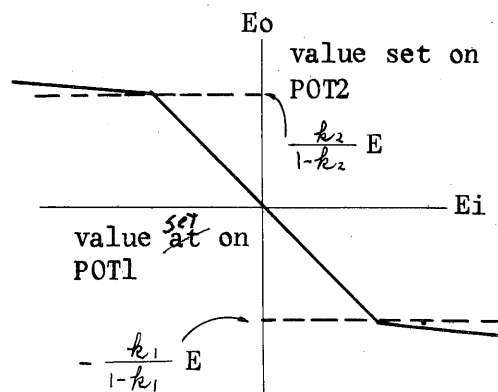


Fig. 2-15

o Simplified saturation characteristics (Refer to Fig. 2-16 (b))



Programming on patch board



Slant due to the resistance component of POT

o Hysteresis characteristic (Refer to Fig. 2-16(b))

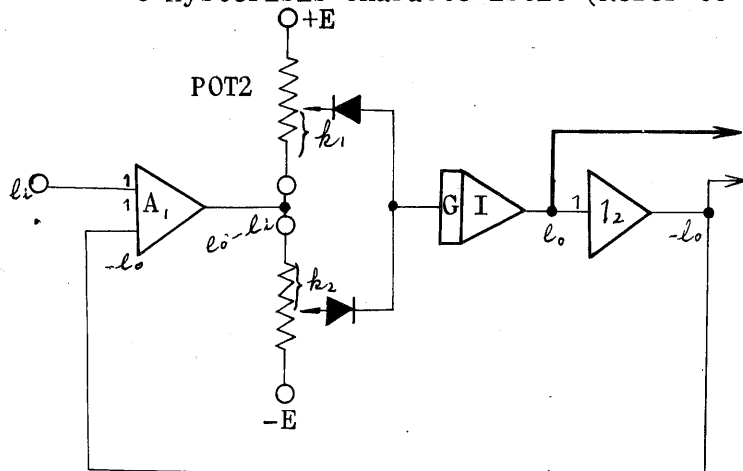
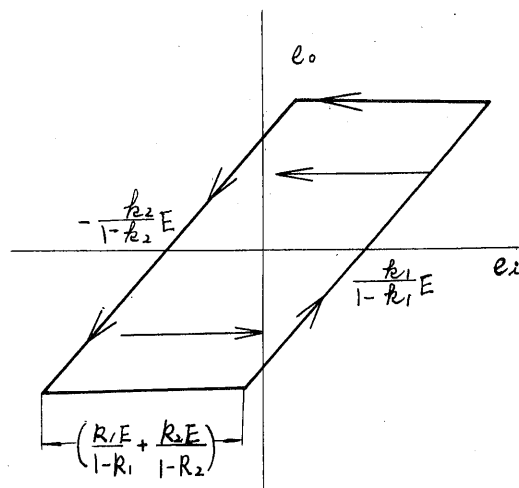


Fig. 2-16



2.7 Multiple junctions (common tiepoints)

The pattern representing multiple junctions (common tiepoints) is shown in Fig. 2-17. These junctions are connected to each other behind the pre-patch board, electrically independent from the other parts.

These junctions are used for the relaying of a patch or to connect several leads to one point in programming.

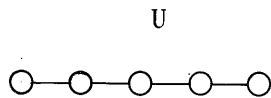


Fig. 2-17

3. Nonlinear panel NA-122

3.1 General

The nonlinear panel NA-122 is equipped with one diode function generating element, one multiplier/divider, one voltage comparator and two inverters or universal operational amplifiers. Two universal operational amplifiers are required for a diode function generator, and one or two inverters for a multiplier/divider. For these cases, this panel does not have enough number of operational amplifiers. So, employ the amplifiers in the linear panel for these purposes.

The Adjustment of levels of operational amplifiers is done in the same way as for panel LA-121.

Here also the Number of each control knob corresponds to the Number of the neon lamp.

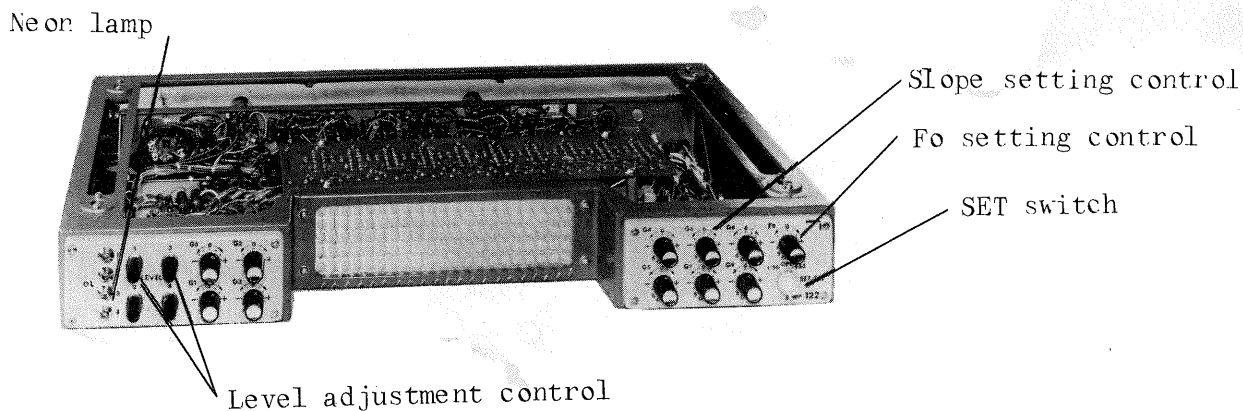


Fig. 3-1 Outside view of nonlinear panel

Non-linear panel NA-122	—	Diode function generating element	1
		Multiplier/divider	1
		Voltage comparator	1
		Inverter or universal operational amplifier	2

3.2 Diode Function Generator (DFG)

The diode function generator approximates any desired function with ten linear segments. The slope of every segment varies continuously within $\pm 5V$, and the level of function output varies within $\pm 50V$. The setting of the voltage at each break point is accomplished with a group of terminals arranged in two rows at the top of the nonlinear patch board. (Refer to Fig. 3-3)

At these terminals, the voltage is divided in increment of 5 volt from 0 to 50 volts.

o Basic patch for diode function generator

1. Patch the two universal operational amplifiers using the amplifiers in this panel or linear panel. (Refer to Fig. 3-2)

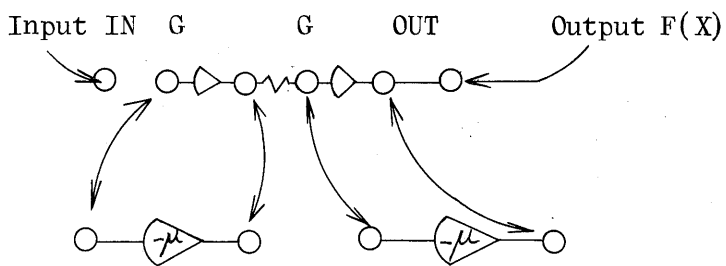


Fig. 3-2

2. Carry out the patch to set the voltage of each break point.

(Refer to Fig. 3-3)

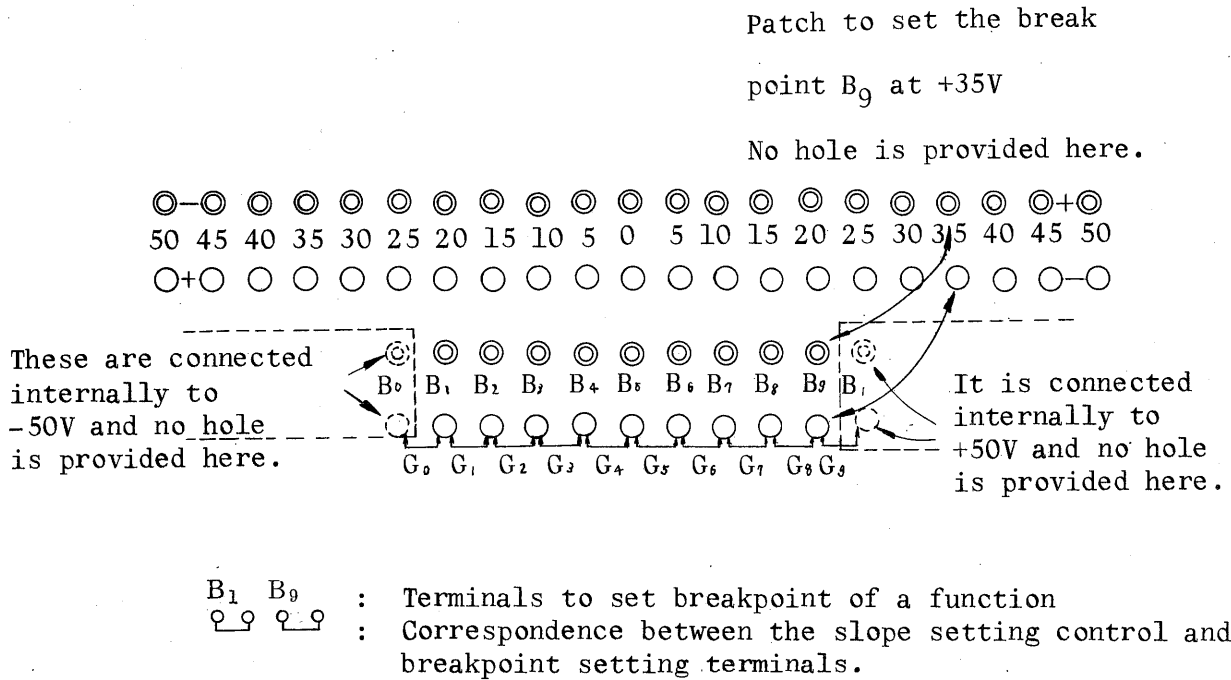
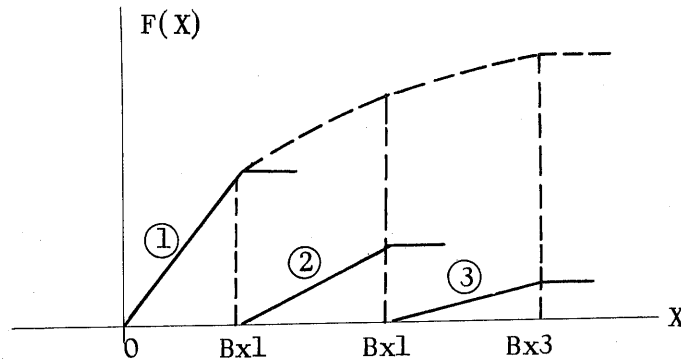


Fig. 3-3

This generator employs the method of summing up proper trapezoidal wave forms to get an approximation for an arbitrary function as illustrated below. So it is necessary to set the rising point, saturating point and the slope between the points. For example, in order to set the linear section ② in the illustration below, the rising point B_{x1} , saturating point B_{x2} (this is, at the same time, the rising point for ③) and the slope G are required.

Now, the rising point of ③ is necessarily determined when the saturating point B_{x2} of ② is set. Therefore, only the slope G and the rising point B_{x1} (an inflection point of the function) will do to set one linear section.

The reason terminals Bi SET VOLT and B₁ through B₉ in Fig. 3-3 are paired with the marks \odot is for the purpose of setting both the rising point and the saturating point of a line segment at a time.



To set this generator, use ①- ② listed below.

- ① Variable resistor to set slope

Variable resistors G0 through G9 to set slopes are used to set slopes independently within ± 5 .

- ② Variable resistor to set F_0

It is used to shift the approximated function level up and down within $\pm 50V$.

- ③ SET SW (Refer to illustration below)

+50V When the slope of which X axis (input) ranges 0 through +50V is set.

OPE Position here at the time of operation after the setting is completed.

-50V When the slope of which X axis (input) ranges 0 through -50V is set.

OPE



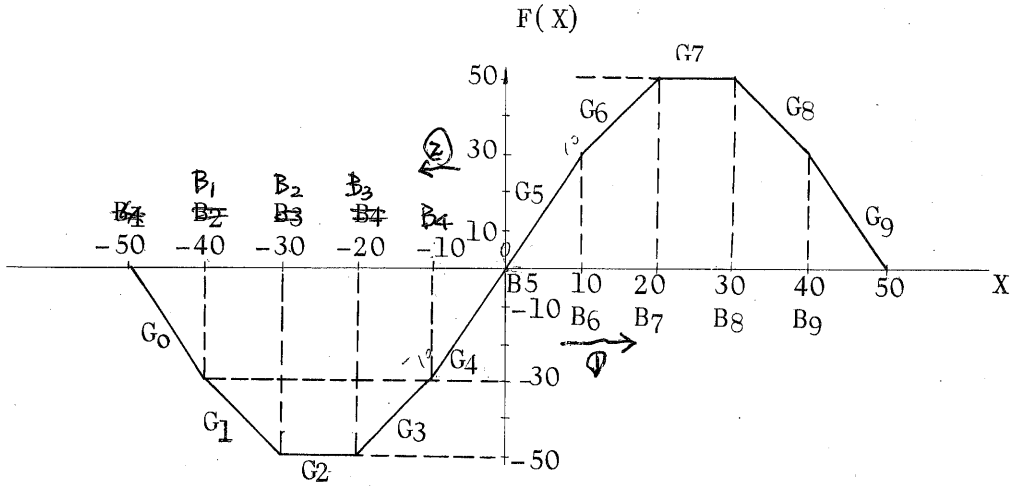
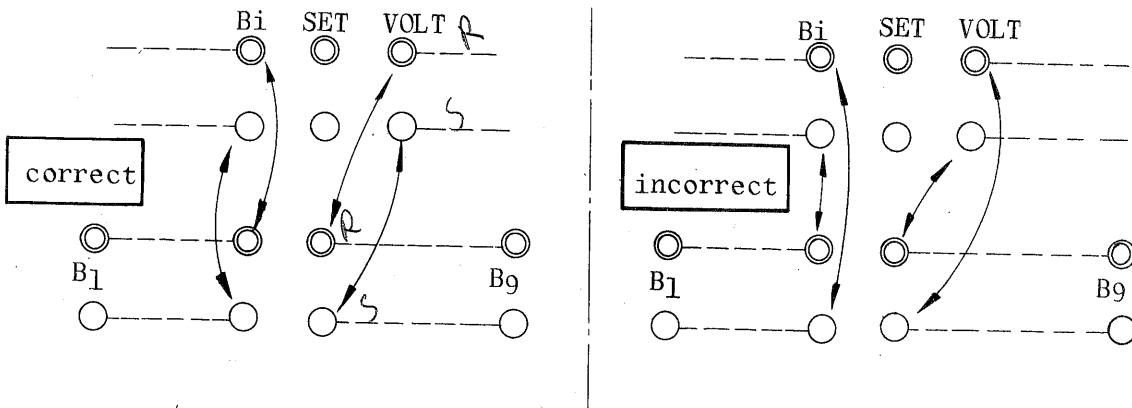


Fig. 3-4

Now, consider the setting of the wave form shown in Fig. 3-4. First, patch the necessary voltages from Bi SET VOLT on the top of the patch board to every inflection point setting holes B_1 through B_9 on the patch board (the voltages on X axis in Fig. 3-4).

The patch should be performed for every pair of B_i SET VOLT and B_1 through B_9 paired and indicated with the mark \odot



Connect the holes of B_1 through B_9 to their corresponding B_i SET VOLT a same mark \odot or \circ as illustrated above on the left-hand side. If they are reversed as in the example on the right-hand side, the function pattern desired will not be obtained.

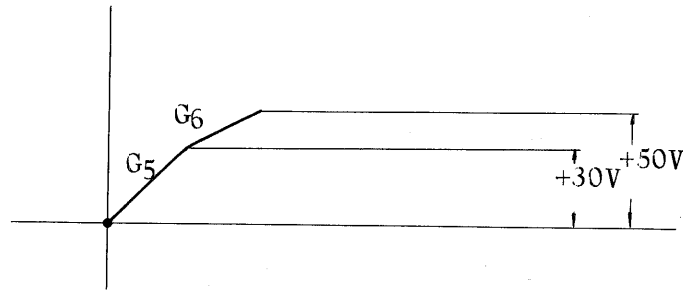
Attention should be taken in the fact that the relations between inflection points B_1 through B_9 and slopes setting controls are as shown in Fig. 3-4. In Fig. 3-4, an example with B_5 at zero is shown, of which function output exists on both sides of X axis i.e. +side and -side of X axis.

However, anyone of B_1 through B_9 can be taken at zero voltage and the wave will then exist only on + side (the 1st and 4th quadrants) or on -side (the 2nd and 3rd quadrants).

3. Setting of function value

After the patching is completed according to the procedures described in para. 2, set the values of G_0 through G_9 and F_0 . At first, turn all the controls of G_0 through G_9 and F_0 counter-clockwise to their limits till the switches attached to them are operated.

- i) Select the output of the output amplifier of the function generator by the AMP SELECT switch. Set the voltmeter on the control board in 50V range.
- ii) Position the "SET SW" switch on the right bottom of this panel at +50.
- iii) Turn (clockwise) from zero position the control for setting the slope of the first linear segment G_5 which lies on the right side (+side of X axis), until the voltmeter points at +30V, the final voltage of this segment.



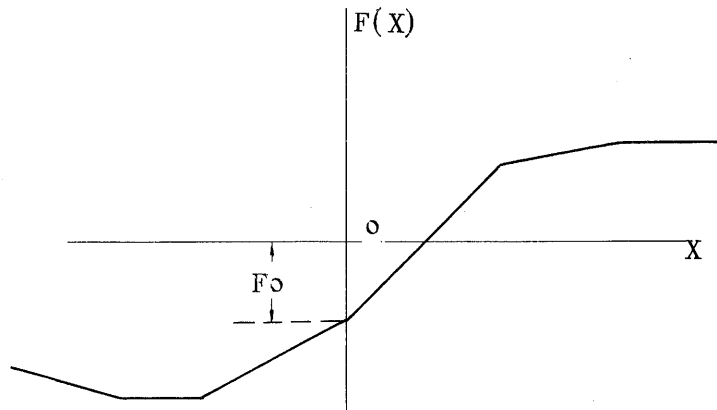
iv) After the setting described above is completed, set G_6 . Turn the control of G_6 clockwise till the final voltage of this linear segment +50V is obtained. Set for G_7 at +50V, G_8 at +30V and G_9 at +0V in the same way. Setting for segments on the left-hand side of zero (-side of X axis) will be carried out after those of +side are finished.

v) When all the settings for side segments are completed, position the "SET SW" switch at -50V and set G_4 (-30V), G_3 (-50V), G_2 (-50V), G_1 (-30V), and G_0 (0V) in the same way as the +side.

vi) Thus the desired function form is set.

When the function has some value $F(X_0) = F_0$ at zero input, position the "SET SW" switch at OPE and (after checking zero input) set the F_0 control to get the output voltage of F_0 .

(Refer to the illustration below.)



4. Example of setting a function

As an example, a setting of a function illustrated in Fig. 3-4 will be explained.

First of all carry out the basic patch shown in Fig. 3-2. Combining trapezoidal wave forms 1 through 10, the overall pattern shown with dotted line in Fig. 3-5 will be obtained for this function.

(Among trapezoidal wave forms, that of zero slope is also included.)

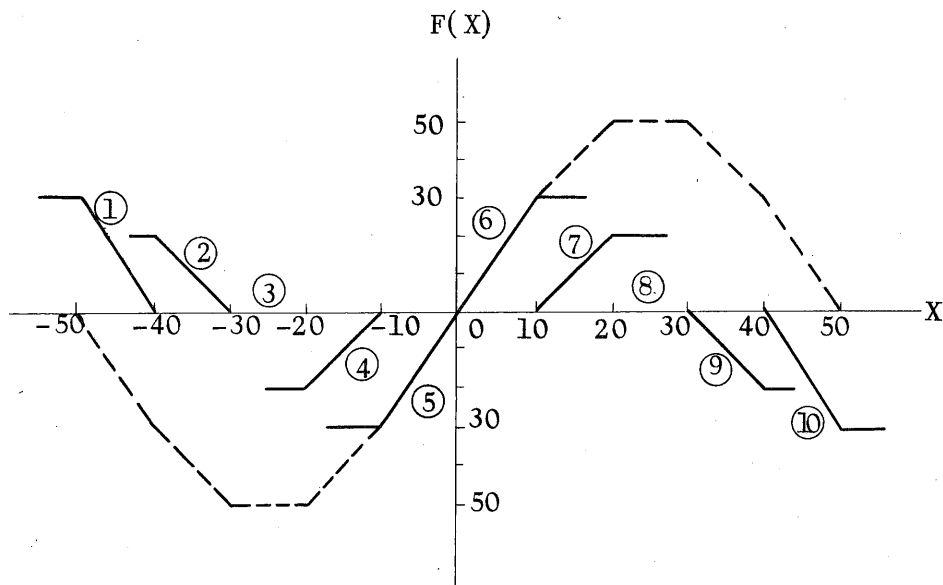


Fig. 3-5

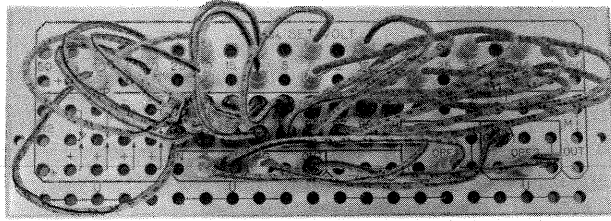


Fig. 3-6

Decide which one of B_1 through B_9 is set at zero of X axis. Placing this point to the center, carry out the setting procedures for + side and - side respectively. The patched condition for this function is shown in Fig. 3-6.

Here the voltages shown in Fig. 3-4 are patched for the break points B_1 through B_9 .

- i) Turn all the controls G_0 through G_9 and F_0 counter-clockwise to their limits until the switches are operated and the white marks on the controls stop at OFF.
- ii) On a voltmeter, check the output of output amplifier of function generator selected with the AMP SELECT switch.
- iii) Set the voltmeter in 50V range.
- iv) Position the "SET SW" switch located at the right-hand side below this panel at +50V side. Starting from the linear segment ⑥ in the right-hand side of X axis the setting is

made in the order of ⑦ - ⑨ as shown in Fig. 3-5.

First, turn the control for G_5 clockwise until the voltmeter indicates +30V, the final voltage of the linear segment G_5 in Fig. 3-4. Thus the setting for G_5 is achieved.

- v) Turn G_6 clockwise until the voltmeter indicates +50V, the final value of the linear segment G_6 .
- vi) Turn G_7 clockwise until the voltmeter indicates +50V, the final value of the linear segment G_7 .
- vii) Turn G_8 clockwise until the voltmeter indicates +30V, the final value of the linear segment G_8 .
- viii) Turn G_9 clockwise until the voltmeter indicates 0V, the final value of the linear segment G_9 .

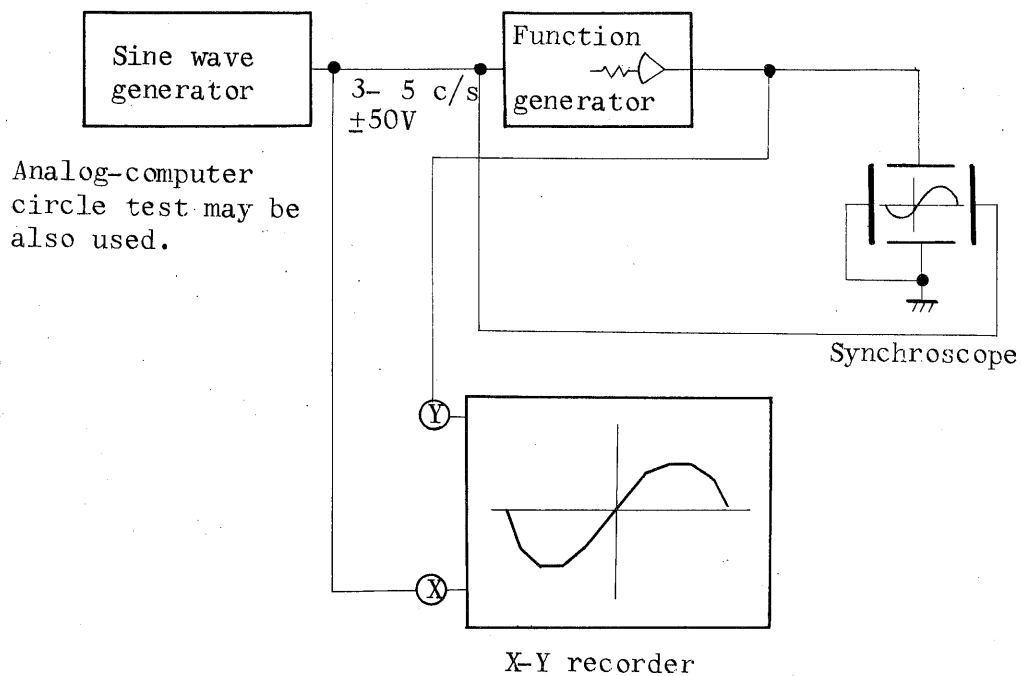
Thus the settings for the +side of X axis is completed.

- ix) Position the "SET SW" at -50V side.
- x) Turn G_4 clockwise until the voltmeter indicates -30V, the final value of the linear segment G_4 .
- xi) Turn G_3 clockwise until the voltmeter indicates -50V, the final value of the linear segment G_3 ,
- xii) Turn G_2 clockwise until the voltmeter indicates -50V, the final value of the linear segment G_2 .
- xiii) Turn G_1 clockwise until the voltmeter indicates -30V, the final value of the linear segment G_1 .
- xiv) Turn G_0 clockwise until the voltmeter indicates 0V, the final value of the linear segment G_0 .

xv) Position the "SET SW" at OPE again

When the wave form shown in Fig. 3-4 has some value F_0 at zero input after the step xv) is followed, set the input to function generator at zero and turn the control F_0 clockwise till the voltmeter indicates the value F_0 .

The wave form thus set may be checked by observation of the visual pattern of input/output on the phase plane. The connection for this is shown in Fig. 3-7.



The oscillation frequency is most favourably 0.1 c/s when the X-Y recorder is used.

Fig. 3-7

3.3 Multiplier/divider (MULT or DIV)

This multiplier/divider employs quarter-square system on the basis of approximate square characteristics produced by a diode function generator.

As this multiplier-divider includes an operational amplifier (amplifier No.1) in itself, it will do well as desired without any inverter when four kinds of inputs $\pm X$ and $\pm Y$ are employed.

It requires, however, two inverters when only two kinds of inputs X and Y are used for operation. In this case, use the components of this panel as inverters as shown in Fig. 3-9. (When these of this panel are used as the other operational amplifiers, use those in the linear panel LA-121.)

o Use as a multiplier (with 4 inputs $+X, -X, +Y, -Y$) (Fig.3-8)

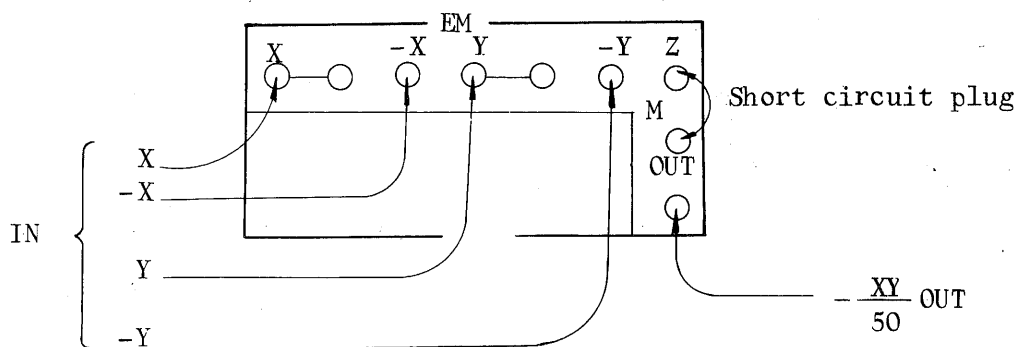


Fig. 3-8

The input impedance for any one of $X, -X, Y$ and $-Y$ is about $100\text{ K}\Omega$. So it is required that the output impedances for these signals should be low enough as compared with these of input's.

o Use as a multiplier (with 2 inputs X, Y)

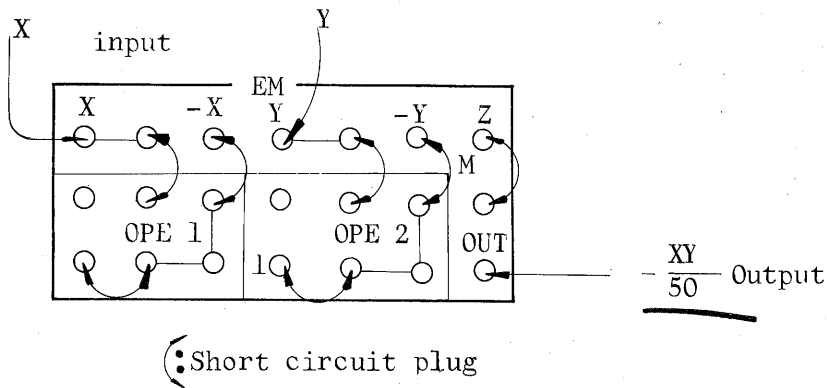


Fig. 3-9

As the input impedance for X or Y is about 100 KΩ, it is required that the output impedance for every signal should be low enough as compared with these of input's.

o Use as a divider

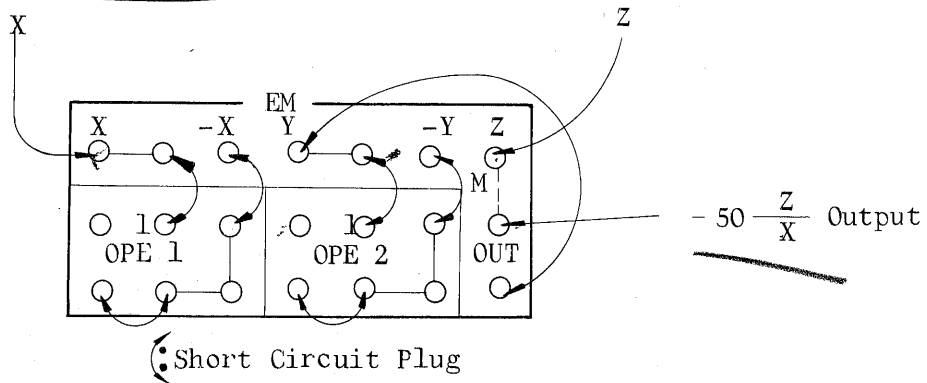


Fig. 3-10

Take off short circuit plugs indicated by in Fig. 3-9 and patch as shown in Fig. 3-10.

As the input impedance for Z is 1 MΩ, and the input impedance for

X is about $100\text{ K}\Omega$, it is required that the output impedance for X signal should be low enough as compared with these of input's.

Note for division

It is necessary that the input signals X, Z should meet the conditions described below at any moment; namely,

$$X > Z,$$

$$X > 0.$$

3.4 Voltage comparator (CP)

This voltage comparator is equipped with an operational amplifier (amplifier No.3), so it is easily handled.

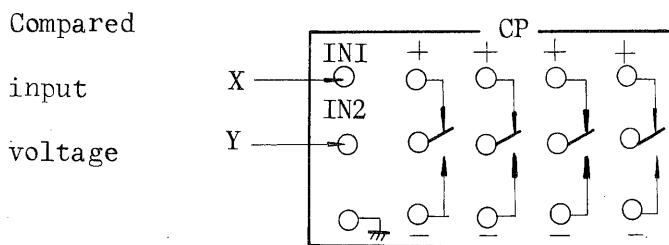


Fig. 3-11

It works when the total voltage at its input point is negative. Patch as shown in Fig. 3-11. Apply two kinds of voltage X and Y to be compared with to the input terminals of the voltage comparator. Then, if the total value of them is negative the voltage comparator will operate (relay turns to ON) and is changed over to ⊖ side.

Fig. 3-12 shows an example.

As shown in the illustration on the left-hand side, the voltage comparator operates and its relay contacts are changed to \ominus side, when IN1 is applied with \ominus and the IN2 is grounded.

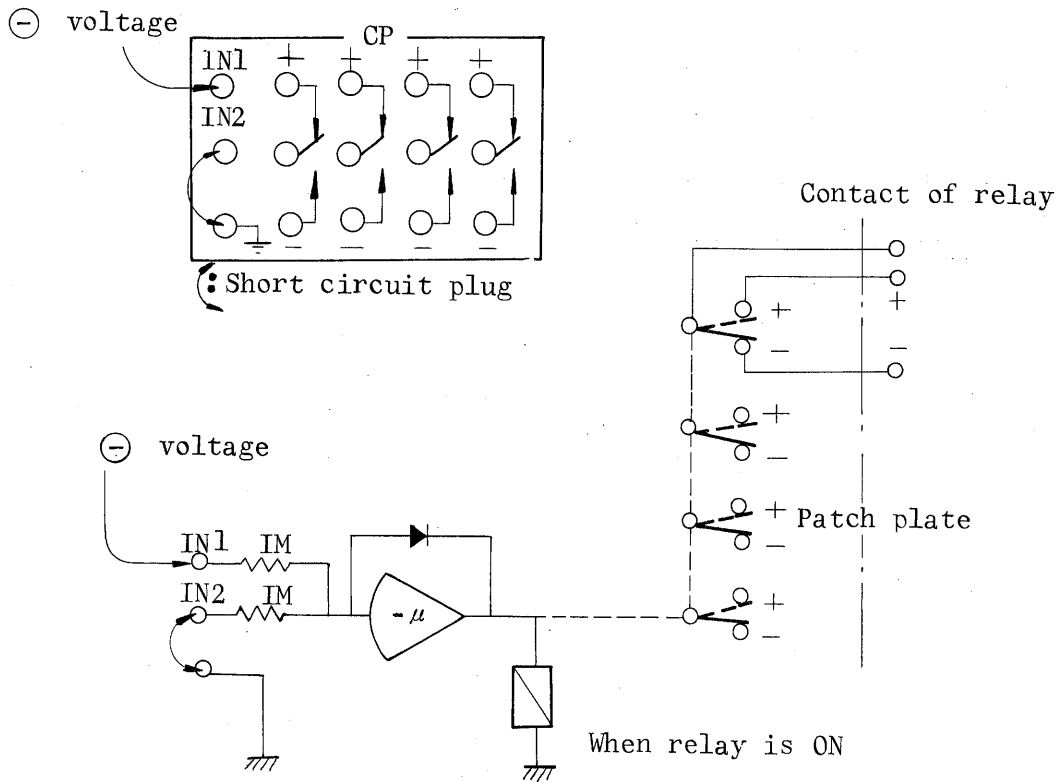


Fig. 3-12

3.5 Inverter or universal operation amplifier

It consists of amplifiers No.1 and No.2 and works as an inverter or universal operational amplifier by the patching procedure (putting in or pulling off of short circuit plugs).

It is usually used as an operational amplifier of nonlinear component. To connect this inverter to a multiplier-divider, patch by means of short circuit plugs. (Refer to Fig. 3-9 and Fig. 3-10)

o Used as an inverter

It can be used as an inverter with short circuit plugs inserted as shown below (Fig. 3-13) on the prepatch board. In this case of use, it is usually used for multiplier-divider.

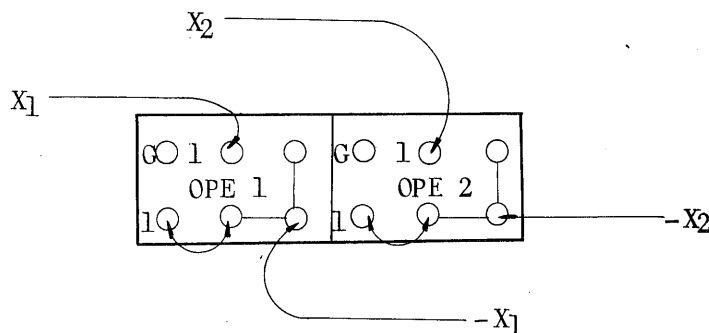


Fig. 3-13

o Usued as a universal operational amplifier

It is possible to use it as a high gain operational amplifier with "G, OUT" on the prepatch board made as the input and output and output as shown in Fig. 3-14.

It is usually used as a diode function generator when it is an operational amplifier.

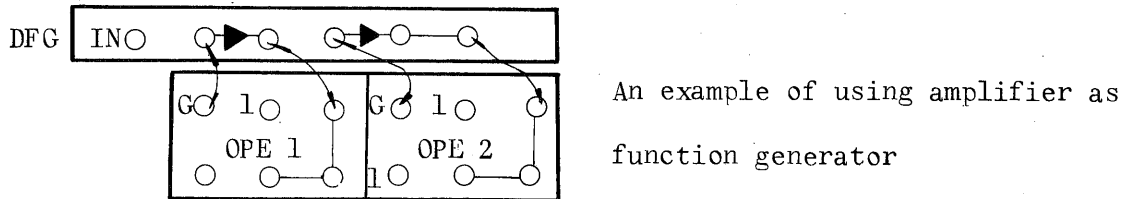


Fig. 3-14

4. Non-linear panel NA-121

4.1 General

The non-linear panel NA-121 is equipped with one diode function generating element, one multiplier/divider element and one voltage comparator element.

A diode function generator requires two universal operational amplifiers. A multiplier/divider also requires inverters and one operational is required. Therefore, the amplifiers on the linear panel LA-121 are employed for these purposes.

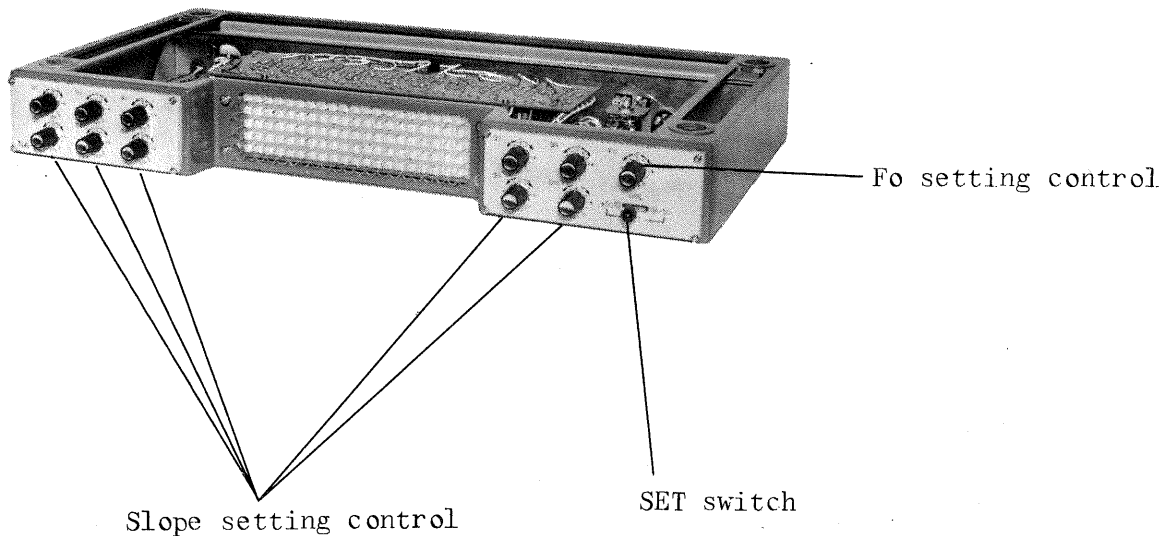


Fig. 4-1 Outside View of Nonlinear Panel NA-121

Non-linear panel NA-121	[	diode function generating element	1
		multiplier/divider element	1
		voltage comparator element	1

4.2 Diode Function Generator (DFG)

The diode function generator approximates any desired function with 10 linear segments. The slope of each segment varies continuously within $\pm 5V$ while the level of function output varies within 50V.

Settings of voltages for breakpoints are accomplished through a group

of terminals arranged in 2 rows at the top of non-linear patch board (Fig. 4-3). On these terminals, voltages ranging 0 to $\pm 50V$, are provided for use in setting the voltages at breakpoints at every 5 volt step.

o Basic patch for diode function generator

1. Patch the two universal operational amplifiers by use of amplifiers in the linear panel (Fig. 4-2).

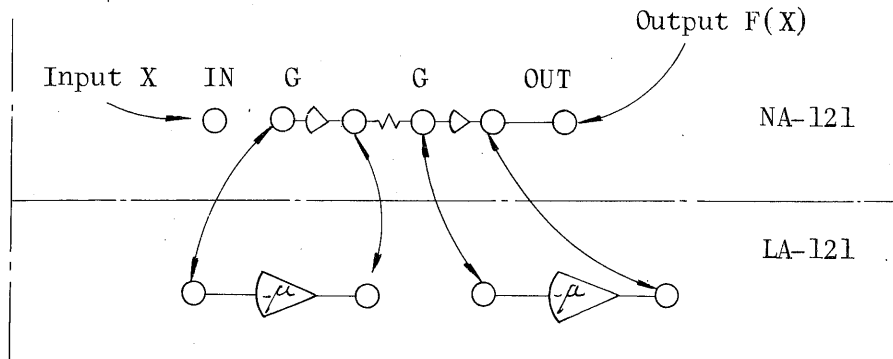
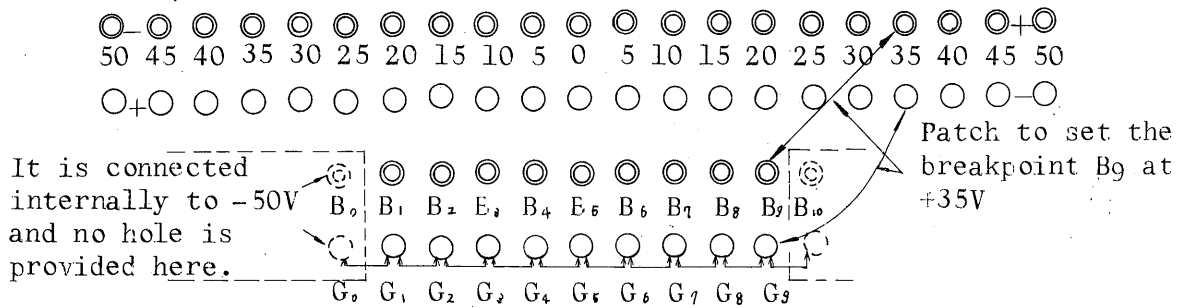


Fig. 4-2

2. Carry out the patch for setting voltages at each breakpoint (Fig. 4-3).



- B_1-B_9 : Terminals to set breakpoints of function
- G_0-G_9 : Correspondence between slope setting control and breakpoint setting terminal

Fig. 4-3

This generator employs a method of summing up proper trapezoidal wave forms to get a desired shape of a function as illustrated in Fig. 4-4. Therefore, it is necessary to set the rising point, saturating point and the slope between them.

For example, to determine the linear section ② in the illustration below, the rising point Bx_1 , saturating point Bx_2 (this is, at the same time, the rising point for ③) and the slope G should be known. The rising point of ③ is necessarily determined when the saturating point Bx_2 of ② is set. Thus, only the slope of G and the rising point Bx_1 (an breakpoint of the function) are enough to set one linear section.

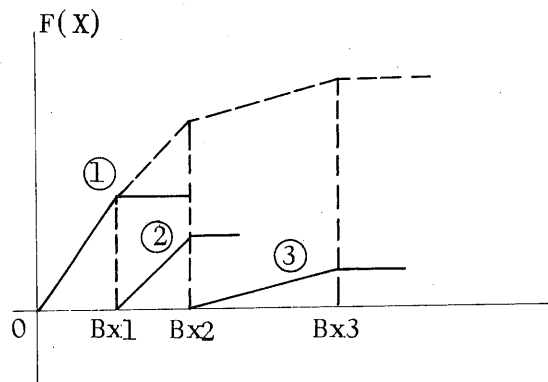


Fig. 4-4

That the terminals B_i SET VOLT and B_1 through B_9 in Fig. 4-3 are paired with the marks of ① is to set both the rising point and the saturating point of a linear segment at a time. The setting of this generator is made by using ① through ③ described below.

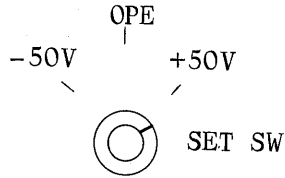
① Slope setting variable resistor

Slope setting variable resistors G_0 through G_9 are used to set slopes independently within ± 5 .

② Fo setting variable resistor

It is used to shift a diode function level up and down within $\pm 50V$ along the axis $F(x)$.

③ SET SW (Fig. 4-5)



+50V: Position for setting the slope of a segment when X axis (input) lies in the range of 0 to +50V.

OPE : Position for operation after the setting is completed.

-50V: Position for setting the slope of a segment when X axis (input) lies in the range of 0 to -50V.

Fig. 4-5

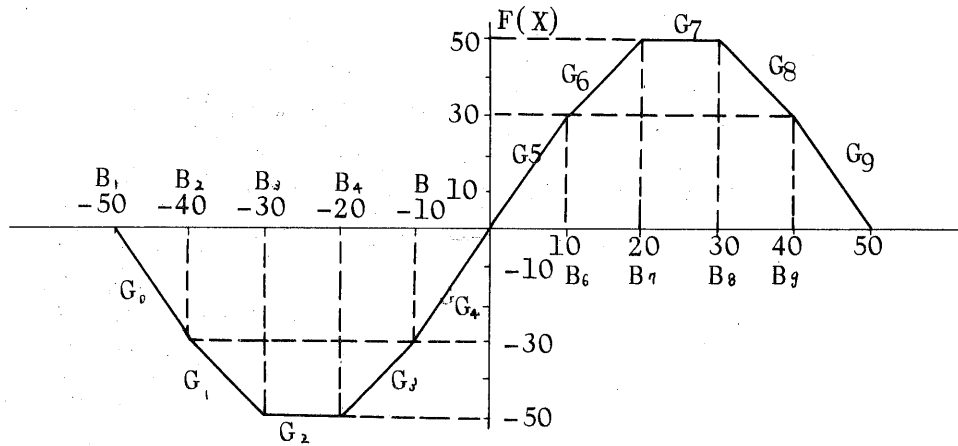


Fig. 4-6

Now, consider to set a wave form shown in Fig. 4-6. Patch the necessary voltages from the terminals B_i SET VOLT on the top of patch board to corresponding breakpoint setting terminals (holes) B_1 through B_9 on the

patch board. (Refer to the voltages on X axis in Fig. 4-6)

Patch for every pair. The terminals Bi SET VOLT and B₁ through B₉ are paired with the marks \odot or \circ labeled to the pair.

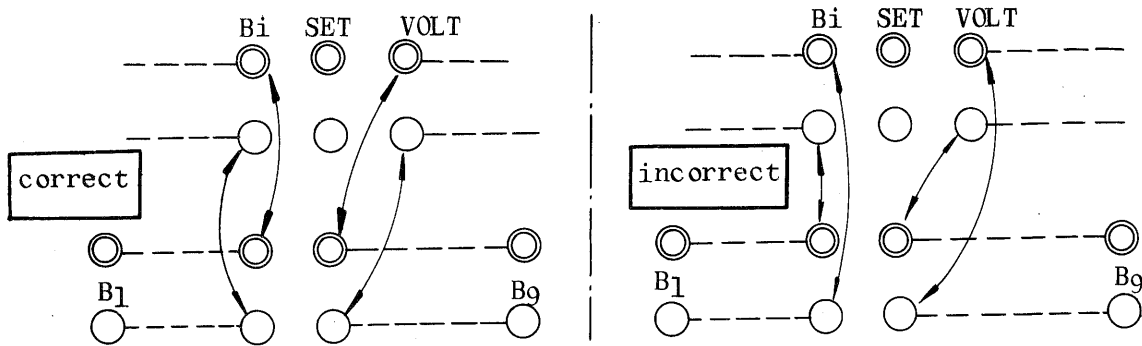


Fig. 4-7

Connect B₁ through B₉ to their respective Bi labeled with a same mark \odot or \circ as illustrated on the left-hand side of above Fig. 4-7. If they are reversed as in the illustration on the right-hand side, the function pattern desired will not be obtained.

Pay attention that the relations between each of breakpoints B₁ through B₉ and each of slope setting controls are as shown in Fig. 4-6. In Fig. 4-6, an example with B₅ set at zero is shown, of which function outputs exist on both sides, +side and -side of X axis.

However, by setting any of B₁ through B₉ at zero voltage, output can be made to exist only on +side, (the 1st and 4th quadrants) or on -side (the 2nd and 3rd quadrants).

3. Setting of function value

After the patching is completed according to the procedures described in para. 2, set the values of G₀ through G₉ and F₀.

At first, turn all controls of G₀ through G₉ and F₀ counter-clockwise to their limits till the switches combined to them are operated.

- i) Select an output of the output amplifier of the function generator with the AMP SELECT switch. Set the voltmeter on the control board in 50V range.
- ii) Position the "SET SW" switch on the right bottom of this panel at +50.
- iii) From zero position, turn (clockwise) the slope setting control for the first linear segment G_5 which lies on the right-hand side (+side of X axis) until the voltmeter points at +30V, the final voltage of this segment. (Fig. 4-8)

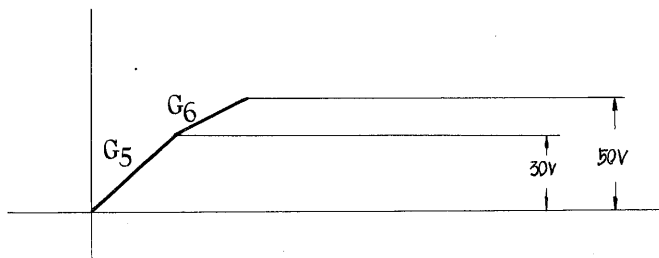


Fig. 4-9

- iv) After the setting described above is completed, set G_6 . Turn the control of G_6 clockwise till the final voltage of this linear segment, +50V, is obtained.
Set for G_7 , G_8 and G_9 in the same way. The settings for segments on the left-hand side from zero (the -side of X axis) will be carried out after those of +side have been finished.
- v) When all the settings for +side segments are completed, position the "SET SW" switch at -50V and set, one by one, G_4 , G_3 and G_0 in the same way as described for +side.

vi) Thus the desired function form is set.

When the function has some value $F(X_0) = F_0$ at zero input, position the "SET SW" switch at "OPE" and (after checking zero input) set the F_0 control so as to get the output voltage of F_0 .

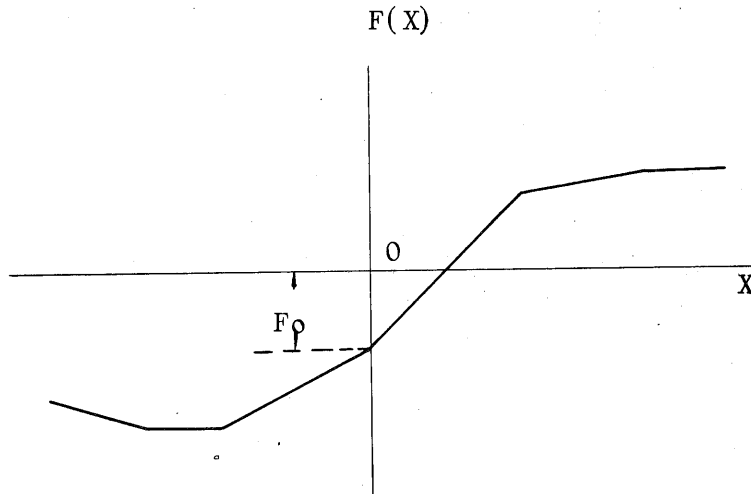


Fig. 4-9

4. An example of function setting

An example of function setting illustrated in Fig. 4-6 will be explained. First, carry out the basic patch shown in Fig. 3-2. Combining trapezoidal wave forms ① through ⑩, the overall pattern shown with dotted line in Fig. 4-10 will be obtained for this function. (Among trapezoidal wave forms is included that of zero slope's)

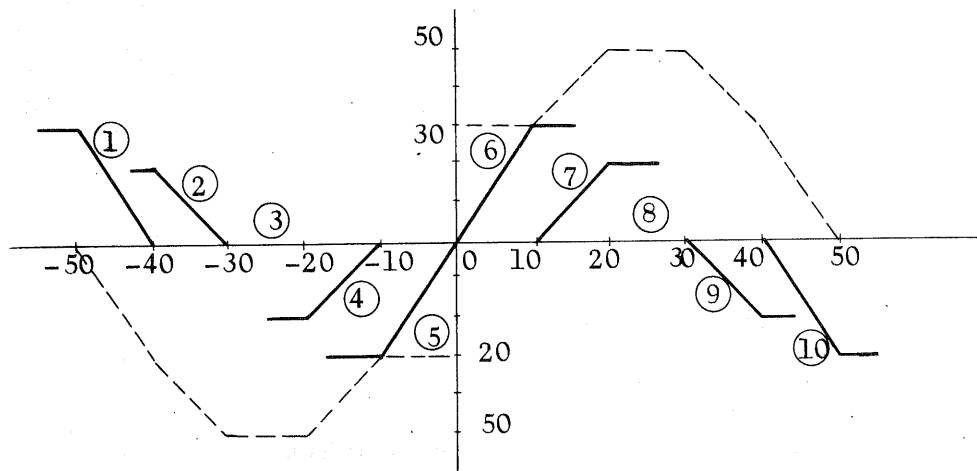
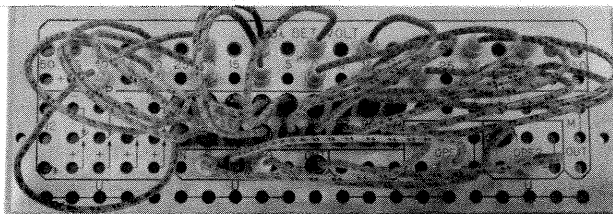


Fig. 4-10



Decide which one of B_1 through B_9 be at zero on the **X axis**. Placing the selected point at the center, carry out the setting procedures for +side and -side respectively.

Here the voltages shown in Fig. 4-6 are patched for the breakpoints B_1 through B_9 .

- i) Turn all the controls G_0 through G_9 and F_0 counter-clockwise to their limits, until their switches are operated and the white marks on controls indicate "OFF".
- ii) On a voltmeter, check the output of the output amplifier for function generator selected with the AMP SELECT switch.
- iii) Set the voltmeter in 50V range.
- iv) Position the "SET SW" switch located on the right-hand side below of this panel at +50V side. Set the linear segments, starting from ⑥ in the right-hand side of X axis toward ⑦ through ⑨ as shown in Fig. 4-8. In other words, turn, first, the control for G_5 clock-

wise until the voltmeter indicates +30V, the final voltage of the linear segment G_5 in Fig. 4-6. Thus the setting for G_5 is achieved.

- v) Turn G_6 clockwise until the voltmeter indicates +50V, the final value of the linear segment G_6 .
- vi) Turn G_7 clockwise until the voltmeter indicates +50V, the final value of the linear segment G_7 .
- vii) Turn G_8 clockwise until the voltmeter indicates +30V, the final value of the linear segment G_8 .
- viii) Turn G_9 clockwise until the voltmeter indicate 0V, the final value of the linear segment G_9 .

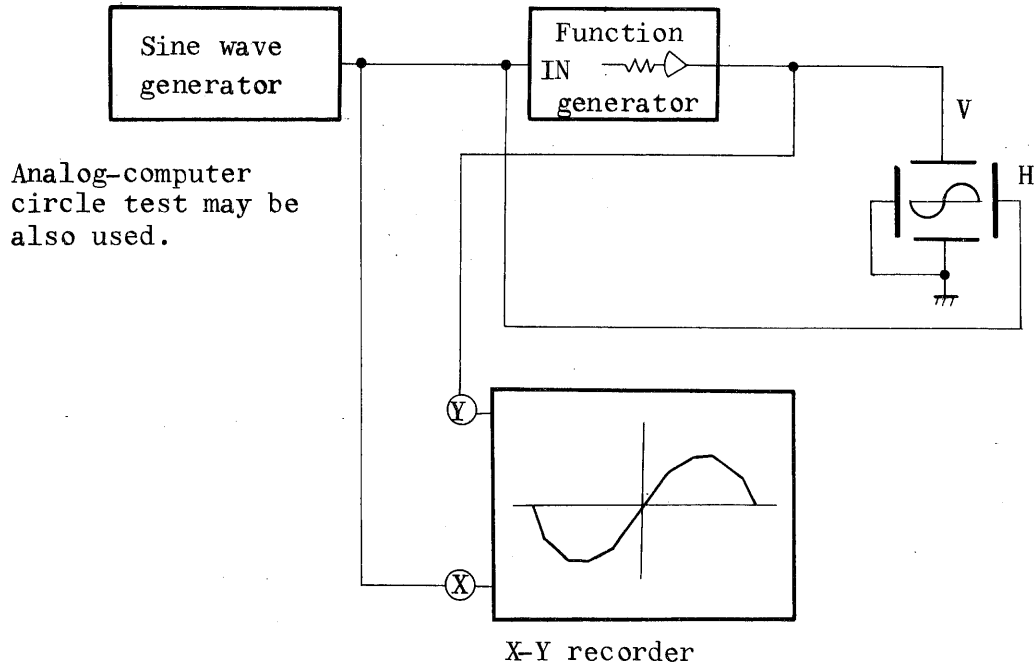
Thus the setting for the +side of X axis is completed.

- ix) Position the "SET SW" switch to -50V side.
- x) Turn G_4 clockwise until the voltmeter indicates -30V, the final value of the linear segment G_4 .
- xi) Turn G_3 clockwise until the voltmeter indicates -50V, the final value of the linear segment G_3 .
- xii) Turn G_2 clockwise until the voltmeter indicates -50V, the final value of the linear segment G_2 .
- xiii) Turn G_1 clockwise until the voltmeter indicates -30V, the final value of the linear segment G_1 .
- xiv) Turn G_0 clockwise until the voltmeter indicates 0V, the final value of the linear segment G_0 .
- xv) Position the "SET SW" at OPE again.

When the wave form shown in Fig. 3-4 has some value F_0 at zero input, set the input to function generator at zero after the step xv) and turn F_0 control clockwise until the voltmeter indicates the value F_0 .

Thus, the setting is completed.

The wave form thus set may be checked by observation of the visual pattern of input output on the phase plane. The connection for this is shown in Fig. 4-12.



0.1 c/s is the most preferable frequency of the oscillator when the X-Y recorder is used.

Fig. 4-12

4.3 Multiplier or divider (MULT OR DIV)

This multiplier-divider employs the quarter-squares system by realizing square characteristics with diode approximating function generator.

It requires one operational amplifier and two inverters to constitute a multiplier-divider. But, for four kinds of input $+X$, $-X$, $+Y$, $-Y$, it does two kinds of input X and Y are used for operation.

4.3.1 Use as a multiplier (with four inputs $+X$, $-X$, $+Y$, $-Y$) (Fig. 4-13)

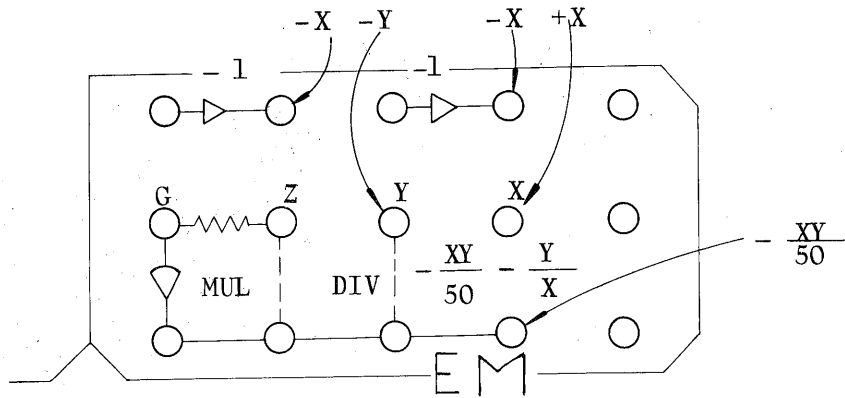
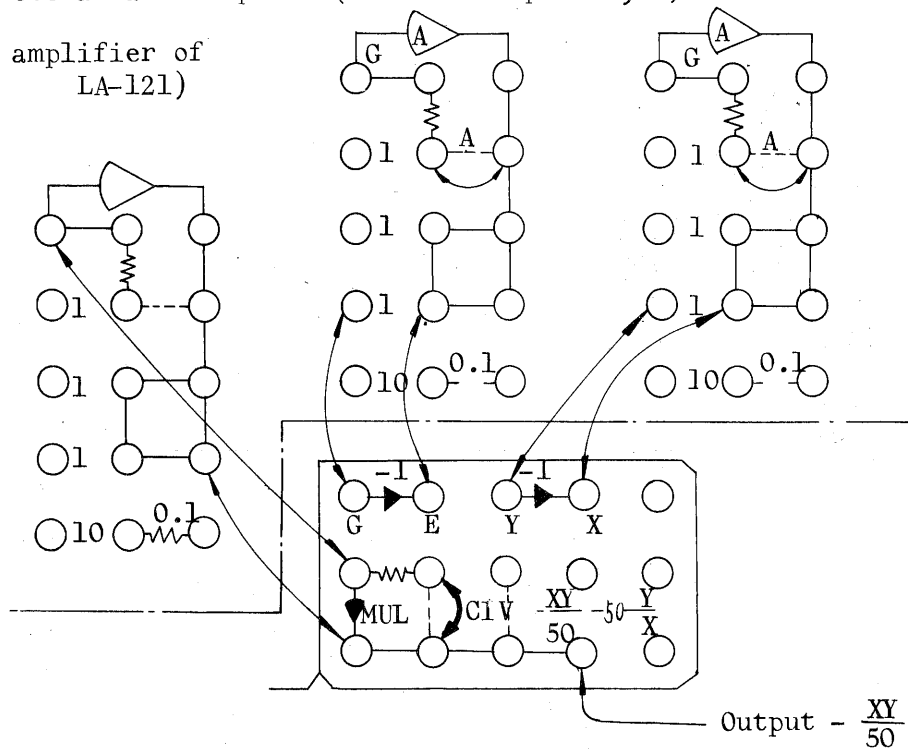


Fig. 4-13

As the input impedance of the multiplier is less than $100\text{ K}\Omega$, it is required that every output impedance for $\pm X$, $\pm Y$ should be low enough in comparison with the input impedance.

4.3.2 Use as a multiplier (with two inputs X, Y)

(Use amplifier of LA-121)



As the input impedance of the multiplier is less than $100\text{ K}\Omega$, it is required that every output impedance for X, Y should be low enough in comparison with them.

Fig. 4-14

4.3.3 Use as a divider

(Use amplifier of LA-121)

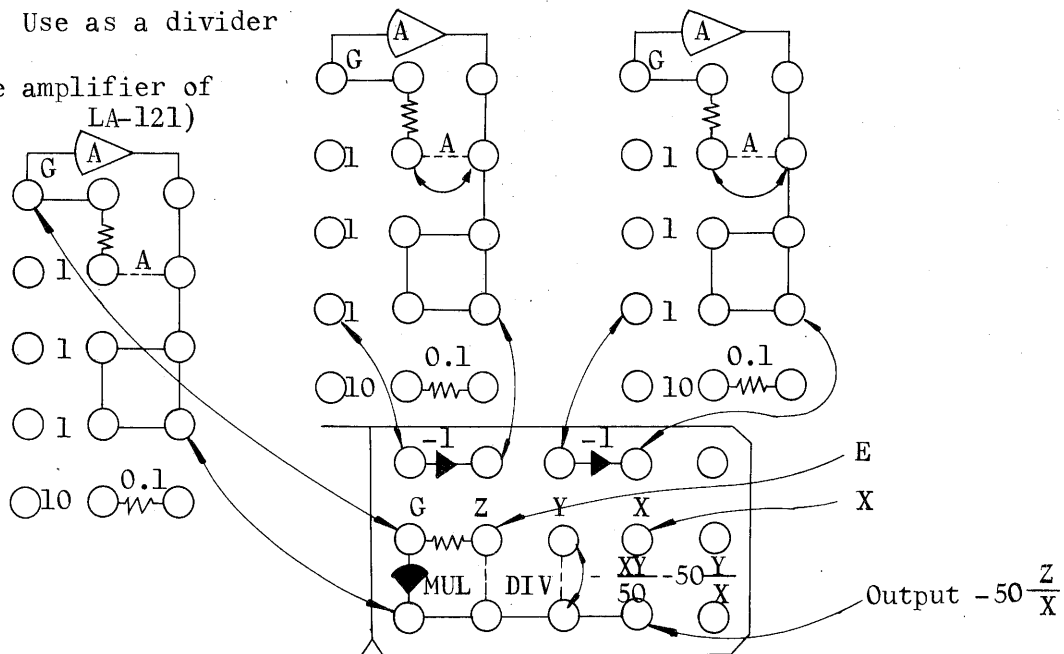


Fig. 4-15

5. Control board CT-121

5.1 General

The control board CT-121 contains a control panel and an output selecting panel. It is equipped with every device necessary for control, indication and selection. A power supply is also mounted in the rear of the case. Its outside view is shown in Fig. 5-1.

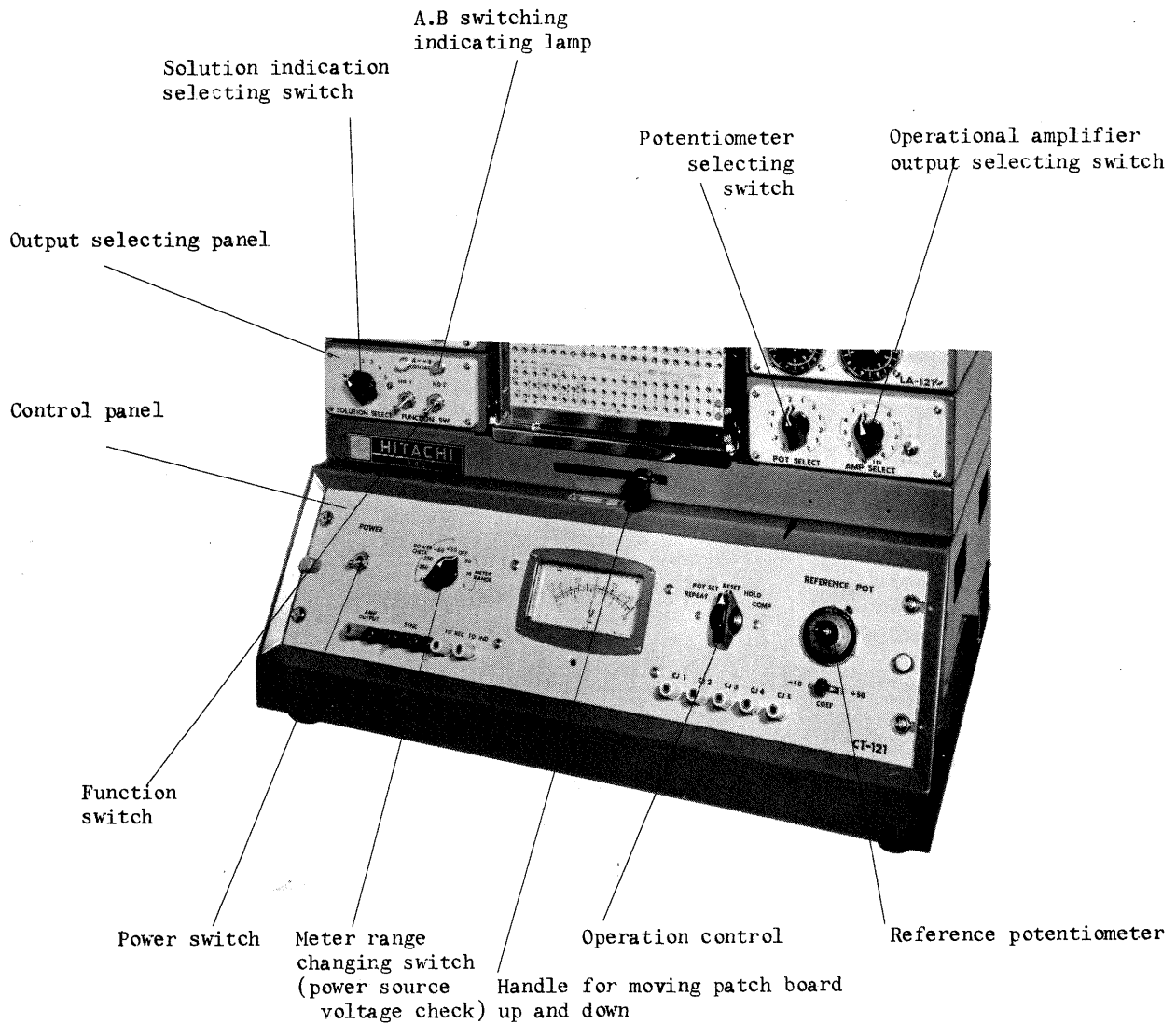
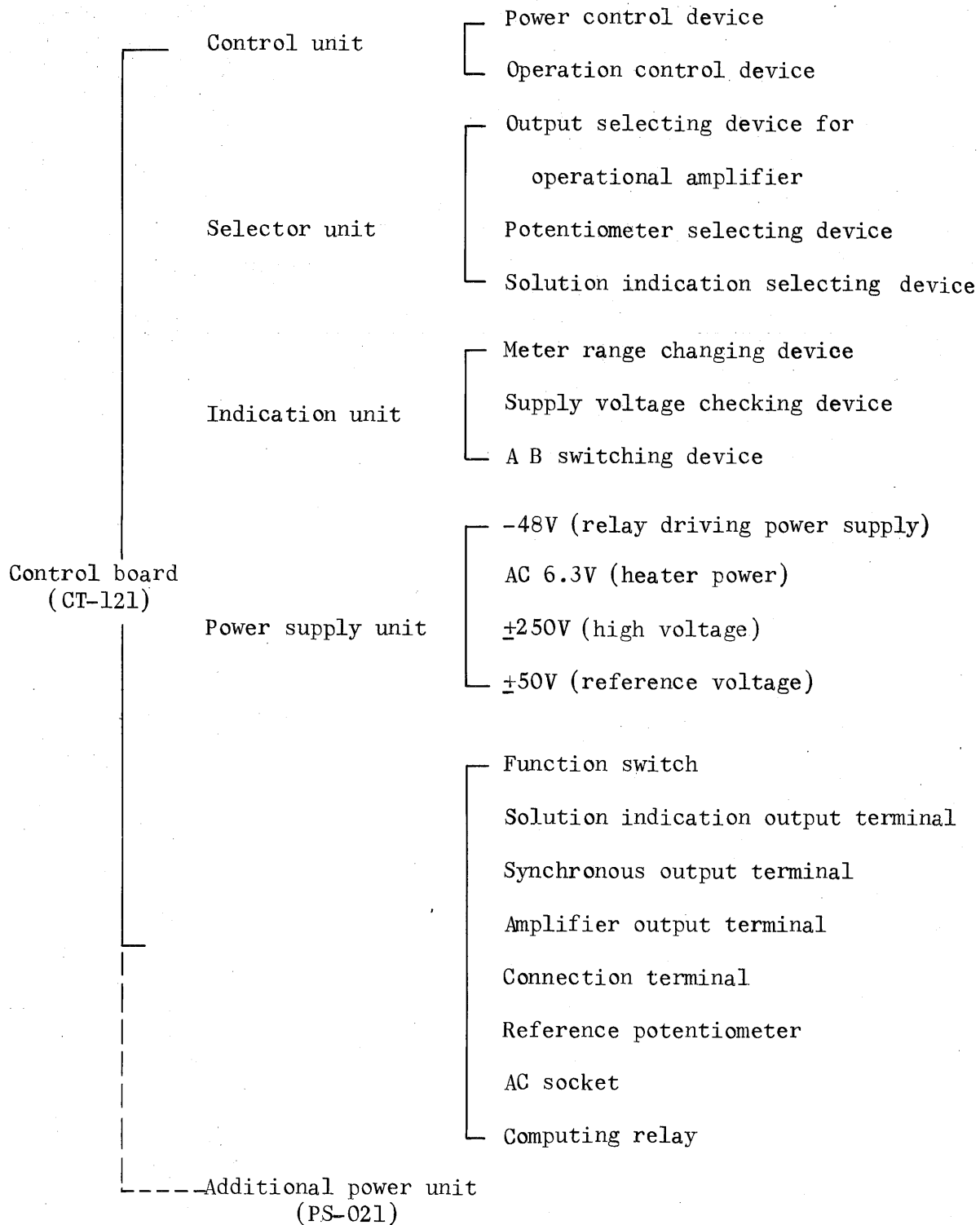


Fig. 5-1 Outside view of control board

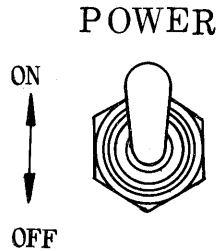
5.2 Composition



5.3 Control unit

5.3.1 Power control device (POWER)

This is a switch which is used to apply AC 115V power for this equipment.



Power switch

Fig. 5-2

•ON The equipment is turned ON and becomes operative. It is indicated by the illumination of the lamp in the voltmeter and AB contact indicating lamp.

•OFF Power is switched OFF.

The equipment stops its operation.

(Note 1) Start operation about 10 minutes after switching-on.

(Note 2) Keep meter range at OFF whenever switches are at ON or OFF position.

5.3.2 Operation control device

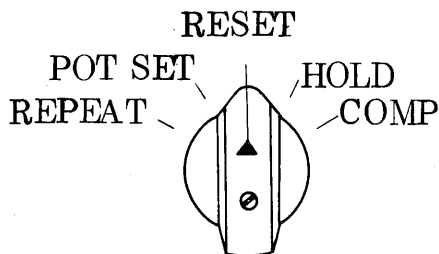
This is a switch which is used to change the operation of the computer.

State of computer in each control position

•POT SET

This is the position where 1 turn type potentiometer POT 1 and 2 equipped in the linear panel (LA-121) are set.

(Note) Meter range and power source checking facilities become operative.



Operational control switch

Fig. 5-3

•REPEAT

This is the position where the operation speed is increased by 100 times, and the repeating operation in operational period of about 0.1 second is achieved without any change in patching connection.

(Note) Keep meter range at OFF.

•RESET

This is the position where all operational components are ready for computation. It is chiefly used to feed an initial value to the integrator.

•COMPUTE

This is the position where all operational component is ready to make functional operation.

•HOLD

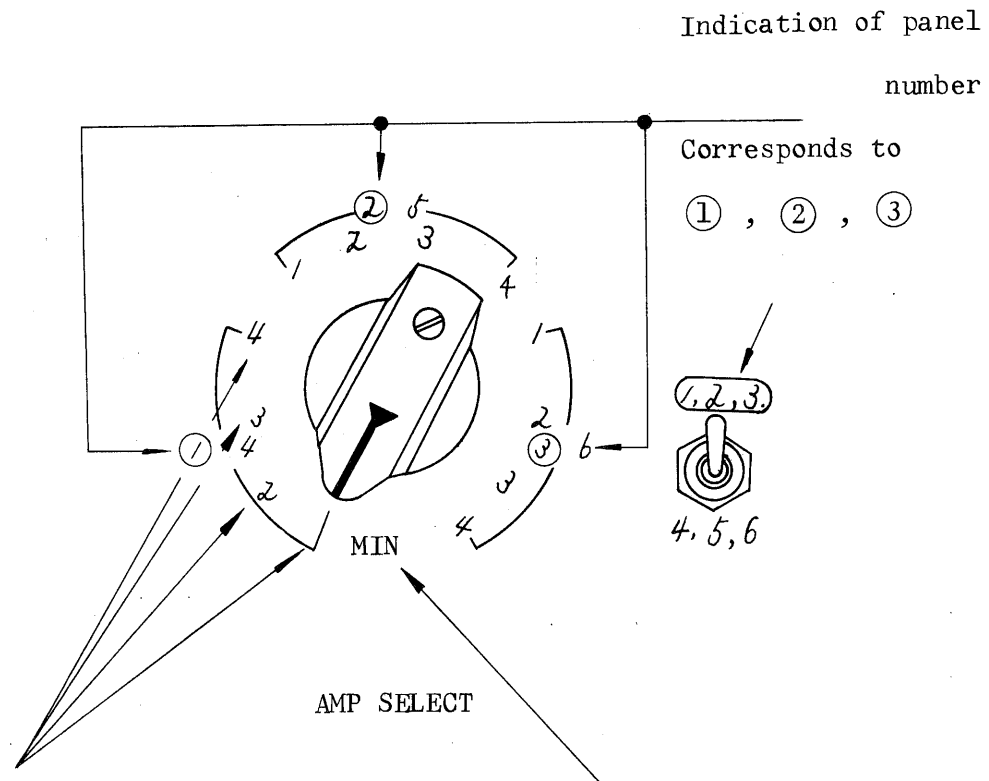
This is the position where the operation is stopped and all connections of operational components are held.

5.4 Selector unit

5.4.1 Output selecting device for operational amplifier (AMP SELECT)

This is used to select an output of dc-amplifiers (the number of amplifiers mounted depends upon the composition), which is connected to the voltmeter in the center of the control panel and the terminal AMP OUT.

Therefore, the amplifier output voltage selected is read on the meter and can be led out to the external from the terminal AMP OUT. The position MIN has no direct connection with AMP OUT. With the switch placed to this position, the voltage applied on the terminal MIN on the pre-patch board can be read on the voltmeter of the control panel.



Indication for amplifier No. of each linear panel

Input from terminal MIN on pre-patch board can be indicated on voltmeter.

Fig. 5-4

5.4.2 Potentiometer selecting device (POT SELECT)

This is used to select 1-turn type potentiometers equipped in the linear panel LA-121. (The number of potentiometers depends upon the composition.) It is chiefly used when the operation control switch is placed at POT SET.

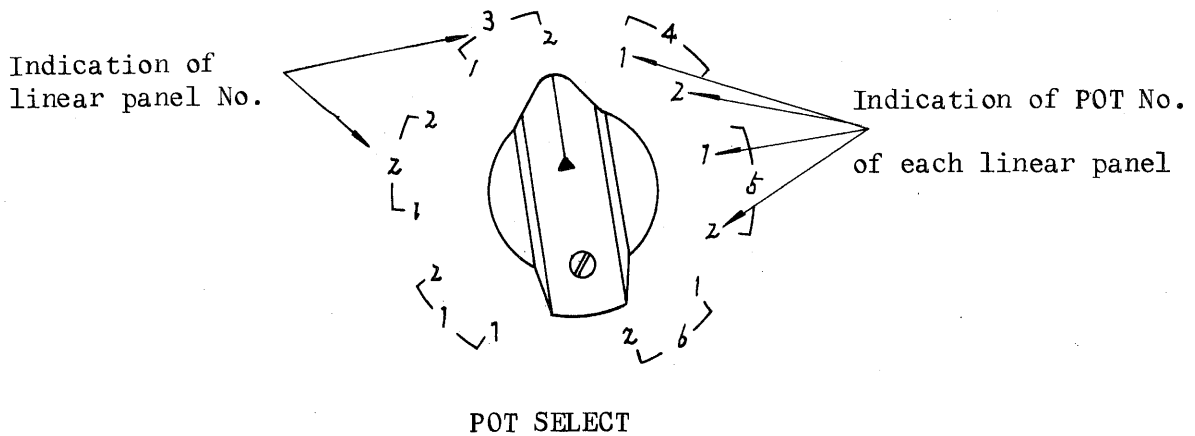
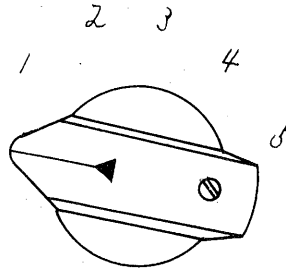


Fig. 5-5

5.4.3 Solution indication selecting device (SOLUTION SELECT)

Some solutions to be obtained by operation are patched beforehand on the SOLUTION terminals of the pre-patch board. A desired solution among them is selected and connected to the TO REC terminal or TO IND terminal of the control panel by means of the switch SOLUTION SELECT. The solution is connected only to the terminal TO REC for low speed operation, and only to TO IND for repetitive operation, respectively.

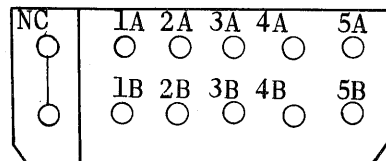
The solution connected to the SOLUTION terminal NC on basic patch board is connected to TO REC or TO IND regardless of AB switching device.



SOLUTION SELECT

Fig. 5-6

One of pairs of "SOLUTION" terminals 1A,B, 2A,B ...5AB on basic patch board is selected.



(Note) Connect only one solution to NC terminal.

Connection more than 1 will cause damage.

5.5 Indication unit

5.5.1 Meter range changing device

This is used to change the ranges of the meter, if necessary, in three steps such as 50V, 10V and 1V full scale respectively, except when the operation control switch is placed at POT SET.

Place the range changing switch at OFF when the operation control is at REPEAT (repeating operation). This is because the operation speed is too fast to read its solution and serious damage can occur to the meter.

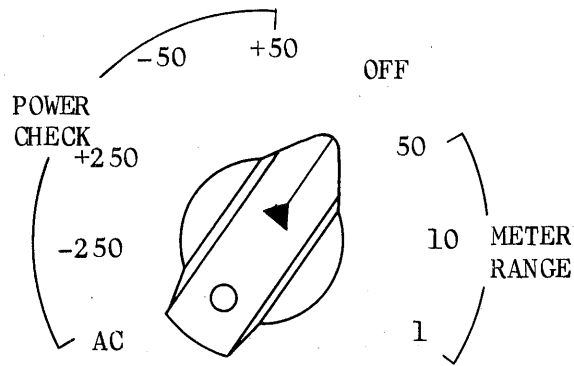


Fig. 5-7

5.5.2 Supply voltage checking device

AC : This is the position when the voltage of the commercial power AC 115V is checked. Check that the pointer is located within AC mark (in red) on the scale.

If the pointer is over this range, the power supply voltage may be outside the range of $115V \pm 5V$. In this case it is necessary to adjust the voltage through the voltage regulator (sliding transformer).

-250V : Check if the pointer indicates the full-scale of -side (-250V).

+250V : Check if the pointer indicates the full-scale of side (+250V).

-50V : Check if the pointer indicates the full-scale of -side (-50V).

+50V : Check if the pointer indicates the full-scale of side (+50V).

When indications are as described above, the power source is normal. Adjustment should be made if the indicated values different from those described above. Refer to the adjustment

method in section 5.7, power unit.

5.5.3 A B switching device

This is a relay mechanism which switches over A to B (or B to A) when the operation control returns to RESET from COMPUTER. AB switching device operates for both slow operation and repeating operation.

For slow operation, the operation control is done manually in the order of RESET, HOLD, COMPUTE, HOLD and RESET. In this sequence the AB switching device operates when the control is changed into RESET. Therefore, if a desired solution is patched beforehand on the SOLUTION terminal of the patch board and manual operation control is repeated, two kinds of solutions are obtained automatically on the recorder for the first and second operations.

Positioning the REPEAT, operation control is repeated automatically between RESET and COMPUTE with the constant repetition frequency of 8 c/s and AB switching device operates automatically when the control changes from COMPUTE to RESET.

Two kinds of solution can be observed on a CRT with long persistence screen. Check for the AB switching operation by use of the A→B indicating lamp.

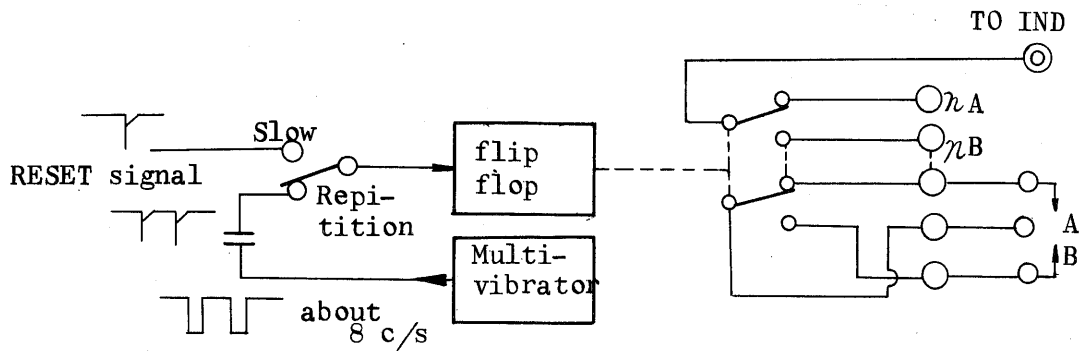


Fig. 5-8

5.6 Prepatch mechanism

Employing a prepatch method, this computer has a mechanism to mount or dismount the patch board and also the mechanism to move it up and down. To move the patch board up and down, operate the handle rightward or leftward, respectively, in two positions, A and B, as shown in Fig. 5-9.

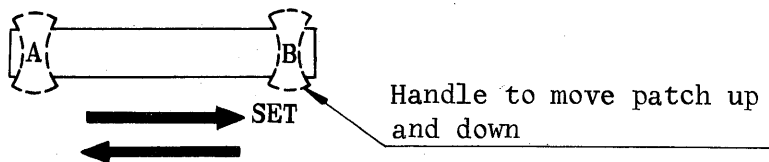


Fig. 5-9

•Position A; the position to mount or dismount the prepatch board and patch pins. Carry out the control by pushing the mounting knob at the top of patch board to the inside as shown in Fig. 5-10.

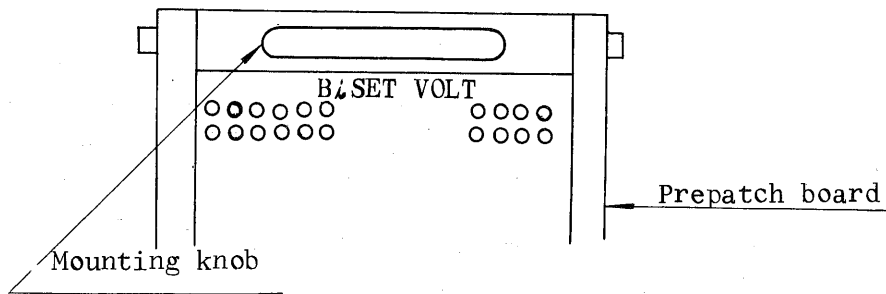


Fig. 5-10

(Note) An operation can be made at the position A where patch cords and patch pins are disconnected.

Position B; the position to make operation.

Carry out the precise balance check with the meter, if necessary, at this position.

(Note) Never put in or pull off the patch cords in this position.

5.7 Power supply unit

5.7.1 General

The power supply unit for this computer is equipped in the lower rear side of the case. When the total number of linear panels LA-121 and non-linear panels NA-122 is more than 3 (half equipped composition). An additional power unit must be used besides the basic power supply unit. Specifications of the basic power supply unit is as follows.

Input voltage	AC 115 ± 5V	50~60 c/s	1 φ
Output voltage	+250V 80 mA	}	high voltage
	-250V 80 mA		
	+50V 25 mA	}	reference voltage
	-50V 25 mA		

-48V 0.4 mA Source for relays
(unstabilized)

5.7.2 Adjusting voltages

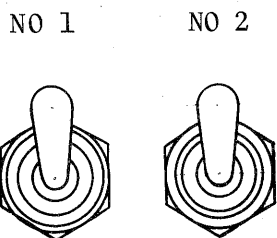
To adjust the voltages $\pm 250V$ and $\pm 50V$, proceed as follows:
Watching the meter on the control panel, adjust these voltages
by placing the PS CHECK in each position.

- ① Adjustment of variable resistor for $-250V$
- ② Adjustment of variable resistor for $+250V$
- ③ Adjustment of variable resistor for $-50V$
- ④ Adjustment of variable resistor for $+50V$

After completing the all the above adjustments, check for
voltages again.

5,8 Attached unit

o Function switch (FUNCTION SW)



FUNCTION SW

Fig. 5-11

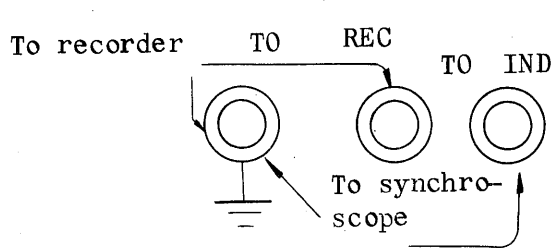
This is composed of two switches as
shown in Fig. 5-11. It is used to add
any stepping voltage, function voltage
or disturbance from external at any
time during the operation.

It is also used to change operational
circuits.

Terminals for these switches are provided
on the patch board PB-111B.

o Solution indication output terminal (TO REC, TO IND)

Connect the input of the recorders to
this terminal to display the solutions
on the pen recorder (for slow operation,

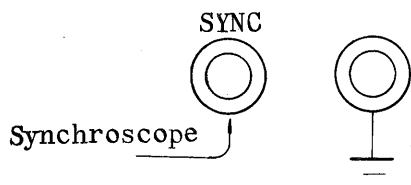


use TO REC) or synchroscope (for repeating operation use TO IND).

The output selected by SOLUTION SELECT appears at this terminal.

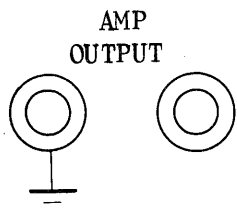
o Synchronous output terminal (SYNC)

From this terminal, the trigger signal synchronized with repetition frequency is obtained, which is applied to an external trigger input terminal of synchroscope to get the still image of solutions on its screen during repeating operation.



o Amplifier output terminal (AMP OUT)

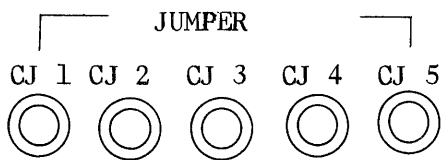
To this terminal, the output voltage of dc-amplifier is connected, which is selected by the output selecting device of the operational amplifier (AMP SELECT). It is connected in parallel with the voltmeter at the center of the board. Therefore a signal for X or Y can be taken out from this terminal to display the solutions on the phase plane with XY recorder or synchroscope.



If the amplifier which is generating the signal of X or Y is selected by means of the output selecting SW, any

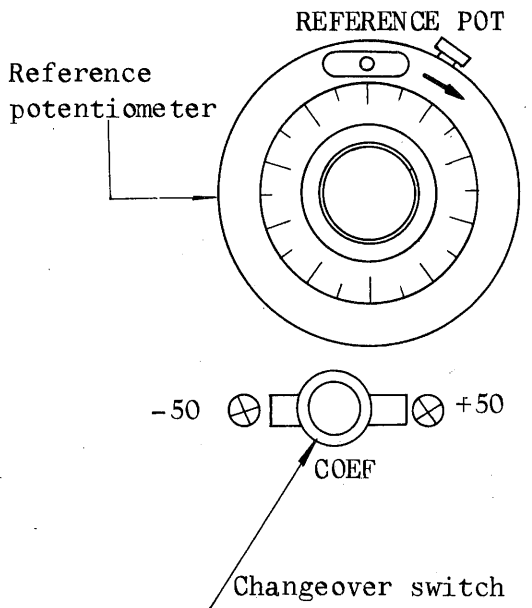
signal other than that selected by SOLUTION switch can be taken out from this terminal.

o Jumping terminals (JUMPER)



These are used to make connection with the external devices of the computer. They are connected with CJ on the pre-patch board in one to one relationship. They are used when it is necessary to take out more than 3 computer outputs. For example, they are used to feed many solutions in parallel to multi-channel recorder or XY-recorder. They are also used to connect other equipment to the patch board.

o Reference potentiometer



This is used widely to set a reference value at POT SET, an initial value for the integrator, or a general multiplication constant.

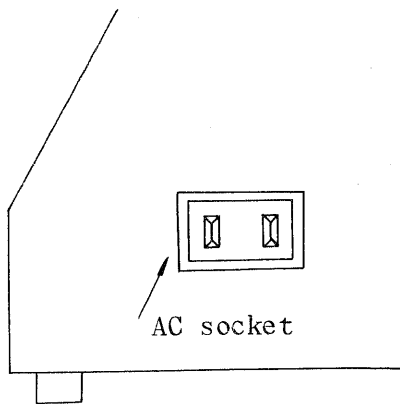
The functions of the Siemens type key are as follows:

- +50 The reference voltage of +50V is applied to the potentiometer.
- COEF This operates as a 10-turn type potentiometer. The input and output appear in the pre-patch board.

-50 The reference voltage of -50V is applied to the potentiometer.

This switch will lose its function when the computer is in the state of POT SET.

o AC socket

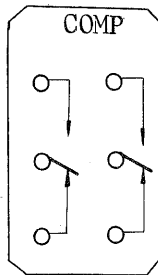


There is an AC 115V socket which is provided in the both side of the case, for use in supplying power to other equipment such as the synchroscope.

Power capacity less than 400VA is allowable output from each socket.

Great care should be taken not to exceed this limit.

Computing relay



Whether the computer power switch is turned ON or OFF, AC power is always available at this outlet.

The relay closes the lower side contacts when the operation control switch is placed at "COMPUTE" during the slow operation. (It is equipped in the patch board PB-111B).

6. Pre-patch board

6.1 General

The Pre-patch board is modular for every panel, therefore, there is no requirement to manufacture additional new pre-patch boards nor to modify boards in case of changing or increasing composition.

The patch board can be extended at will according to the composition.

6.2 Engraved Front

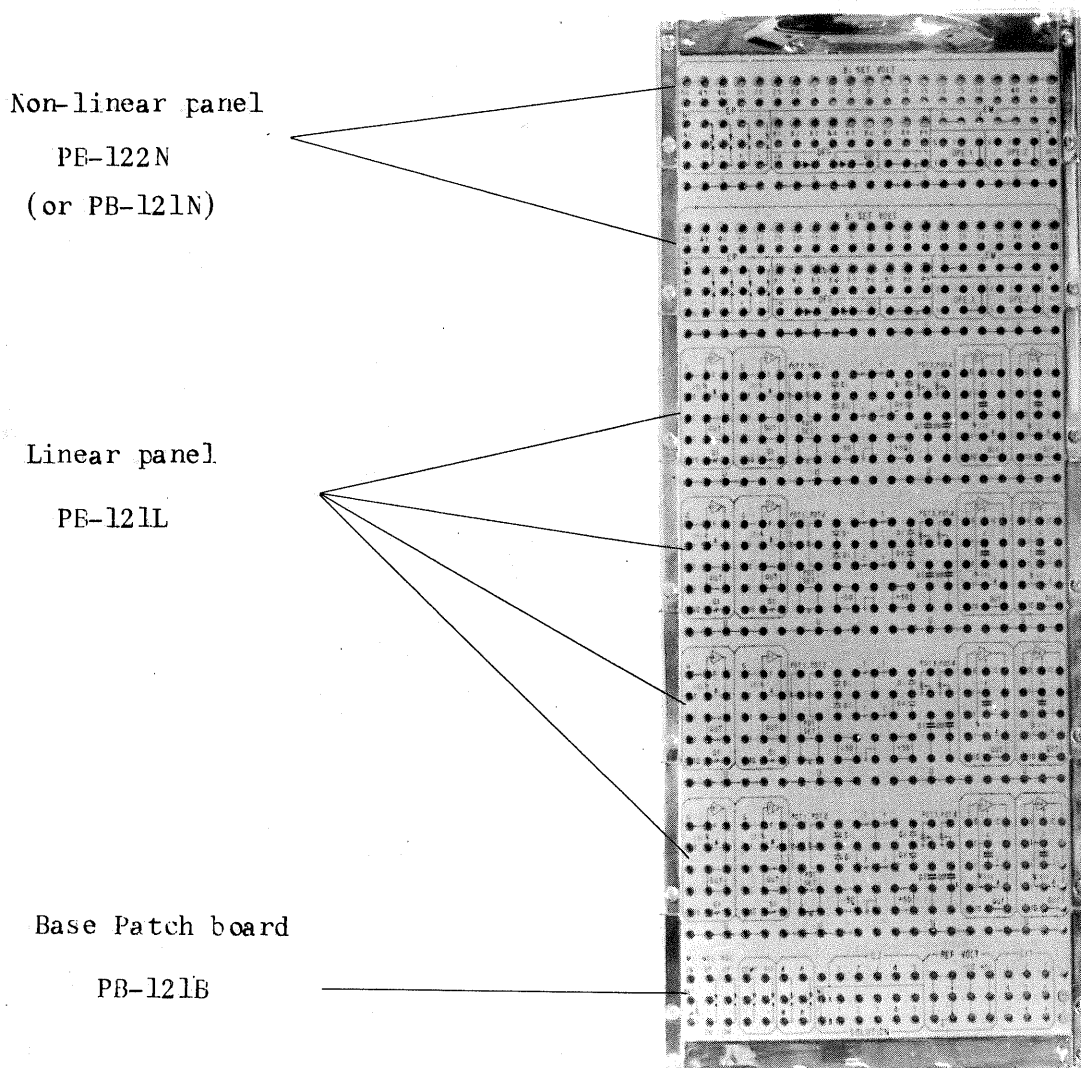


Fig. 6-1 Outside view of the pre-patch board.

7. Additional power unit, PS-021

7.1 General

The additional power unit is required when the total number of panels of the linear panel LA-121 and the non-linear panel NA-122 exceeds three.

Attention should be called to use of the isolated additional power unit as a non-stabilized power supply only. It merely can work satisfactorily as an additional power unit in conjunction with the original power unit contained in the control board.

Major specifications of the power supply after an addition of this unit is as follows.

Input voltage	AC 115V $\pm 5V$	50~60 c/s, 1 ϕ	
Output voltage	+250V	160 mA	} High voltage supply
	-250V	160 mA	
	+50V	25 mA	} Standar supply
	-50V	25 mA	
	-48V	0.4A	Relay energizing power supply (not stabilized)

Refer to item 5.7.2 as to voltage adjustment method.

7.2 Additional connection method

7.2.1 Connection of the additional power unit PS-021

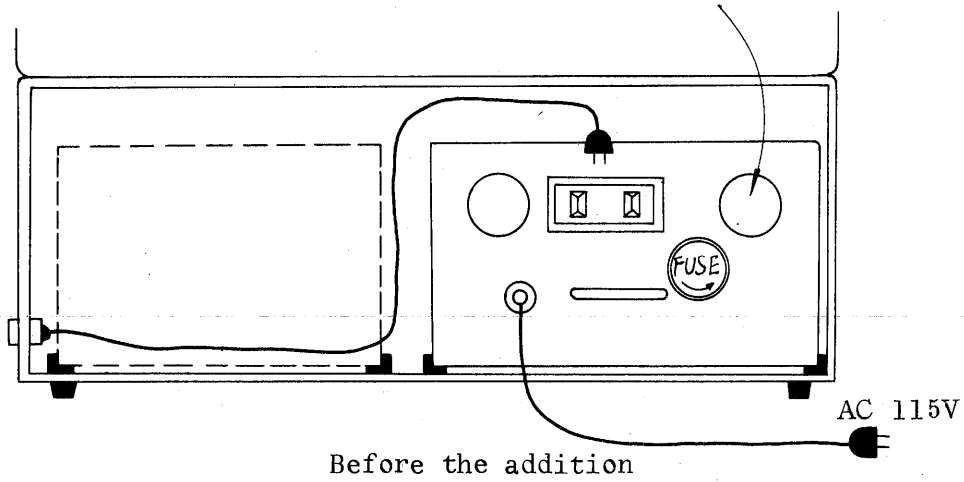
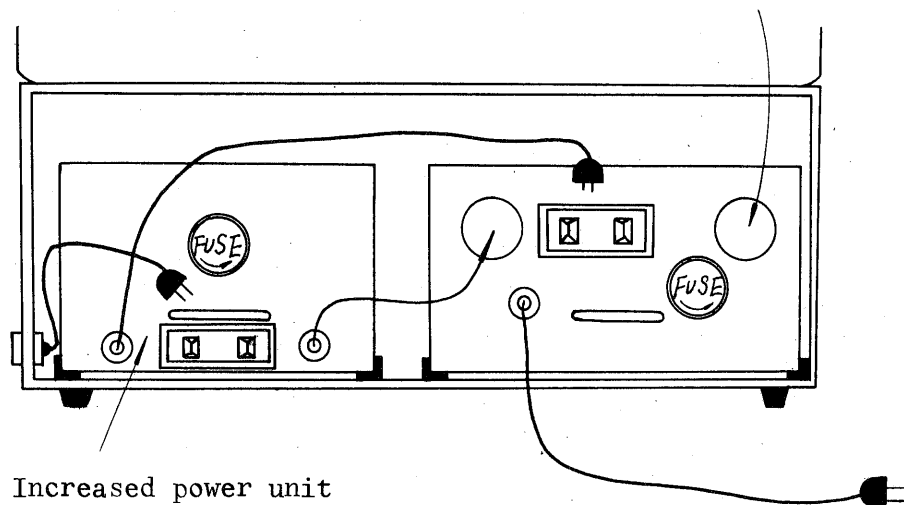


Fig. 7-1



After the addition

Fig. 7-2

7.2.2 Addition of panels

Addition of panels is performed as follows.

1. Turn the heads of four binding studs about 5 times counter-clockwise respectively. (Refer to Fig. 7-3)
2. Remove them. (Refer to Fig. 7-3)
3. Remove the top plate and the panels of upper part of the plate to insert additional panels. (Refer to Fig. 7-3)
4. Position the additional panel and replace the original ones on it. (Fig. 7-4)
5. Apply some of glue to the threaded portion of binding studs and screw in the stud piece. (Refer to Fig. 7-5)
6. Insert the binding studs through the top plate. (Refer to Fig. 7-4)
7. Turn the heads of studs clockwise and tighten them. (Refer to Fig. 7-4)

NOTE: An additional panel is accompanied by four stud pieces and a tube of glue.

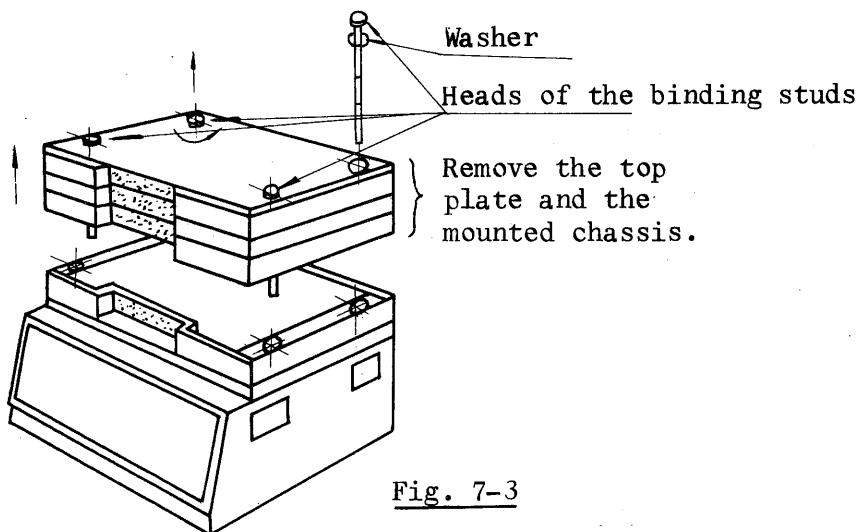
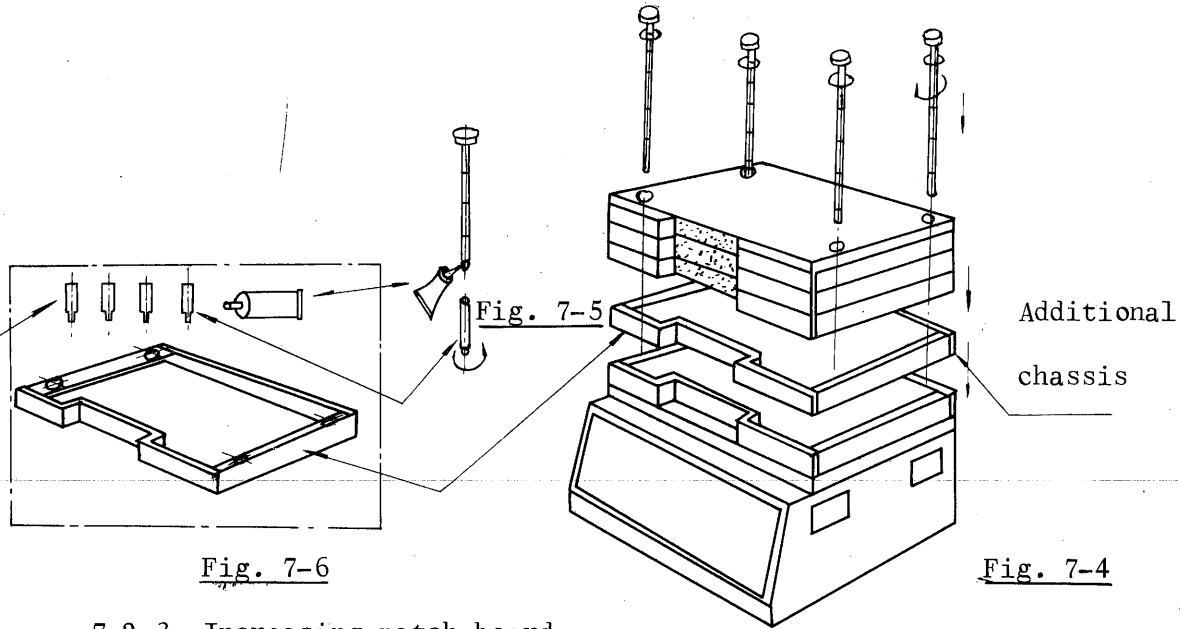


Fig. 7-3



7.2.3 Increasing patch board

1. Remove the screws of patch board on that portion to be increased (Refer to Fig. 7-7)
2. Remove the patch board. (Refer to Fig. 7-8)
3. Connect the additional patch board. (Refer to Fig. 7-9)
4. Assemble by tightening it with screws. (Refer to Fig. 7-10)

NOTE: An additional patch board is accompanied by two connecting pieces and two pairs of screws and nuts.

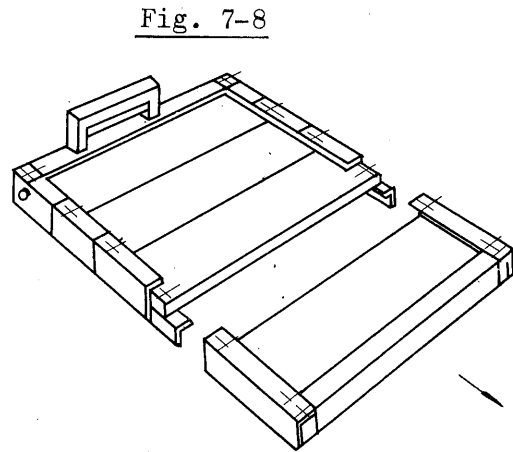
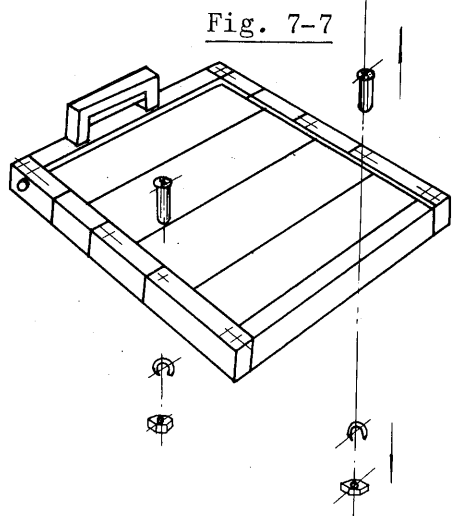


Fig. 7-9

Additional patch plate

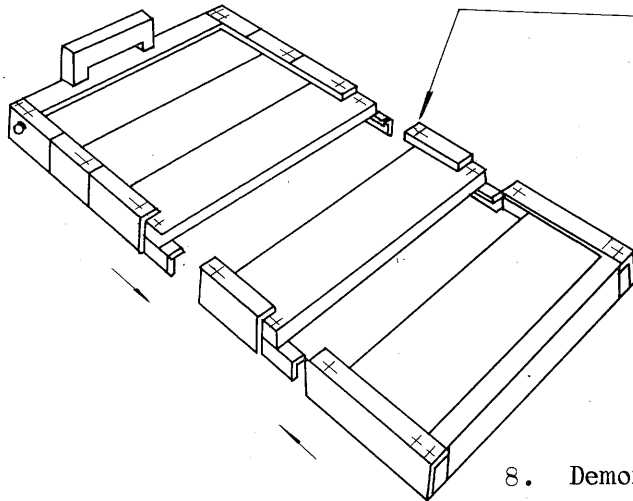
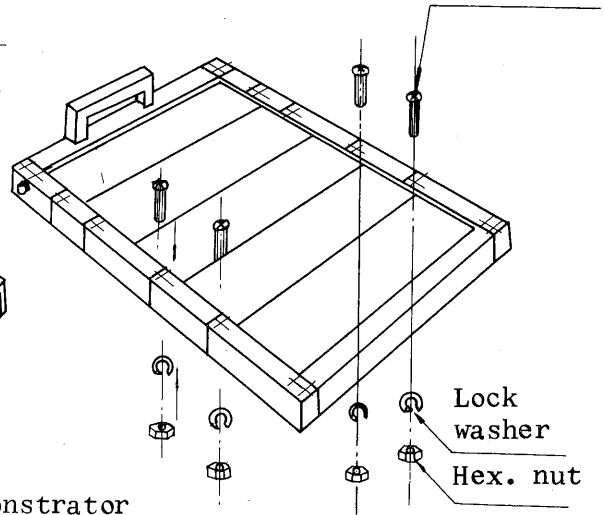


Fig. 7-10

Oval flat cross head screw



8. Demonstrator

8.1 General

The demonstrator is a detached module of the main body of analog-computer. This device is equipped with minimum units of the fundamental linear components together with the various operational components composing the main body and the control device.

The circuit composition of the operational amplifier and the action of the operational relays can be observed from outside. So, it is a convenient device for demonstrating the basic operation of the analog-computer.

The demonstrator is composed of an operational amplifier, DC amplifier, two potentiometers for voltage setting, two operational relays, one group of operational impedances and a control device.

Various operational impedances can be selected as input impedance Z_i and feed back impedance Z_f of the operational amplifier. Simulations of every kinds of the transfer function can be easily made by using them.

The exterior view of the demonstrator is shown in Fig. 8-1.

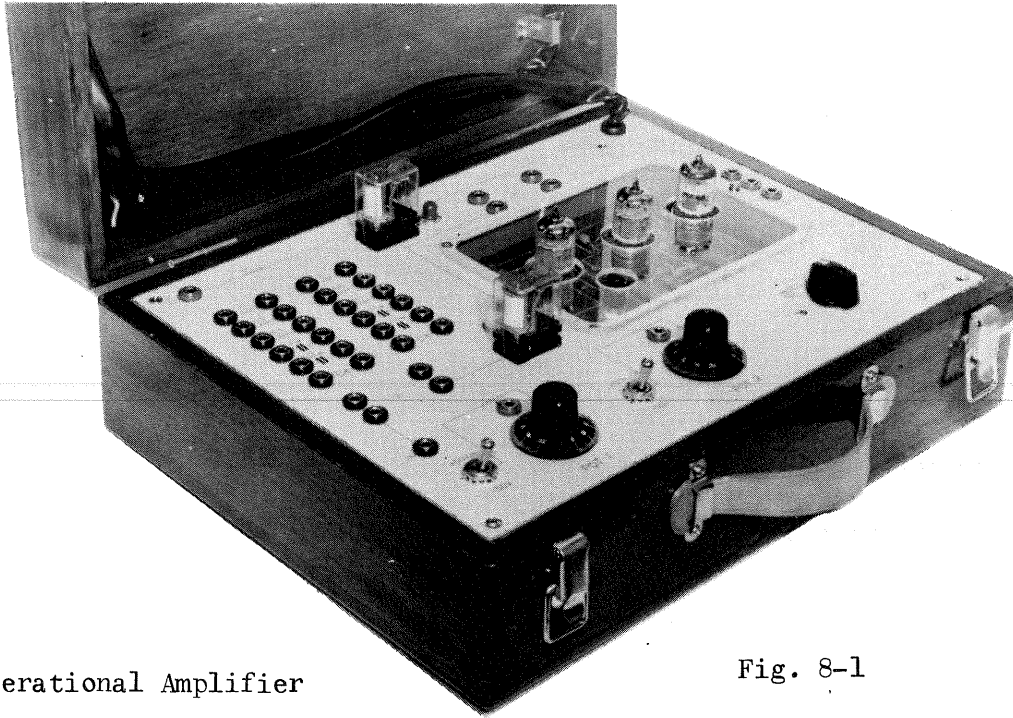


Fig. 8-1

8.2 Operational Amplifier

The operational amplifier is a DC amplifier representative of those contained in the main body. It is equipped with printed wiring. Necessary power for the amplifier is supplied from the main body through a connecting cord.

For the input and output impedances any simulation of the transfer functions such as summer, inverter, integrator, differentiator and first degree lag component can be made by connecting the operational impedance group with patch cords. Output can be observed on the meter mounted on the main body or with an external voltmeter.

8.3 Operational impedances

Impedances and diodes as follows are connected to the terminals and they can be used separately.

Their contents are as follows.

Resistor	1 M ohm	2
	0.5 M ohm	2
	0.1 M ohm	2
Condenser	1 μ F	1
	0.1 μ F	2
	0.01 μ F	1
Diode		2

When the above operational impedances are used as Z_i and Z_f , connect them between the terminals with patch cords.

Example of connection (Select impedances according to Table 10-1)

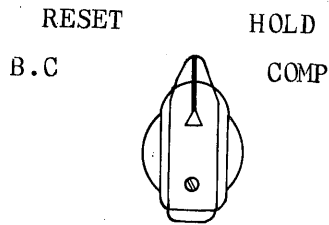
	Z_i	Z_f
Summer	0.1 M ohm	1 M ohm in case of $\times 10$
	0.5 M "	1 M " in case of $\times 2$
Inverter	1 M "	1 M "
Integrator	1 M "	1 μ F time constant of 1

8.4 Potentiometer for voltage setting

The potentiometer is used for applying the voltage for the input of the operational amplifier or the initial value of the integrator. This is provided with two potentiometers. Each can be applied with \pm 50V by switching. Selection of either of +50V or -50V is carried out by switching.

8.5 Operation control device

This device is a combination set of switches and relays which are necessary to change the operating condition of the operational amplifier. The operational relays works automatically by the changing of the positions of control switch as shown in Fig. 8-2.



B. C: Position for zero balancing on the operational amplifier.

RESET: Position for incoming initial value when operated as an integrator

HOLD : Operation stops at this position and the integrator holds its value as it is.

COMP : Computing state

Fig. 8-2 Control switch

The operating states of the relays K_1 and K_2 at each position of the switch are shown below.

Position	K_1 (resetting relay)	K_2 (computing relay)
B.C	OFF (green lamp on)	ON (yellow lamp off)
RESET	ON (green lamp on)	ON (yellow lamp off)
HOLD	OFF (green lamp off)	ON (yellow lamp off)
COMP	OFF (green lamp off)	OFF (yellow lamp on)

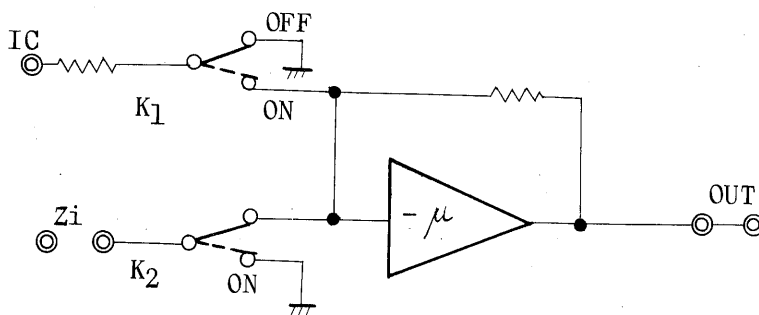


Fig. 8-3

8.6 Basic procedures

8.6.1 Connection of Power-supply cord

Connect the power-supply cord which is drawn out from the upper right part of the demonstrator to the back of the main

body. (Refer to Fig. 1-2 Input selector unit) The main switch on the main body shall be "OFF" before insertion of the plug, then "ON", after connecting to main body.

8.6.2 Patching

Patching is carried out to make required transfer functions.

Example: Integrator

- (1) Decide the integration time constant and connect resistor to "Zi" and capacitor to "Zf".
- (2) Connect the output of the potentiometer for voltage setting to the input.
- (3) If the initial value is necessary, connect the output of the potentiometer for voltage setting to the input terminal for the initial value "IC".
- (4) Decide and set the input value, polarity sign of the initial value and setting value.
- (5) Connect the output of the amplifier "OUT" to the terminal "M IN" of the main body and set the switch "AMP SELECT" at "M IN".

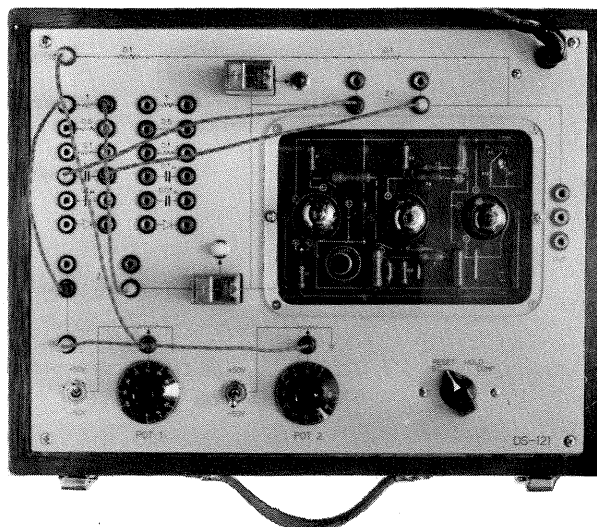


Fig. 8-4

8.6.3 Balance checking

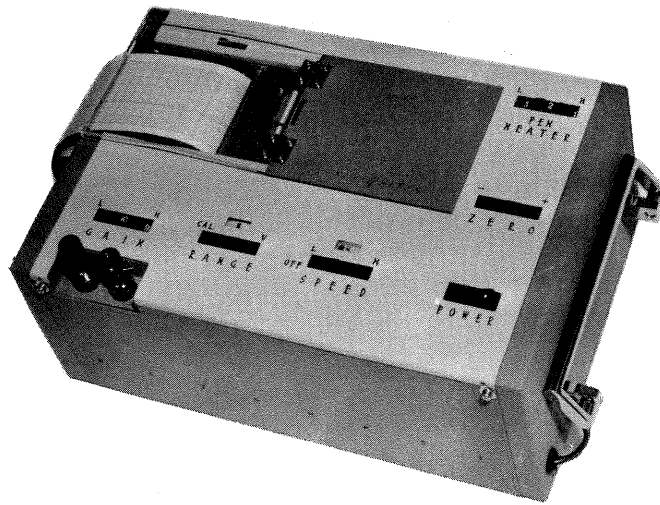
This is an adjustment to get zero output on the amplifier when its input is zero.

- (1) Set the adjusting switch on the demonstrator at "B.C".
- (2) Set the switch "METER RANGE" at "1".
- (3) Adjust the rheostat on the amplifier (printed base plate) of the demonstrator to get zero deflection of the meter.

~~Close adjustment is unnecessary for this checking.~~

9. Single Channel Recorder

1. General 82
2. Composition 82
3. Instructions for use 83



RA-121 recorder

9.1 General

This recorder is a single channel, thermal pen type. As the amplifier is transistorized it is small in size and light in weight. Owing to the employment of thermal pen type, the recorded wave form is shown on a rectangular coordinate which permits more easy observation.

9.2 Composition

The recorder is composed of following sections.

- (a) Input sensitivity adjusting section
- (b) Zero level adjusting section for the pen
- (c) Paper speed changing device
- (d) Pen heater adjusting section
- (e) Power supply switch
- (f) Paper loading mechanism
- (g) Input connecting terminals
- (h) Pen galvanometer
- (i) Recorder amplifier
- (j) Power unit
- (k) Accessories and spare parts

Recording paper	5 rolls
Spanner for the pen	1
Screw driver ⊕	1
Screw driver ⊖	1
Vinul cover	1
Fuse	2
Pilot lamp	2

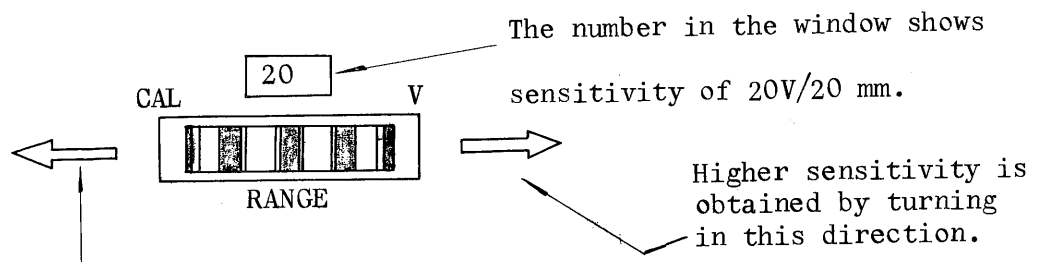
9.3 Instruction for use

Instruction for operation of each section are as follows.

9.3.1 Input sensitivity adjusting section

(a) Input sensitivity selection "RANGE"

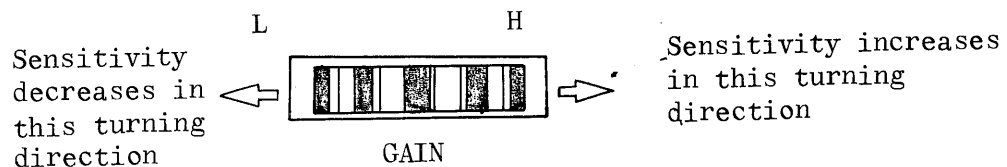
This switch is for changing the input sensitivity of recorder. A proper range can be selected according to input signal level. The number appearing in the window of the switch shows the voltage which causes 20 mm deflection of the pen on the recording paper.



Lower sensitivity is obtained by turning in this direction. Direction of the pen can be calibrated at "CAL" "CAL" appears in full turning.

(b) Input sensitivity adjusting section "GAIN"

Higher sensitivity is obtained by turning in such direction that the number on the wheel becomes larger, and lower vice versa. As mentioned above, recording sensitivity can be adjusted by both means (a) and (b). It is desirable to calibrate the sensitivity before operation.



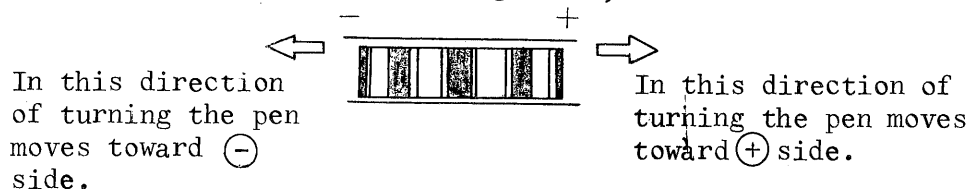
(c) Calibration

Turn the wheel "RANGE" noted in the item (a) leftward until "CAL" comes in sight. At this condition, adjust the wheel "GAIN" noted in item (b) until deflection of the pen displays 10 mm.

By above adjustment, the number shown in the window coincides with the full deflection of the pen at the resultant sensitivity of (a) and (b).

9.3.2 Zero level adjusting for the pen, "ZERO"

This is used for adjustment of the zero position of the pen when input signal is zero. The pen moves toward ⊕ side by the turning of this control rightward, and vice versa.

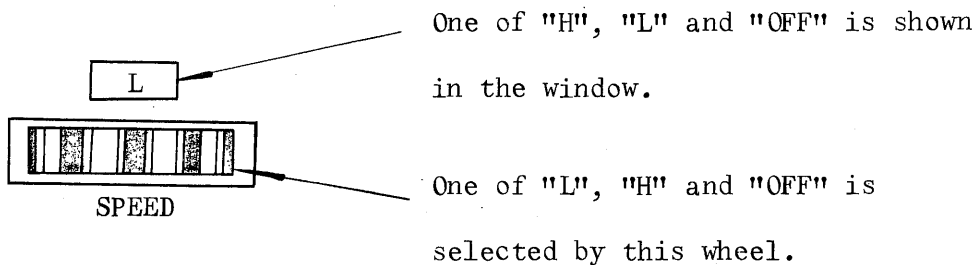


9.3.3 Paper speed changing device

Paper speed can be changed at the following two parts:

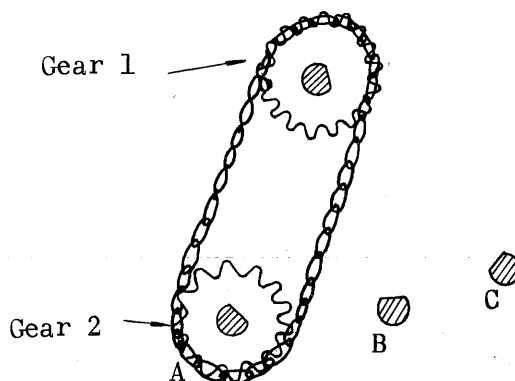
- (a) At the panel front: High (H), Low (L), Off (OFF)
- (b) At the side of this device: A(50, 25), B(10, 5),
C(2, 1)mm/sec. (Changeable in three blocks.)

The paper speed changing device at the panel front is used to select the speed either high or low which is noted in the parentheses in the item (b). Beside this, 0(OFF) is provided for stopping paper.



The paper speed changing device at the side of the recorder permits changing of paper speed in three blocks by inserting the gear to a proper shaft of A, B or C.

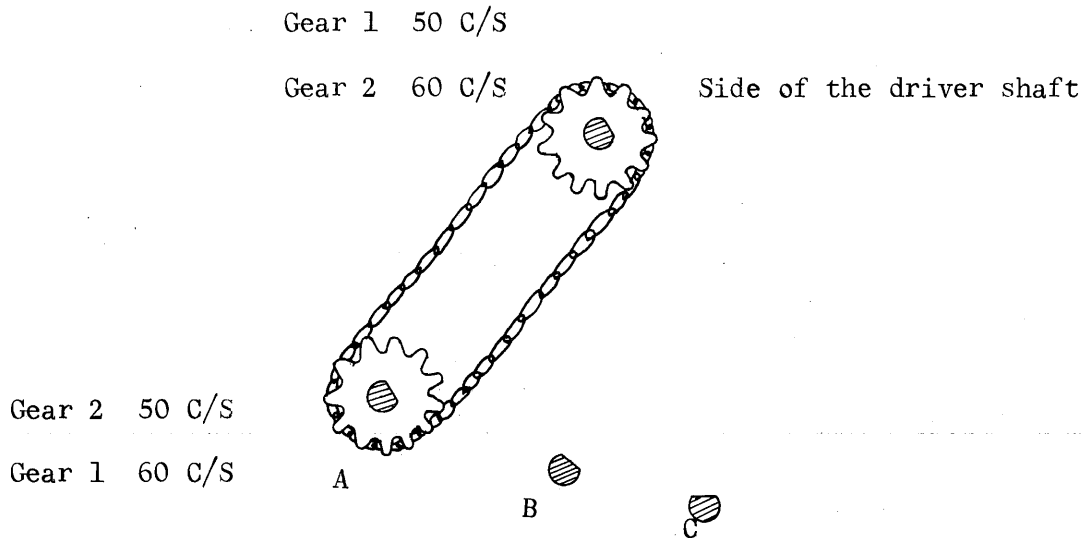
The gear and the shafts are provided inside of the opening lid at the pen galvanometer side. Thus any one speed among A(50, 25)mm/sec, B(10, 5)mm/sec and C(2, 1)mm/sec is selected.



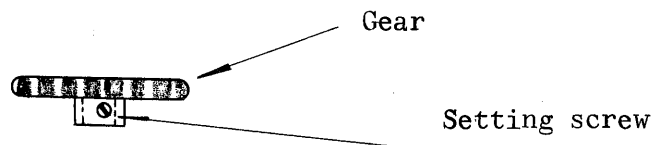
The gear "2" is put on one of the shafts "A", "B" and "C" according to the required speed.

(c) Frequency selection (50, 60 c/s)

As the speed of the driving motor changes with the frequency of power supply, paper speed is decided according to the frequency of the power supply. In the figure below, gear "1" fits for 50 c/s and "2" for 60 c/s.

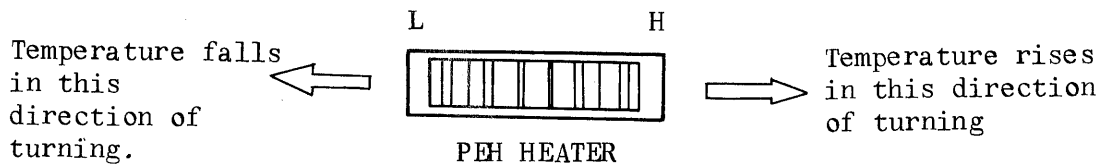


Fix the driving gear with the setting screw when the frequency is selected. Changing sides of axes should not be fixed to facilitate ease of axes change.



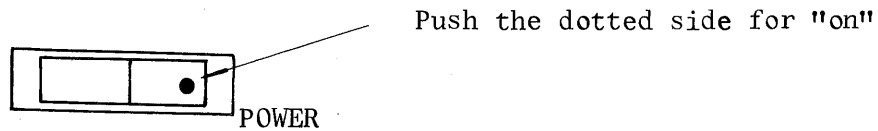
9.3.4 Pen heater adjusting section "PEN HEATER"

The thickness of line of the recording paper is affected by the pen temperature as the pen is of a thermal type. The line thickness is adjusted by the wheel "PEN HEATER". Low temperature of the pen is suitable for slow recording, and high for rapid.



9.3.5 Power supply

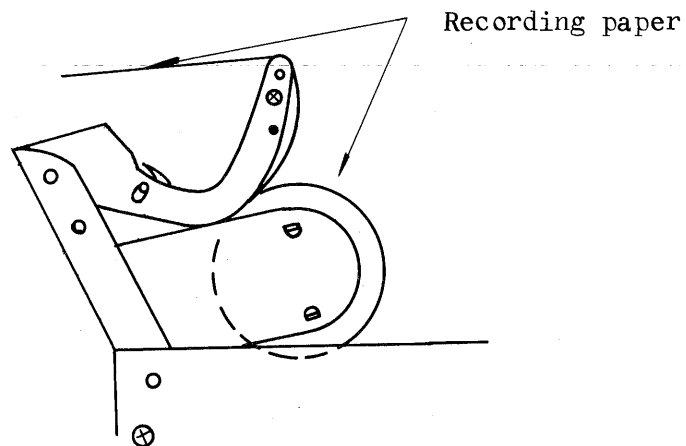
Power for the apparatus is supplied from 115V A.C. through the AC-cord. ON and OFF control is carried out by the switch "POWER" on the panel.



9.3.6 Paper loading

Lift the plastic cover on the front of the unit. Depress the lever to the left of the galvanometer; this releases the paper roll holder.

Load new roll of paper (see figure below) and press entire roll mechanism down into place. This completes the loading.



9.3.7 Input connecting terminal

Input signal to be recorded is supplied to the connecting terminals. The terminals are equipped on the left-hand side of the apparatus. The apparatus is on the ground side.

10. Appendix

Programming of the computer

10.1 Programming and it's symbols

10.1.1 What is programming?

A simple definition of an analog computer would be that it is a device for obtaining a solution to a problem by means of an electrical simulation of general physical phenomena. So, the composition of electrical circuits is an indispensable process and is called programming. In other words to express a problem given in the form of an equation as a block diagram for the computer and to compose it on the patch board.

10.1.2 Procedures for using patch board

Great care should be taken in the following:

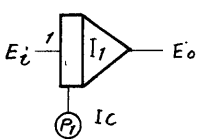
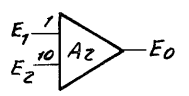
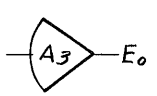
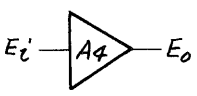
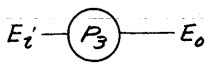
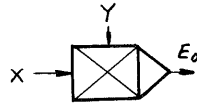
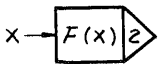
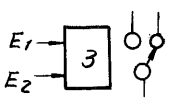
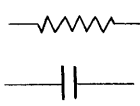
- (1) Do not plug in the patch cord with the patch board attached to the computer. In doing so you may damage the spring connectors.
- (2) Programming shall be set up with the patch board isolated from the computer.
- (3) Use as short a circuit plug as possible in programming, for easy observation of the programming.
- (4) Be careful to avoid misconnection of short circuit plugs used to decide the function of an amplifier, such as integrators, summers, and operational amplifiers.

10.1.3 Symbolic expression of operational components

It is convenient to use symbols to represent necessary computing components for the purpose of expression of a given

equation in the block diagram. Symbols listed in Table 10-1 are generally used. There are some other expressions but they differ little from each other.

Table 10-1 Analog computer symbols

	Computing components	Note	Formulas	Remarks
1	Integrator		$E_o = -\int E_i dt$	possible for multiple input adding provided with multiplying factors 1, 10.
2	Summer		$E_o = -(E_1 + E_2)$	provided with multiplying factor 10
3	Operational amplifier		$E_o = -\frac{Z_f}{Z_i} E_i$	Possible for simulation of transfer functions.
4	Inverter		$E_o = -E_i$	
5	Potentiometer		$E_o = K E_i$ $0 \leq K \leq 1$	Resistance 50 K Ω , 100 K Ω
6	Multiplier		$E_o = KXY$	$K = \frac{1}{50}$, reciprocal of the base voltage. negative sign is allowed.
7	Function Generator		$E_o = F(X)$	Negative sign is allowed.
8	Voltage comparator			Used as a logic circuit by comparison between E_1 and E_2 .
9	Operational element (resistor and capacitor)			$R = 1 \text{ M}\Omega$ $C = 1 \mu\text{F}$ ($0.01 \mu\text{F}$) } basic repetition

In addition to the above, there are various computing components and symbols. This table describes the components mounted on HITACHI 303.

10.1.4 Basic example of programming

Usual procedure of programming is as follows.

- (1) Express given problem in equations.
- (2) Transform the equations by calculation to fit for the analog-computer. For instance, it is desirable to make the equations into the form which is available for the integrator without the differentiator and to decide suitable scale factors and so on.
- (3) Make block diagrams based on the equations arranged by above treatment.
- (4) Set up the programming according to above block diagrams.

The following example shows a method of solving a simple ordinal differential equation according to the above process.

Example:

$$\begin{array}{l}
 A \frac{d^2y}{dt^2} + B \frac{dy}{dt} + Cy = 0 \dots\dots\dots(a) \\
 \left. \begin{array}{l} \\ \text{where, at } t=0, \frac{dy}{dt} = 0, y=y_0 \dots\dots\dots(b) \end{array} \right\} \dots (1)
 \end{array}$$

In most cases it is necessary to consider the initial condition. In other words, it means how the phenomenon expressed with the equation is at the moment the solving starts. This condition is expressed in the equation of (1)-(b).

- 1) Solve the equation (1) -(b) about $\frac{d^2y}{dt^2}$. (Generally it may be solved about the highest order differential coefficient in the equation.)

$$\frac{d^2y}{dt^2} - \frac{B}{A} \frac{dy}{dt} - \frac{C}{A}y \dots\dots\dots (2)$$

- 2) Supposing $\frac{d^2y}{dt^2}$ is obtained make the block diagram as Fig. 10-1.

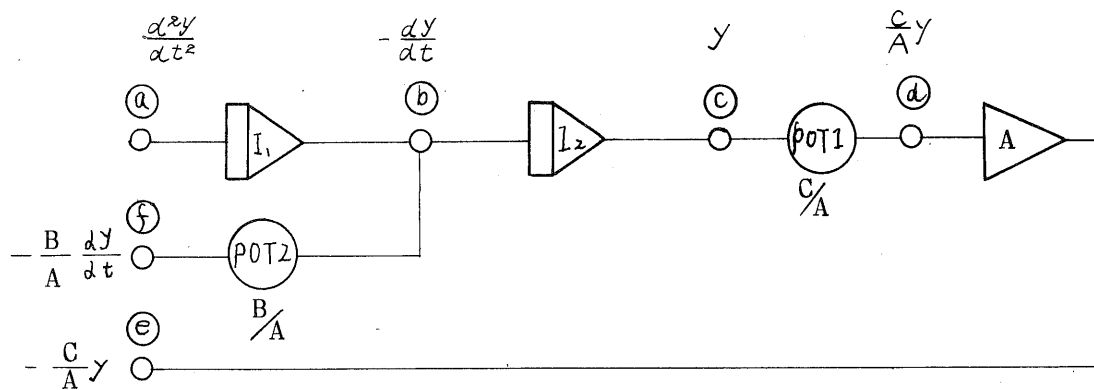


Fig. 10-1

Namely, assuming that $\left(\frac{d^2y}{dt^2}\right)$ is obtained at the point (a), give this signal to the integrator I_1 . Then $\left(-\frac{dy}{dt}\right)$ is obtained at the output point (b). (Negative sign is resulted from going through an amplifier.)

- 3) Give the signal obtained at (b) to the integrator I_2 , and y is got at the output point (c).
- 4) Multiply the signal at (c) by the constant $\left(\frac{C}{A}\right)$ in the potentiometer. Now $\left(\frac{C}{A}\right)$ is obtained at (d). Change the sign of the above signal and obtain $\left(-\frac{C}{A}\right)$ at (e) for the equation (2).

is made of the base voltage or $\pm 50V$ throughing the potentiometer.
The final block diagram is accomplished as shown in Fig. 10-3.

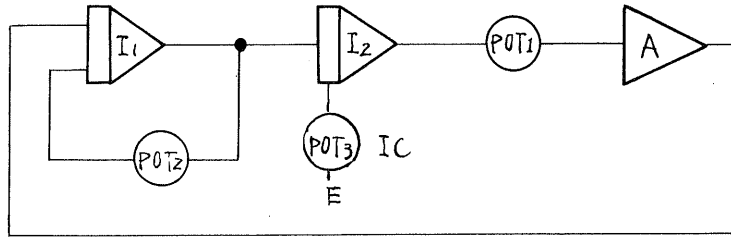


Fig. 10-3

NOTE: The polarity signs of the applied voltage to the terminal "IC" and output voltage of I_2 are opposite each other even when the initial condition is given.

An example of the patched state of the block diagram shown in Fig. 10-3 is illustrated in Fig. 10-4.

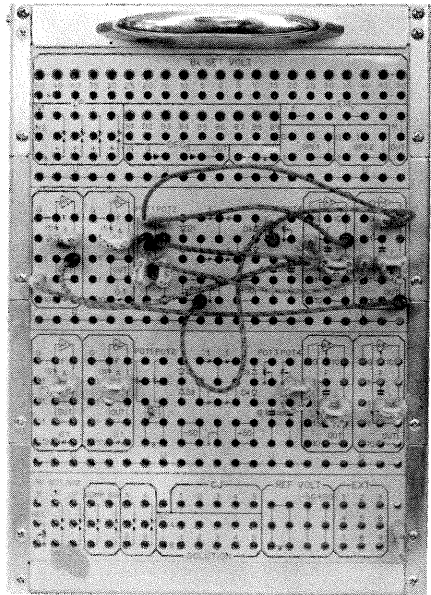


Fig. 10-4

10.1.5 Time scale factor and scale factor

1) Time scale factor

The available frequency for the computing component of the analog-computer is limited. In case the frequency is too high or too low compared with the proper frequency of the computer, it is better to adjust the time of the phenomena by extending or compressing it in order to obtain such results as having less error. This adjustment for time is called conversion of time scale and its ratio is called time scale factor.

The motion of the reproduced picture photographed with high speed camera is an example of extended time scale, namely, a time scale multiplied by a time scale factor.

For the model HITACH 303, $\omega = 1-5$ is favorable as its operational frequency. An example will be explained below.

$$\left. \begin{aligned} \frac{d^2 y}{dt^2} + 3 \frac{dy}{dt} + 900y &= 0 \\ \text{--- } t=0, \quad \frac{dy}{dt} &= 0, \quad y=C \end{aligned} \right\} \dots\dots\dots (3)$$

As the frequency included in the equation (3) is $\omega_p = \sqrt{900} = 30$, its time scale must be converted over such range as $\omega = 1-5$ to fit for HITACHI303. The frequency of the phenomena in the equation (3) is $\omega_p = 30$, and it is favorable to extend this time by thirty times. Then the velocity of the phenomena becomes one thirtieth and the computation will be carried out slowly.

When the equation (3) is considered in general, the time is to be multiplied by Δt .

$$t \Delta t = T \dots\dots\dots (4)$$

Hereupon T is a converted new time, i.e. a computing time of the analog computer. This ratio Δt is called time scale factor.

According to the value of Δt ;

$(\Delta t > 1)$ means to extend the time, and

$(\Delta t < 1)$ means to compress the time.

Now, put $\Delta t = 20$ in the equation (3). (Δt may be 30, but let it be 20 here.) From the relation of the equation (4) the following relation is brought out. This relation is used to rewrite the equation with the new time T.

$$\left. \begin{array}{l} t \longrightarrow \frac{1}{\Delta t} T \\ \frac{dy}{dt} \longrightarrow \Delta t \frac{dy}{dt} \\ \frac{d^2y}{dt^2} \longrightarrow \Delta t^2 \frac{d^2y}{dt^2} \\ \frac{d^3y}{dt^3} \longrightarrow \Delta t^3 \frac{d^3y}{dt^3} \end{array} \right\} \dots\dots\dots (5)$$

Substitute above relations and the value of Δt into the equation (3), and rearrange them.

$$\left. \begin{aligned}
 &400 \frac{d^2y}{dT^2} + 3 \times 20 \frac{dy}{dT} + 900y=0 \\
 &\frac{d^2y}{dT^2} + 0.15 \frac{dy}{dT} + 2.25y=0 \\
 &\text{at } T=0, \quad \frac{dy}{dT} = 0, \quad y=C
 \end{aligned} \right\} \dots\dots\dots(6)$$

The equation (6) is a machine equation for the analog-computer. Both block diagrams of the equations (3) and (6) are illustrated in Fig. 10-5 and 10-6 for comparison.

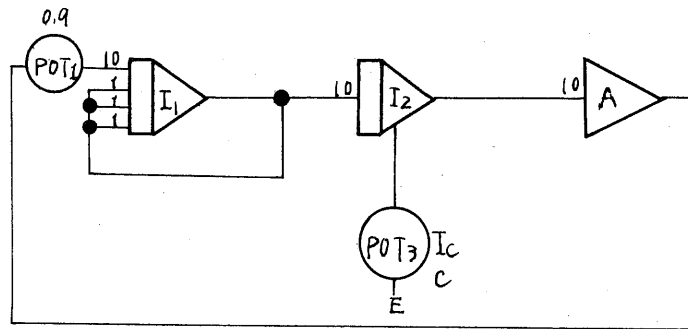


Fig. 10-5 Block diagram of the equation (3)

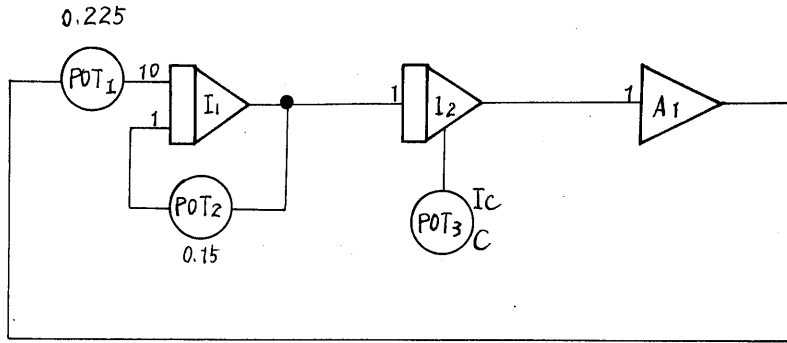


Fig. 10-6 Block diagram of the equation (6)

The states of both solutions are given in Fig. 10-7

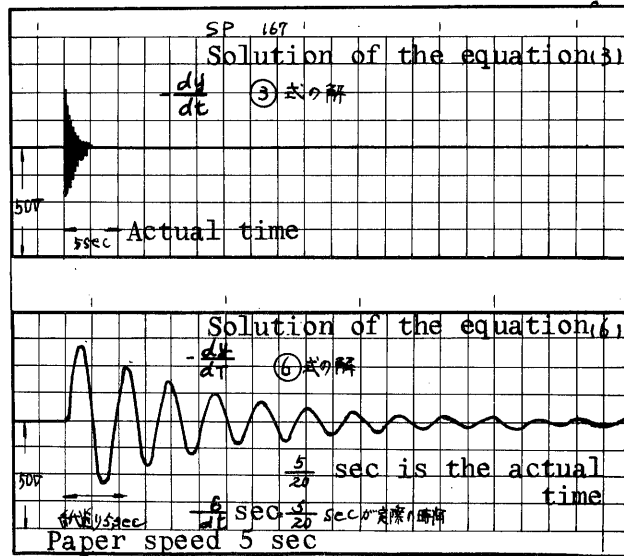


Fig. 10-7

(2) Scale factor

This scale factor has been explained in para. (1) and here the scale factor regarding dependent variable y and its differential coefficient will be set forth. As the value of y varies widely, it is difficult to make the value correspond the voltage of the analog-computer as it is. Hence, the conversion coefficient is considered as follows.

$$\lambda_y y = Y \dots\dots\dots (7)$$

λ_y is called scale factor, which is the coefficient to make the value of y correspond to the voltage of Y volts. The conversion coefficients of such differential coefficients of λ_y as in $\frac{dy}{dt}$, $\frac{d^2y}{dt^2}$ and so on are also decided readily when λ_y is done. They are given by the equation (8). It is necessary to take care that λ_t is related to the equation (8).

$$y = \frac{1}{\lambda_y} Y$$

$$\left. \begin{aligned} \frac{dy}{dt} &= \frac{dt}{\lambda_y} \frac{dY}{dT} \left(\frac{dt}{\lambda_y} : \begin{array}{l} \text{the scale factor of the first} \\ \text{order differential coefficient} \end{array} \right) \\ \frac{d^2y}{dt^2} &= \frac{dt^2}{\lambda_y} \frac{d^2Y}{dT^2} \left(\frac{dt^2}{\lambda_y} : \begin{array}{l} \text{the scale factor of the second} \\ \text{order differential coefficient} \end{array} \right) \end{aligned} \right\} \dots(8)$$

When only λ_t , the scale factors of the first order differential coefficient, and that of the second order differential coefficient are given, the scale factor λ_y can be got from the relation of the

parenthesized passage of the equation (8).

10.2 Example of computation

Let us analyze the transient phenomena in the circuit as shown in Fig. 10-8 and get the variation of charge. Hereupon the capacity C has been charged with the initial value of 20V.

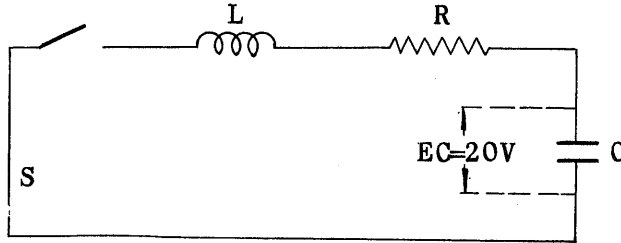


Fig. 10-8

The equation of this circuit is given by the equation (9).

$$L \frac{d^2q}{dt^2} + R \frac{dq}{dt} + \frac{1}{C} q = 0 \dots\dots\dots (9)$$

Substitute the constant and solve about $\frac{d^2q}{dt^2}$,

$$\frac{d^2q}{dt^2} = -20 \frac{dq}{dt} - 4 \times 10^6 q \dots\dots\dots (10)$$

The actual angular frequency is $\omega_p = \sqrt{4 \times 10^6} = 2000$.

This is too high as the computing frequency for the HITACHI 303. It is necessary to convert the time scale. It is estimated that the time extended by 1000 times is suitable for computation with the HITACHI 303 of which computing angular frequency is in the range of $\omega = 1-5$.

So, put $\alpha dt = 1000$, and at $t=0$, C is charged with the initial voltage of 20V. Let q_0 is the initial value of the charge q .

$$q_0 = CE_C = 0.5 \times 10^{-6} \times 20 = 10^{-5}$$

There is no larger value of q than q_0 in the circuit because q decrease its value gradually from q_0 .

Make q_0 correspond to 25V.

$$\alpha q = \frac{Q_0}{q_0} = \frac{25}{10^{-5}} = 25 \times 10^5 \dots\dots\dots (11)$$

The relation of the equation (11) is used to get the value of q from the voltage solution with the correspondence of the equation (8) in reading of the solution.

Substitute the relation of the equation (5), dt and dq , to the equation (10).

$$\frac{\alpha^2 t}{d q} \times \frac{d^2 Q}{d T^2} = -200 \frac{d t}{d q} \cdot \frac{d Q}{d T} - 4 \times 10^5 \frac{1}{d q} Q \dots\dots\dots (12)$$

NOTE: 1) $d q$ is eliminated in the equation (9) since every term includes q of a same degree.

2) $d q$ is eliminated when the degree of q are the same even if the degree is higher than the second.

Put the value of q and arrange the equation.

$$\frac{d^2 Q}{d T^2} = -0.2 \frac{d Q}{d T} - 4 Q \dots\dots\dots (13)$$

The solution is obtained by the analog-computer HITACHI 303 by programming the equation (13) on the patch board. The block diagram is shown in Fig. 10-9 and the patching example in Fig. 10-10.

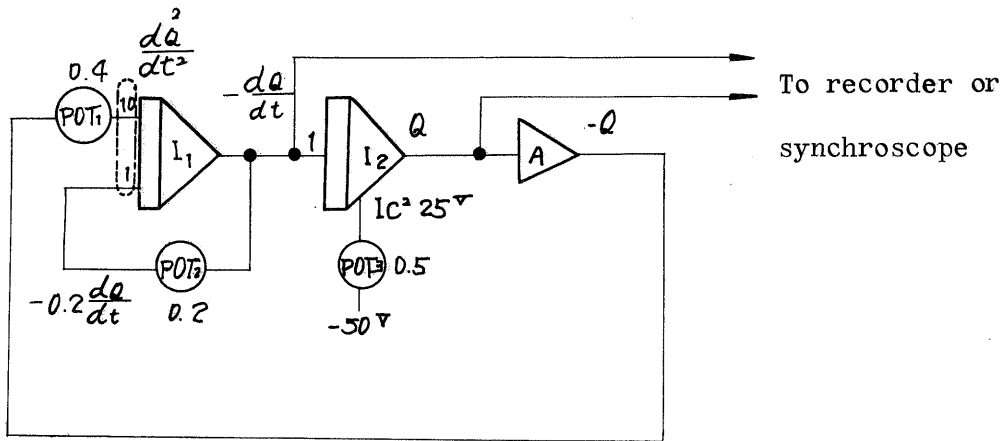


Fig. 10-9

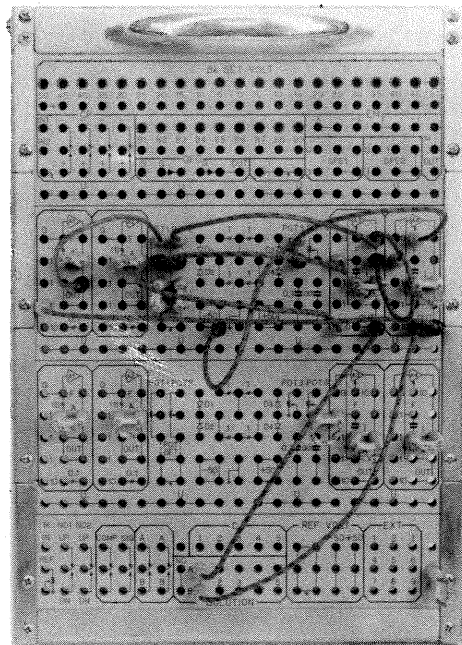


Fig. 10-10

Fig. 10-11 shows the solution.

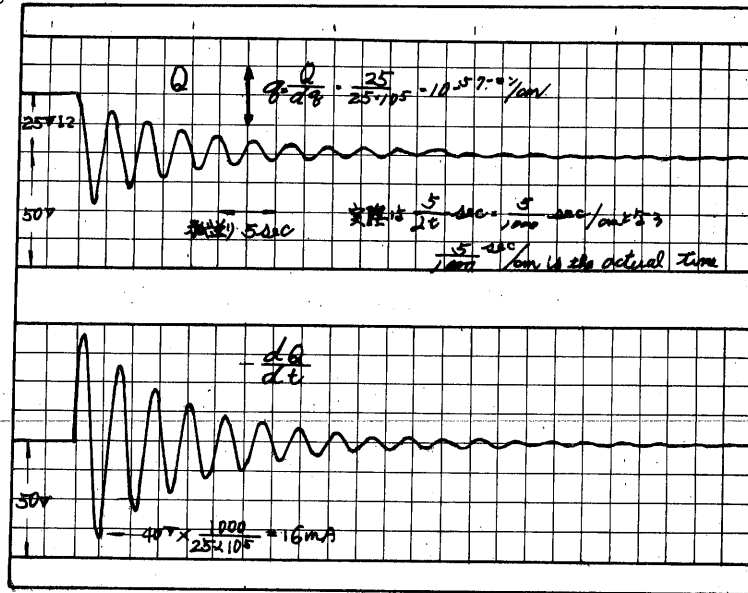


Fig. 10-11

The former values of q and $\frac{dq}{dt}$ are obtained by reversing the operation from y and t using each Q and $\frac{dQ}{dT}$ which are given as the voltage on Fig. 10-11.

Then from the equation (8),

$$\left. \begin{aligned}
 q \text{ (coulomb)} &= \frac{1}{28} Q \text{ (volt)} \\
 t \text{ (second)} &= \frac{1}{2t} T \text{ (second)} \\
 \frac{dq}{dt} \text{ (A)} &= \frac{2t}{28} \frac{dQ}{dT} \text{ (V)}
 \end{aligned} \right\} \dots\dots\dots (14)$$

