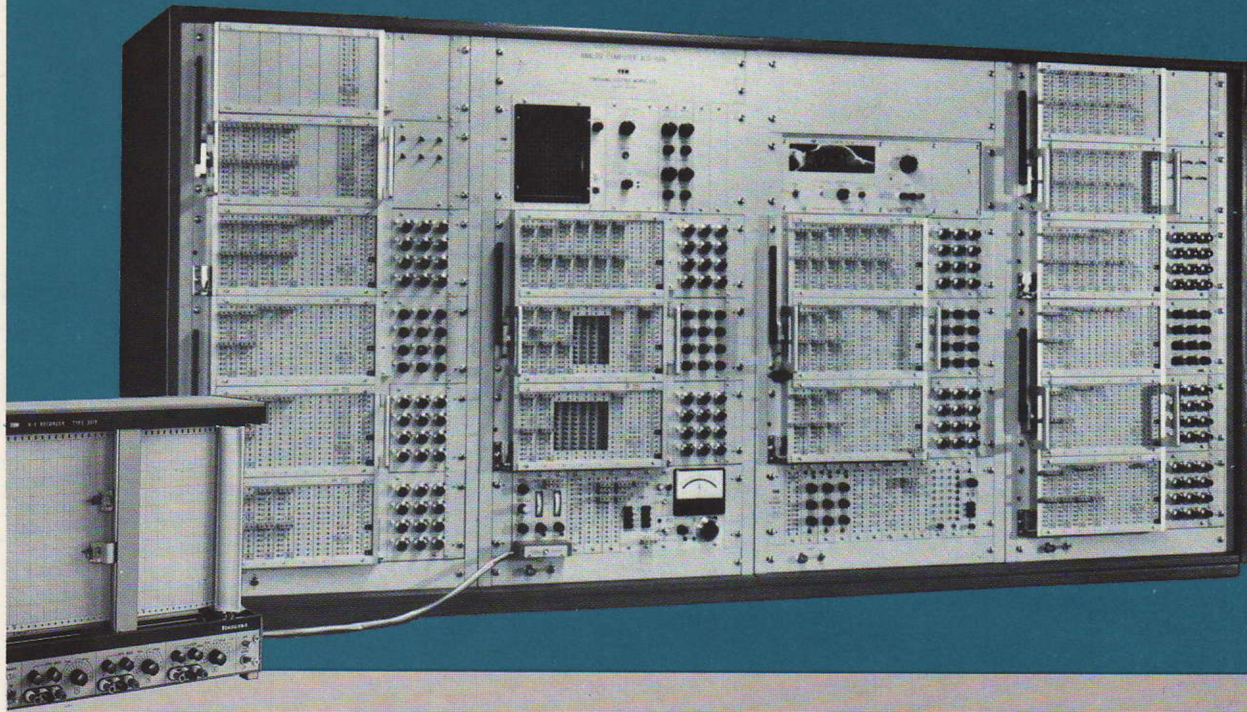
ANALOG COMPUTERS

3300

Series 3300

ANALOG COMPUTER & PERIPHERAL EQUIPMENT



From Analog Computation of Summation, Subtraction, Multiplication, Division and Square Root to Problem Analysis by Differential Equations and Transfer Functions!

All Solid-State

Low-drift and stable operational amplifiers

High Speed Computation—Low Speed Conversion Type

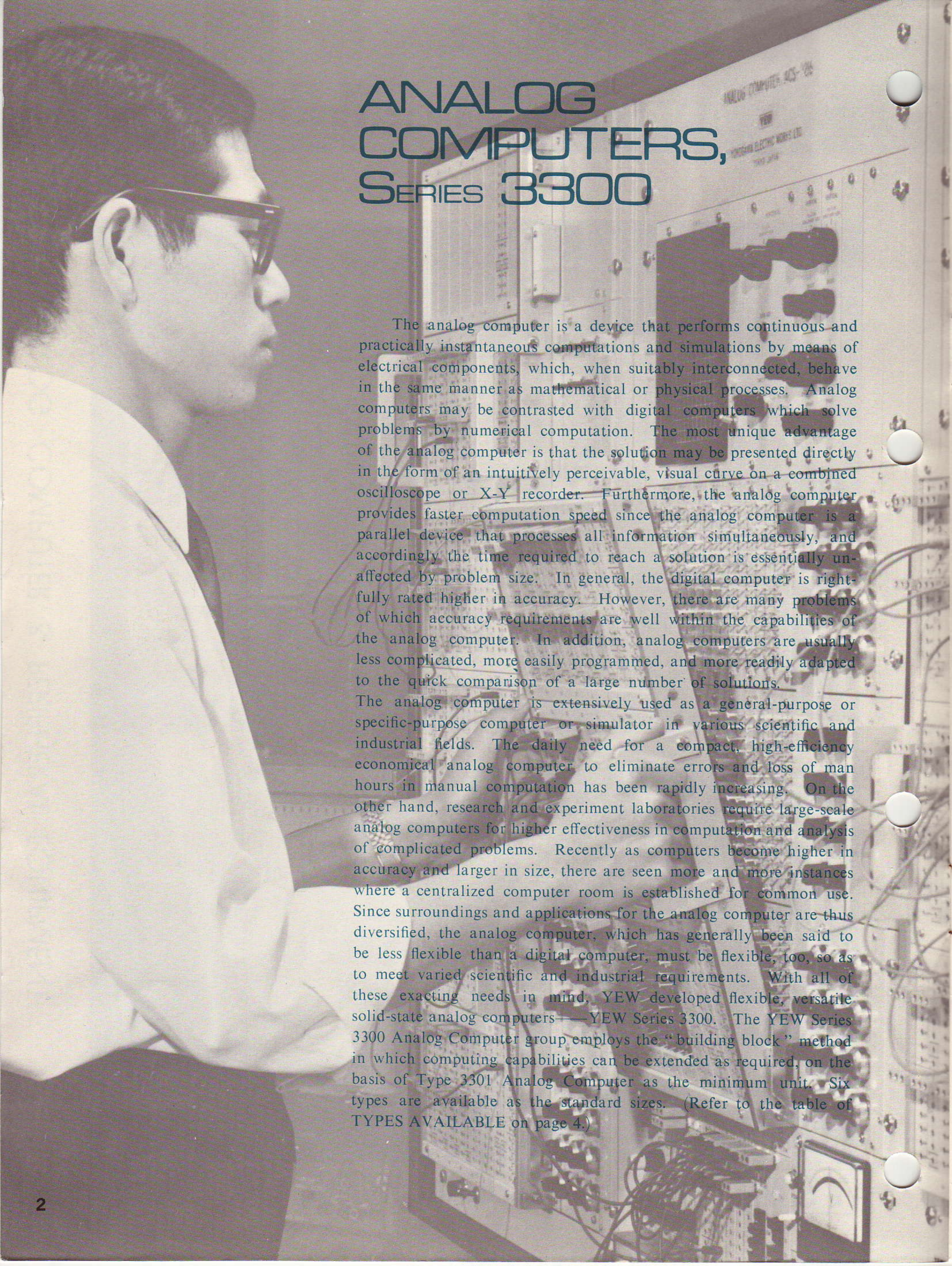
While observing waveforms on a Cathode-ray oscilloscope, you can simultaneously record them with an X-Y Recorder (in combination with Waveform Translator for Recorder).

Computation Impedance of 0.1%

0.1% computation accuracy is ensured for all linear computing elements and such non-linear computing elements as multipliers and variable diode function generator.

YEW YOKOGAWA ELECTRIC WORKS, LTD.

CATALOG NO. YEW 3300A

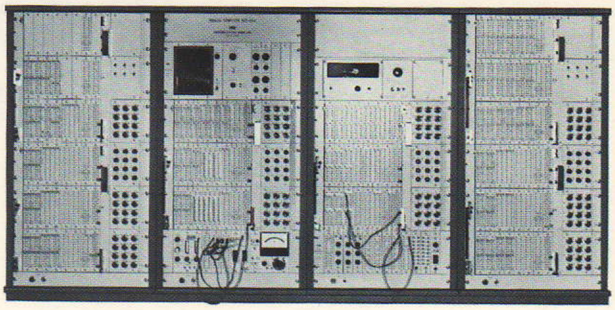


ANALOG COMPUTERS, SERIES 3300

The analog computer is a device that performs continuous and practically instantaneous computations and simulations by means of electrical components, which, when suitably interconnected, behave in the same manner as mathematical or physical processes. Analog computers may be contrasted with digital computers which solve problems by numerical computation. The most unique advantage of the analog computer is that the solution may be presented directly in the form of an intuitively perceivable, visual curve on a combined oscilloscope or X-Y recorder. Furthermore, the analog computer provides faster computation speed since the analog computer is a parallel device that processes all information simultaneously, and accordingly the time required to reach a solution is essentially unaffected by problem size. In general, the digital computer is rightfully rated higher in accuracy. However, there are many problems of which accuracy requirements are well within the capabilities of the analog computer. In addition, analog computers are usually less complicated, more easily programmed, and more readily adapted to the quick comparison of a large number of solutions.

The analog computer is extensively used as a general-purpose or specific-purpose computer or simulator in various scientific and industrial fields. The daily need for a compact, high-efficiency economical analog computer to eliminate errors and loss of man hours in manual computation has been rapidly increasing. On the other hand, research and experiment laboratories require large-scale analog computers for higher effectiveness in computation and analysis of complicated problems. Recently as computers become higher in accuracy and larger in size, there are seen more and more instances where a centralized computer room is established for common use. Since surroundings and applications for the analog computer are thus diversified, the analog computer, which has generally been said to be less flexible than a digital computer, must be flexible, too, so as to meet varied scientific and industrial requirements. With all of these exacting needs in mind, YEW developed flexible, versatile solid-state analog computers——YEW Series 3300. The YEW Series 3300 Analog Computer group employs the "building block" method in which computing capabilities can be extended as required, on the basis of Type 3301 Analog Computer as the minimum unit. Six types are available as the standard sizes. (Refer to the table of TYPES AVAILABLE on page 4.)

GENERAL DESCRIPTION



One of the most outstanding features of YEW Series 3300 Analog Computer family is that they have a summing integrator with a wide range of time constants covering both low speed computations and high speed repetitive computations. Due to the employment of this unique integrator, YEW Analog Computers can provide advantages of both high speed and low speed computations. Particularly, the YEW original "High Speed Repetitive Computation—Low Speed Conversion" method makes the YEW analog computers distinguished from all other analog computers in the market.
The following two types of computing systems are available for any 3300-Series Analog Computer:

High Speed Repetitive Computation—Low Speed Conversion Type

In this type of computing system the high-speed-computed solution waveforms are observed on a cathode-ray oscilloscope and at the same time recorded by an X-Y recorder after the solution is low-speed-converted by the unique sampling type waveform translator. The large waveforms on the X-Y recorder facilitate highly accurate readout. The adoption of sampling method enables the recorder to accurately record even such solutions as contain high frequency components. This system consists of computing elements accurate to 0.1%. This is recommended for high precision analysis in general laboratories.

High Speed/Low Speed Computations Selectable Type

This system is provided with a mode selection switch on its front panel to switch over from the high-speed repetitive computation to the waveform computation so that the solution shown on the cathode-ray oscilloscope may be recorded by an X-Y recorder or a pen-writing oscillograph. This system consists of computing elements with 0.5% accuracy. This is recommended for simple computation or educational training purposes.

To give full play to the functions as the analog computer, various types of linear and non-linear computing elements are made compatible with the YEW Series 3300 Analog Computers. The computing elements are all usable commonly for Types 3301 through 3306 Analog Computers. Therefore, the same accuracy is guaranteed in both small-size and large-size systems, and consequently building up from a small-size unit to a large-size system requires no extra device for adjustment.

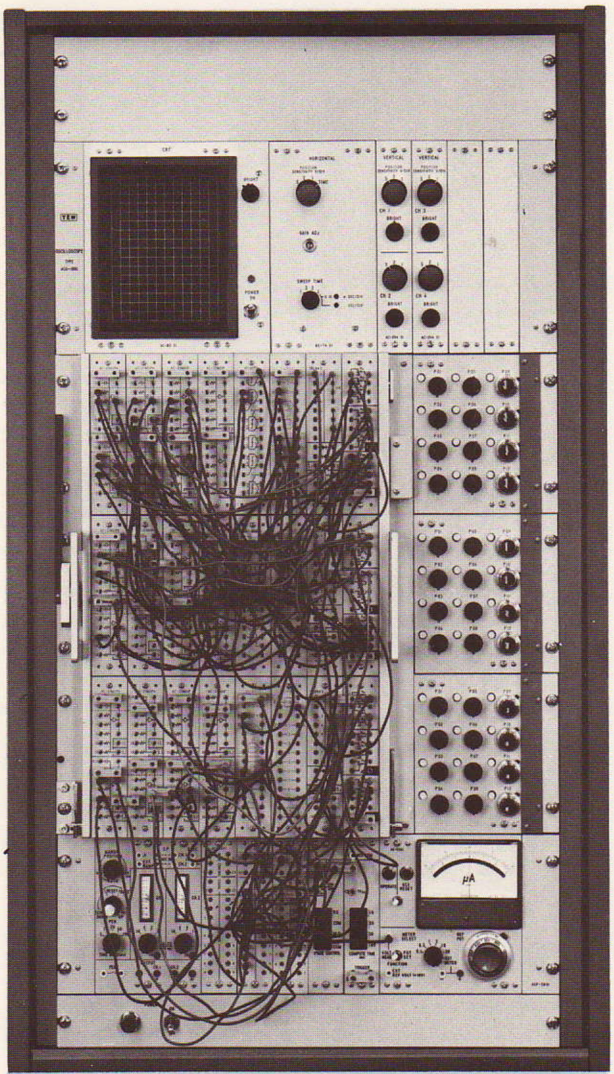
To sum up, the YEW Analog Computers are the products to exactly meet the requirements of today's scientific and industrial activities. They are epoch-making systems designed with an extremely rational mind on the basis of a long time experience of YEW in analog and pulse techniques.

FIELD OF APPLICATION

The scope of application of analog computers is limitless. The following are some examples of phenomena or systems that can be simulated by analog computers:

Field	Phenomena or Systems
Electric Power	Power system, characteristics of rotors.
Electronics	Linear and non-linear circuits, distributed constant system.
Automatic Control	Process analysis, designing of control units.
Atomic Power	Dynamic characteristics of atomic pile, control system.
Mechanical Engineering	Vibrations of beams, vibration system of springs.
Physics	Thermal propagation, sound system, fluid analysis.
Chemistry	Chemical reactions, reaction velocity.
Automobile	Riding comfort, change gears.
Aircraft	Computations of vibrations and stability.
Ship	Wakes
Architecture	Earthquake resistance of buildings and bridges.
Civil Engineering	Flood, tidal waves.
Mathematics	Non-linear differential equation, algebraic equation with multiple unknowns.
Biology	Environmental circumstances and growth of animals and plants.
Medicine and Physiology	Simulation of living bodies.
Economics	Business cycles, economic growth.

OUTSTANDING FEATURES



TYPES AVAILABLE

Analog Computer	Number of Operational Amplifiers incorporated	Prepatch Board
Type 3301	Max. 10	——
Type 3302	Max. 26	——
Type 3303	Max. 36	——
Type 3304	Max. 36	Provided
Type 3305	Max. 72	——
Type 3306	Max. 72	Provided

Completely Solid-State

All circuits are silicon-transistorized with increased reliability and less power consumption. Reduced size provides more convenience for operation.

High Precision

Computing elements are accurate to 0.1%. Highly stable metal film resistors and polystyrol condensers are used as computing impedances.

Accurate Recording of Solution

Accurate recording of any solution waveform is attributed to the sampling type waveform translator incorporated.

Summing Integrator with Two Selectable Time Constants

Time constant for integrator is changeable to 1 sec and 1/10 sec from the front panel for easier observation and analysis of solution variation.

Excellent Stability

FET choppers in operational amplifiers provide very stable operation with minimum drift.

Building Block System for Increasing Flexibility

Series 3300 Analog Computers employ "separate power supply system", so that a larger system can easily be made only by building up additional units on the basis of Type 3301, each of which has an individual power supply. Therefore, it is very easy to increase the computing capabilities.

Modular Construction

Computing elements fully employ modular construction to facilitate replacement or expansion as required.

Prepatch Boards with Graphic Display

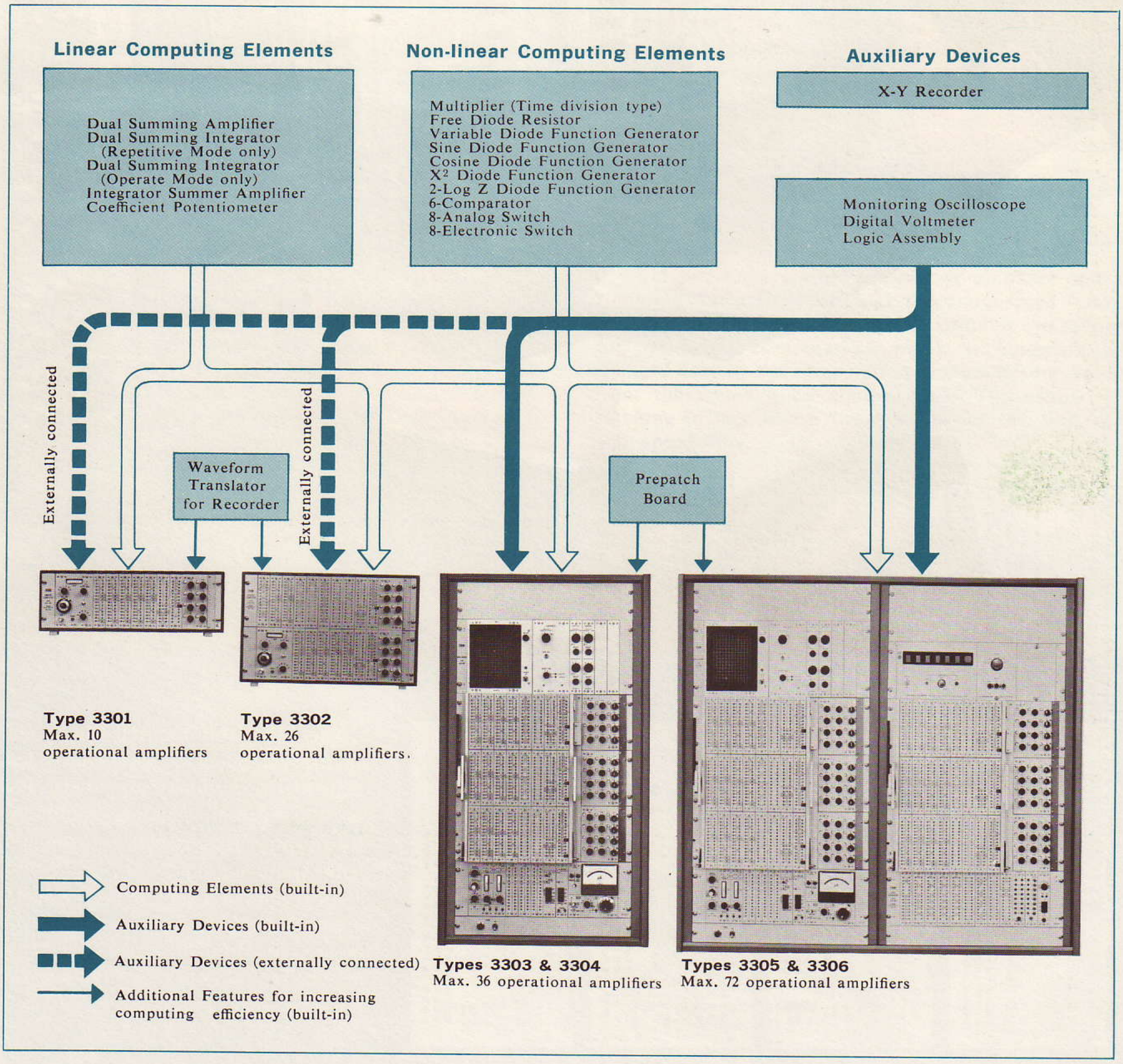
Very convenient for reference to block diagrams or drawings of operating principle.

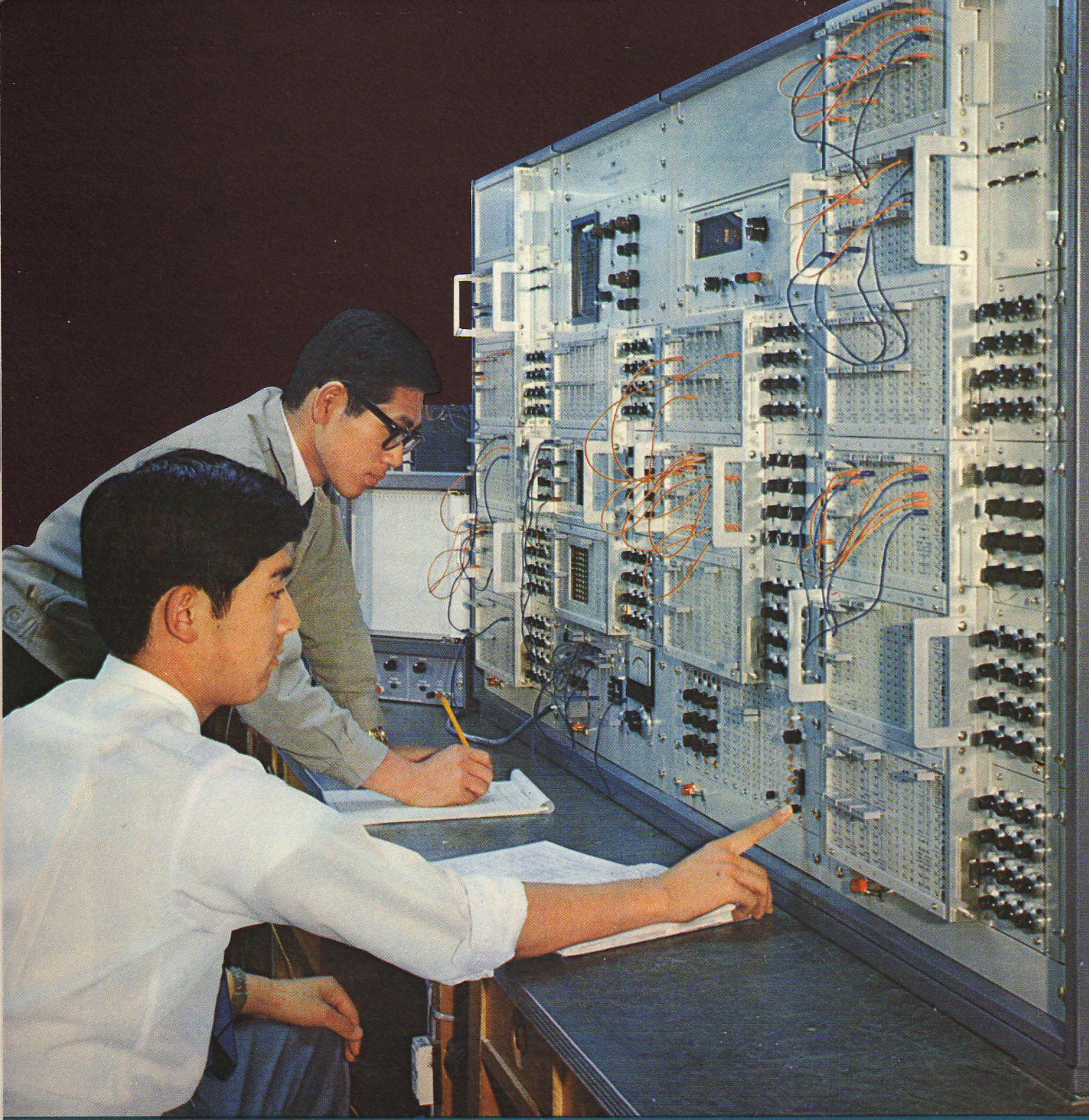
Applicable for Hybrid Computations

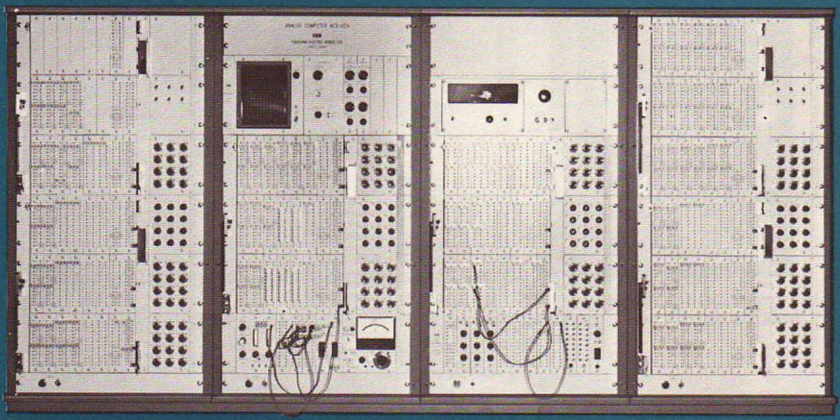
The large-scale system of 3300-Series can perform simple hybrid computations if digital logic units are incorporated. In addition, complicated large-scale hybrid computations can also be made if a digital computer is connected to the YEW analog computer.

"BUILDING BLOCK" EXPANSION SYSTEM

The YEW Series 3300 Analog Computer family is flexibly built up from the minimum unit of 10 operational amplifiers up to the large-scale system of 72 operational amplifiers. In other words, a system of minimum required size for a particular analysis can easily be composed by selecting exactly necessary computing elements only. The computing elements can freely be changed in accordance with the size of the problems. The variety of computing capabilities of YEW Analog Computers satisfies computing requirements better than any other analog computer ever produced in the world. The illustration below shows the entire line-up of the YEW Series 3300 Analog Computers including various computing elements.







The photo on the left shows an analog computer which is provided with 216 operational amplifiers, the so-called 216-unit analog computer. Its operational amplifiers are common with those equipped to the 10-unit analog computer and it employs six prepatch boards. This computer can be used for simulating power systems or pipeline networks and for analyzing large-scale processes.

FUNCTIONS OF COMPUTING ELEMENTS

LINEAR COMPUTING ELEMENTS

Coefficient Potentiometer

This is a 1-turn variable resistor for setting coefficients and can be set at an accuracy of 1/1000 by making this unit balance with the reference coefficient potentiometer provided in the computation control unit. A 10-turn helipot can be attached to the unit upon request.

Dual Summing Amplifier

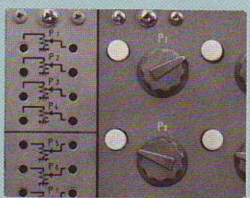
A pair of summing amplifier elements are contained in one unit. When a feedback circuit is made by shorting its upper right and left holes with a bottle plug and multiple inputs are connected to it, this unit provides summing functions and produces an output of reversed polarity. "SJ" is a summing junction terminal. In case there is only one input, this unit works just as a polarity reversing unit. If the feedback circuit formed by the bottle plug is removed, this unit becomes a high-gain operational amplifier, which is used for direct simulation of a control system by connecting arbitrary input impedance and feedback impedance through SJ (summing junction) terminals. It can also be used for non-linear coefficient generation if free diodes are used in combination with it.

Dual Summing Integrator

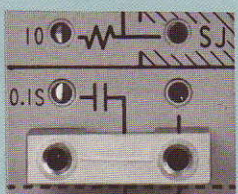
A pair of summing integrators specifically designed for high-speed computation are contained in one unit. When a feedback circuit is made by shorting either of its two upper capacitors with the output side by means of a bottle plug, and then a number of inputs are connected, this unit performs summation and integration and provides an output of reversed polarity. "IC" is a terminal for the initial value of variables at the output side and provides a reversed polarity. (Dual summing integrator specifically designed for low-speed computation to be used for applied measurement is also available upon request.)

Integrator Summer

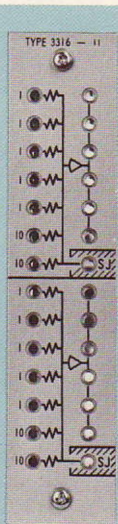
This unit consists of a summing amplifier and a summing integrator for high-speed/low-speed computation. The summing integrator contains a capacitor for low-speed computation which is automatically changed over by the computation mode selecting signal from the computation control unit. The method of patching in this unit is the same as in the unit for high-speed only.



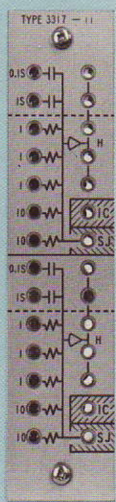
Coefficient Potentiometer



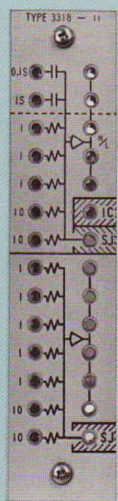
Feedback Circuit (by shorting with bottle plug)



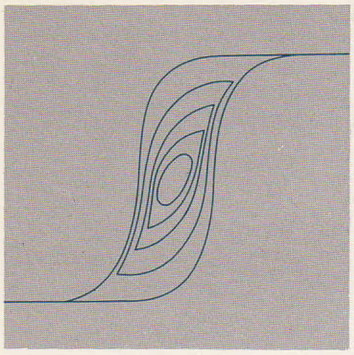
Dual Summing Amplifier



Dual Summing Integrator



Integrator Summer



NON-LINEAR COMPUTING ELEMENTS

Multiplier (Time Division Type)

This is a high-efficiency multiplier which employs the time division technique of multiplication. By changing the position of the bottle plugs, a single unit can perform the three functions of multiplication, division and square root.

Free Diode Resistor

This resistor consists of a unit which provides reference voltages of +10 V and −10 V and two diodes which are incorporated into the unit. This resistor is used in combination with computing elements to generate various non-linear elements (saturation, dead band simulation and hysteresis).

Variable Diode Function Generator

This unit approximates an arbitrary function by means of 10 broken lines. The position and inclination angle of each broken line can be adjusted from the holes on the surface of the patch board with a screwdriver.

Fixed Diode Function Generator

This unit generates a fixed function which is approximated beforehand by broken lines.

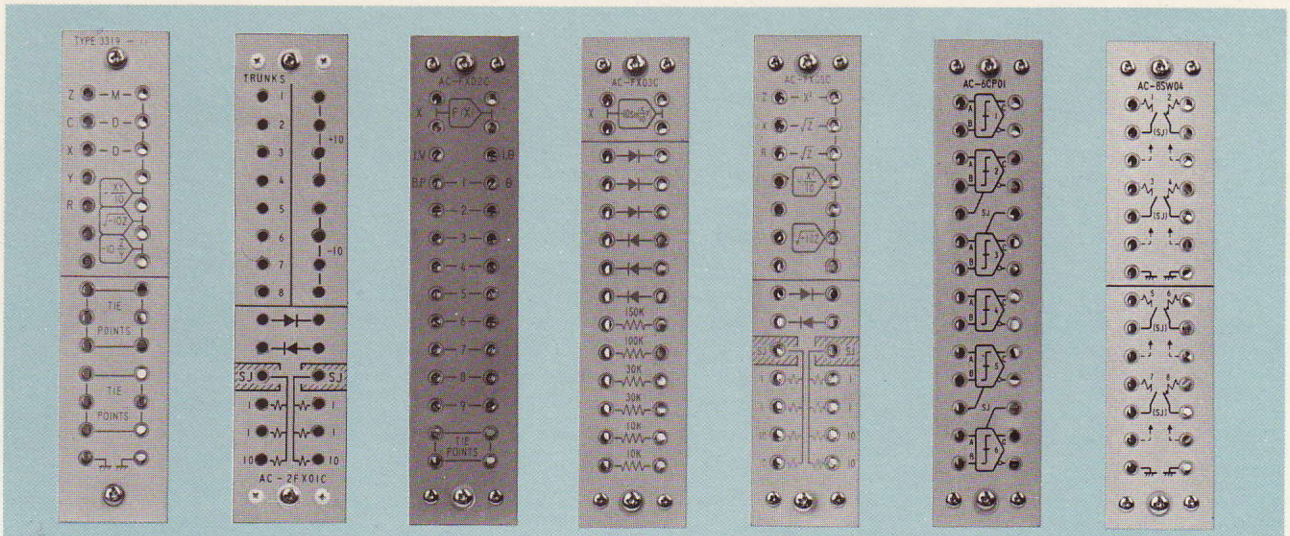
The following kinds of fixed function generators are available:
Sine Diode Function Generator
Cosine Diode Function Generator
X^2 Diode Function Generator
2-Log Z Diode Function Generator

6-Comparator

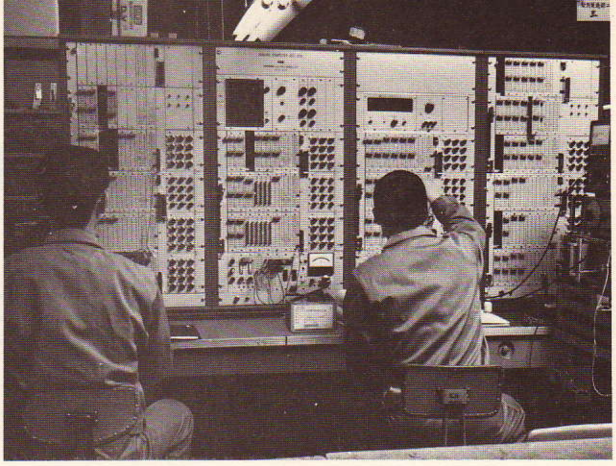
This unit contains six voltage comparators. In combination with an 8-Analog or an 8-Electronic Switch, this unit is used for signal changeover or used as a non-linear element such as saturation, absolute value, etc. This unit is also used in combination with a Logic Assembly for logic computations.

8-Analog Switch
8-Electronic Switch

The 8-Analog and 8-Electronic Switches are electronic switches, the former using mechanical relays and the latter using FET's. Each of these units is composed of four pairs each of make-contacts and break-contacts, which are used being connected to the SJ terminals of Summer or Integrator.



Multiplier (Time Division Type) | Free Diode Resistor | Variable Diode Function Generator | Sine Diode Function Generator | X^2 Diode Function Generator | 6-Comparator | 8-Electronic Switch

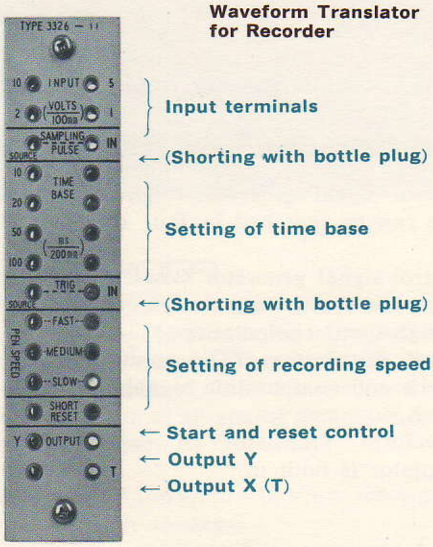


WAVEFORM TRANSLATOR FOR RECORDER

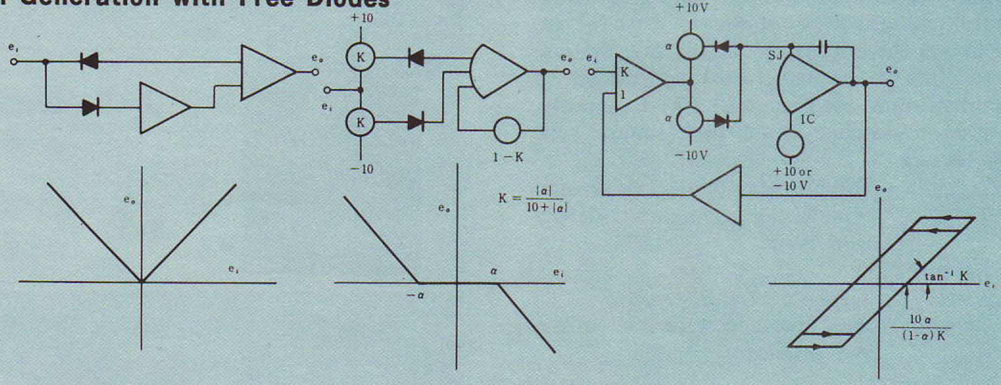
For analysis of low-speed-computed solution waveforms, a pen-writing oscillograph having a frequency response of about 100 Hz is generally used.

However, the recording width of a pen-writing oscillograph is 40 mm or so, and it is difficult to expect a better accuracy than 2～3% from it.
This means that the record analysis by low-speed conversion places a limit on the final recording accuracy even if the accuracy of the computing element is increased.
In high-speed computation, each single computation is performed within a very short time and this computation is repeated. Once the coefficient is fixed, the same solution waveforms are repetitively obtained. Using pulse techniques, this Waveform Translator samples these continuously repetitive waveforms point by point and strings up these points, thereby converting them into waveforms which are completely analogous to the original waveforms, changing so slowly that the X-Y recorder can follow. Since the amplitude and time scale on the recording paper accurately correspond to those of the solution waveform and only the recording speed is converted to a lower speed, the waveform is reproduced on the recording paper with an accuracy of ±0.5%, however complicated it may be.
Since high-speed computation is continued even when recording is being carried out, there is no need of changing over the integrating time constant (capacitor of integrator) from a high speed to a low speed by means of a relay or the like.
Consequently, the translator reliability increases and it provides a solution waveform which is very stable and has excellent reproducibility. A solution waveform at a different parameter can also be recorded being superposed on the same recording paper, and this feature provides convenient comparative observation.

Waveform Translator for Recorder



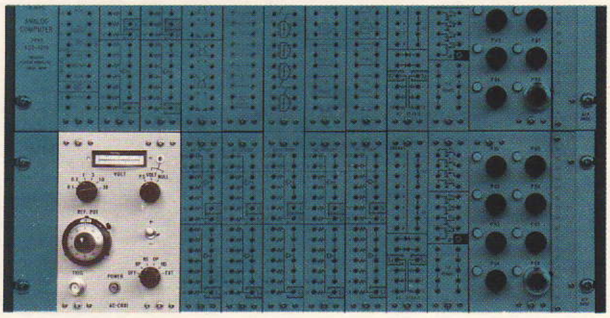
Function Generation with Free Diodes



COMPUTATION CONTROL UNITS AND AUXILIARY DEVICES

TYPE A CONTROL UNIT

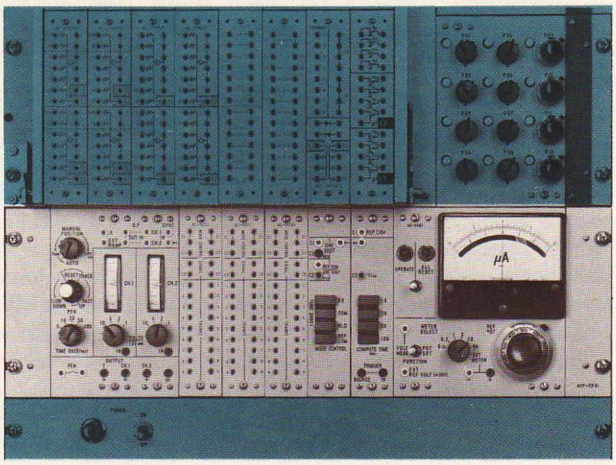
This is a control unit to be used for Types 3301 and 3302 Analog Computers. It consists of a computation controller for start, rest and stop, a voltmeter to measure computation output voltages or set the coefficient potentiometer accurately, and a reference coefficient potentiometer. The high-speed computation time is a constant 55 ms.



TYPE A CONTROL PANEL

This is a console-type control panel for Types 3303 (3304) and 3305 (3306) and consists of the following components:

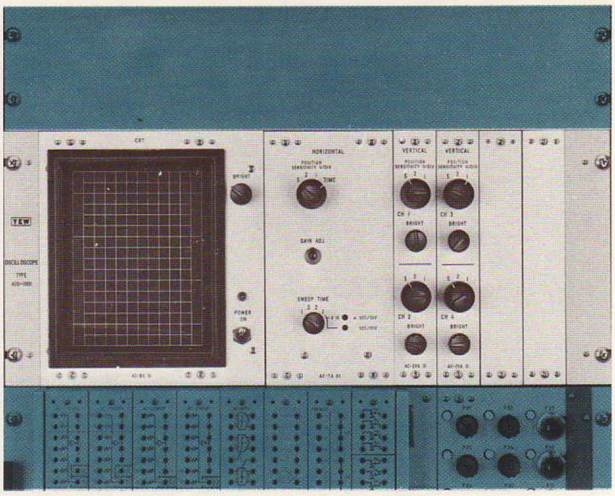
- Power source for reference voltage (provided with a reference coefficient potentiometer and a voltmeter)
- Control signal generator (high-speed) (Computation time can be switched in four stages of 10/20/50/100 ms.)
- Control signal generator (low-speed) (This unit performs low-speed computation control and switching of high-speed computations.)
- Signal distribution (This unit distributes control signals and computation signals to their respective panels.)
- Waveform Translator (A two-channel waveform translator is built in.)



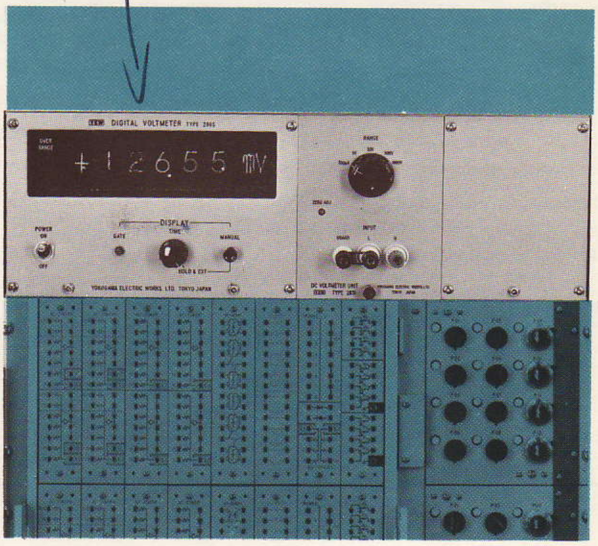
CATHODE-RAY OSCILLOSCOPE FOR MONITORING

This oscilloscope is used for monitoring the solution waveforms on a high-speed computer. With this oscilloscope employing the brightness modulation system, it is possible to observe the waveforms and phases of four channels (maximum six channels) simultaneously. The cathode-ray oscilloscope is a 9 inch square type and very easy to see.

System:	Brightness modulation system
Cathode-ray Oscilloscope:	9-inch electromagnetic deflection type
Number of Channels:	4
Vertical Amplifier:	1/2/5 V; accuracy ±5%
Time Base:	Synchronized with control signal generator



ersetzen durch Type 2502



DIGITAL VOLTMETER <TYPE 2805>

This is an extremely stable, noise-rejected integrating type digital voltmeter capable of 10 μV resolution. It is used for calibration of computing voltages, measurement of output voltages of computing elements and setting of the coefficient potentiometer.

Measurement Method:	Feedback pulse width modulation counting method
Max. Indication:	59900
Accuracy:	$\pm 0.01\%$ of reading ± 1 digit

DELAY DEVICE

As a dead time element, this device is used for a process simulator and for forecasting business cycles. It maintains the amplitudes of input signals as they are and delays time only. Delay time can be changed with the dial. Since this device adopts the delay circuit of a newly developed $\Delta - \Sigma$ modulation system, there is no disturbance in waveforms at rise time as is experienced with the Padé system.

LOGIC ASSEMBLY <TYPES 3351 & 3352>

This assembly widens the scope of application of analog computers. It is capable of such functions as logic judgement, counting and storage, and makes possible such automatic computations as A-D/D-A conversion and sequence control.

Type 3351 Logic Assembly consists of the following units:

Level Inverter	1
10-Nand Gate	4
4-Flip-Flop	1
G.P. Resistor Counter	1
G.P. Indicator	1
Clock and G.P. Indicator Terminal	1
Flip-flop Indicator	1
Clock Generator	1
Tie Points	1

For details, a separate catalog is available.

X-Y RECORDER <TYPE 3077>

This is a single-pen X-Y recorder to be used in combination with the Waveform Translator for Recorder. It has a recording area of 250×250 mm and records the solution waveform of an analog computer accurately and in a large form.

Voltage Divider:	0.1 mV/cm～10 V/cm (changed over in 16-steps)
Accuracy:	$\pm 0.3\%$ of full scale span

HOW TO SELECT COMPUTING ELEMENTS

1. First determine the approximate number of units of operational amplifiers according to the scale of your computation and the probable future expansion of your analog computer.

Select the most suitable analog computer from the following according to the number of units (operational amplifiers) required (see page 5).

If you require less than 10 units:	Type 3301 Analog Computer
If you require 11 to 26 units:	Type 3302 Analog Computer
If you require 25 to 36 units:	Type 3303 or Type 3304 (Prepatch system) Analog Computer
If you require 37 to 72 units:	Type 3305 or Type 3306 (Prepatch system) Analog Computer

Then select the ones you require out of a variety of computing elements, while making sure that the number of computing elements, you have selected is within the number of units shown in the following table (Do not include the Coefficient Potentiometer nor Dual Free Diode Resistor in the number):

Type	3301	3302	3303 · 3304	3305 · 3306
Number of Units	5	13	18	36

Count the Waveform Translator for Recorder as one of the above-mentioned computing elements.

2. How to Select Summing Integrator

For high-speed computation and high-accuracy analysis, use:

Dual Summing Integrator (Code 331711)

Note: When Type 3301 or 3302 Analog Computer is employed for high-speed computation and high-accuracy analysis, add one Waveform Translator for Recorder.

For high-speed computation plus low-speed-computed solution waveform recording, use:

Integrator Summer (Code 331811)

For low-speed computation such as in applied measurement, use:

Dual Summing Integrator (Code 331751)

3. How to Select Coefficient Potentiometer

The one-turn Coefficient Potentiometer is sufficient for all purposes. The ten-turn Coefficient Potentiometer has the advantage of making the setting of coefficients slightly smoother. The number of Coefficient Potentiometers that can be equipped to various analog computers is shown in the following table:

Type	3301	3302	3303 · 3304	3305 · 3306
Number of Units	8	16	36	72

4. How to Select Type A Control Panel (For Types 3303~3306 Analog Computers)

The component units of the panel vary according to computing systems.

High-speed computation:
- Control Signal Generator (low-speed) is not required.

High-speed/low-speed computation selectable type:
- Waveform Translator is not required.

Low-speed computation:
- Neither Control Signal Generator (high-speed) nor Waveform Translator is required.

Three units of Signal Distributors are required in any case.

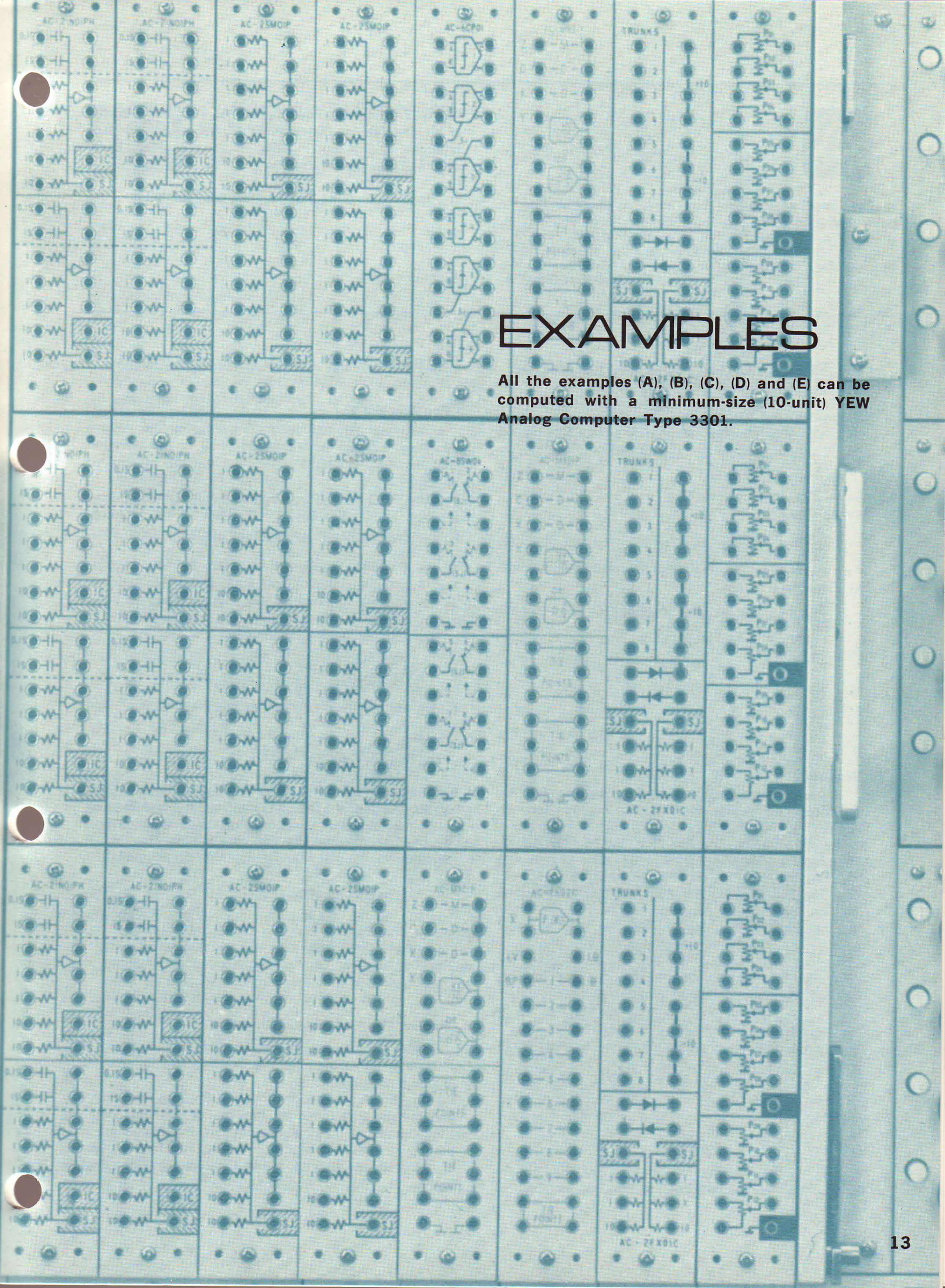
5. Other Devices

The 36-unit Analog Computer can be provided with the following devices: One Monitoring Oscilloscope, or any two units out of the Digital Voltmeter, Delay Device and Logic Assembly.
The 72-unit Analog Computer can be equipped with one each of all the above-mentioned devices.

▶ For Educational Training Use ◀

The following computing elements having 0.5% computation impedance accuracy are also available for training students on analog computers:

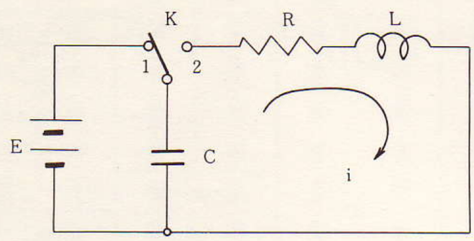
Dual Summing Integrator (for high-speed)	Code 331721
Dual Summing Integrator (for low-speed)	Code 331761
Integrator Summer	Code 331821
Dual Summing Amplifier	Code 331621
Coefficient Potentiometer	Code 331531



EXAMPLES

All the examples (A), (B), (C), (D) and (E) can be computed with a minimum-size (10-unit) YEW Analog Computer Type 3301.

A



In a series resonance circuit, the switch K is placed to E side to charge the capacitor C, and next, the switch is placed to L-R side. Then, let us observe the state of this discharging current.

$E=6.94\ V$, $C=1.2\ \mu F$, $L=5.1\ mH$, $R=20\Omega$

(I) FROM FORMATION OF EQUATION TO PREPARATION OF BLOCK DIAGRAM

〈Formation of Equation〉

If the circuit current at the time switch K is placed to L-R side is denoted by i, we obtain

$$L\frac{di}{dt}+Ri+\frac{1}{C}\int idt=0 \quad \text{.......(1)}$$

Since $\int idt=q$, we obtain

$$L\frac{d^2q}{dt^2}+R\frac{dq}{dt}+\frac{q}{C}=0;\ \text{if } t=0,\ q=CE \quad \text{.......(2)}$$

If we divide the equation (2) by L and substitute numerical values, we obtain

$$\frac{d^2q}{dt^2}+3.92\times10^3\frac{dq}{dt}+1.63\times10^8q=0;$$
$$\text{if } t=0,\ q=8.33\times10^{-6} \quad \text{.......(3)}$$

〈Scaling〉

In computation with an analog computer, the independent and dependent variables are replaced by time and a voltage respectively. Since the range of computation voltages of the YEW Series 3300 Analog Computers is -10 V through $+10$ V, it is necessary that variations in the voltage of dependent variables be within this range. If we assume that the variable in the computer, which corresponds to the actual variable q, is Q volts, we obtain the following conversion:

$$Q=\alpha q \quad \text{.......(4)}$$

α is called the "scale factor" and can generally be obtained from the following equation:

$$\alpha\leqq\frac{\text{Max. computation voltage}}{\text{Max. value of dependent variable}} \quad \text{.......(5)}$$

In the present problem, we obtain from the equation (3)

$$\alpha\leqq\frac{10}{8.33\times10^{-6}}=1.2\times10^6 \quad \text{.......(6)}$$

In consideration of convenience in later conversion, we select $\alpha=10^6$.
The equation after the scaling will be

$$\frac{d^2Q}{dt^2}+3.92\times10^3\frac{dQ}{dT}+1,63\times10^8Q=0;$$
$$\text{if } t=0,\ Q=8.33 \quad \text{.......(7)}$$

〈Time Scaling〉

Although the equation (7) has given the voltage which is within the range of $+10$ V, the solution contains $\omega=\sqrt{1.63\times10^8}$, a frequency component of about 2 kHz.
Because of the frequency response of the computing element and the necessity of recording the solution, it is necessary to do time scaling to reach near $\omega=1$.

$$T=\beta t \quad \text{.......(8)}$$

where T is the computer time after the time scaling and β is the so-called "time scale factor."
To make $\omega=1$ in this problem, it is necessary to make $\beta=\sqrt{1.63\times10^8}=1.28\times10^4$, but we adopt $\beta=10^4$ for the convenience of later conversion.
Now, since $T=10^4t$, we obtain

$$\frac{dQ}{dt}=10^4\frac{dQ}{dT},\quad \frac{d^2Q}{dt^2}=10^8\frac{dQ}{dT}$$

If we substitute the above into the equation (7) and rearrange it, we obtain

$$\frac{d^2Q}{dT^2}+0.392\frac{dQ}{dT}+1.63Q=0;$$
$$\text{if } t=0,\ Q=8.33$$

Here, the differential term of the highest degree in the above equation is kept at the left side, while the rest of the terms are transposed to the right side for preparation of the next step.

$$\frac{d^2Q}{dT^2}=-0.392\frac{dQ}{dT}-1.63Q;$$
$$\text{if } t=0,\ Q=8.33 \quad \text{.......(9)}$$

〈Preparation of Block Diagram〉

Now we will illustrate by block diagrams (Figs. 1~3) how to solve the equation (9) by the combination of computing elements.
Set up a series connection of two Summing Integrators and assume that the input terminal a is d^2Q/dT^2.
Every time the input signal passes through one computing element, the sign is inverted, and the voltages at points b and c bring about the relation illustrated in Fig. 1.

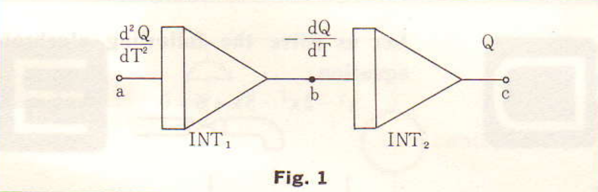


Fig. 1

Take out these signals of -dQ/dT and Q and form the terms on the right side of the equation (9). Now, a value above 1 cannot be set by the Coefficient Potentiometer. Therefore, in order to set the value of 1.63, set 0.163 on the Coefficient Potentiometer and multiply the gain of the computing element ten times.

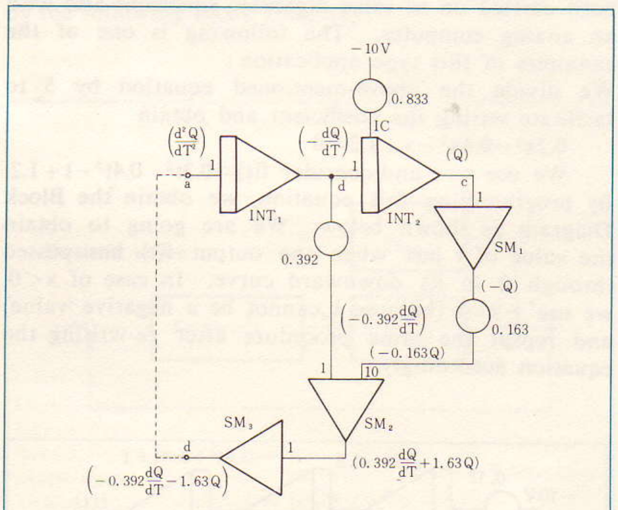


Fig. 2

The equation (9) means that the voltages at points a and d in the diagram (Fig. 2), which was formed in the way explained above, are equal. Therefore, the Block Diagram can be completed for the time being by connecting these two points by a dotted line. The initial value of Q is given to the IC terminal of INT_2 by inverting its sign at the output side.

On looking closer at the diagram in Fig. 2, it is found that INT_1, a Summing Integrator, can add and integrate a multiple number of inputs. Thus SM_2 and SM_3 become unnecessary; and finally, the Block Diagram shown in Fig. 3 is completed.

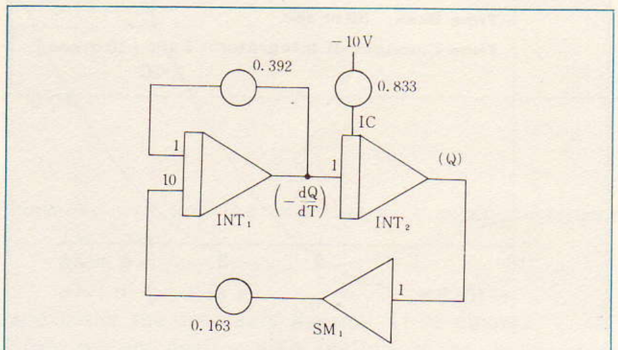
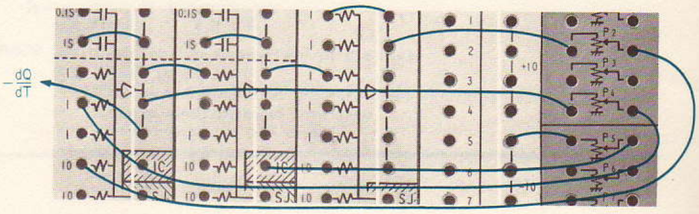
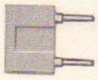


Fig. 3

(II) PATCHING

Patch cords are used in connecting computing elements according to the Block Diagram. The time constant of the Summing Integrator is ordinarily set at 1S. A bottle plug can be conveniently used for connecting two adjoining units.

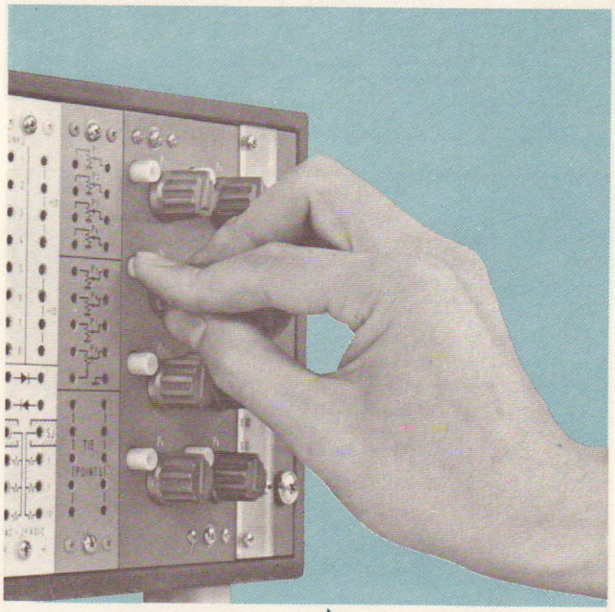




Bottle Plug

(III) SETTING OF COEFFICIENT POTENTIOMETER

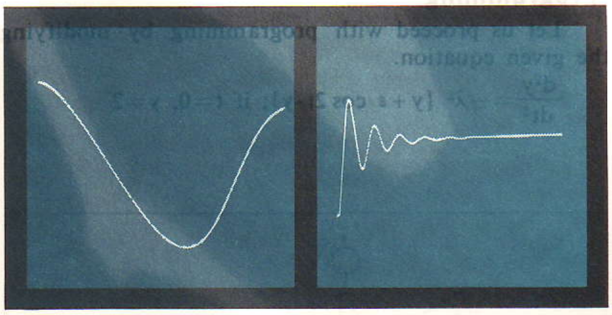
Set the computation mode switch to RS and the voltmeter function switch to PS. For setting the value of, say, 0.29, first set the REF POT of the Computation Control Unit to 0.29. Then while depressing the setting push-button of the Coefficient Potentiometer to be set, using the index finger of the right hand, turn the knob with the thumb and middle finger, so that the pointer deflection of the voltmeter comes to zero (center).



Next for (IV)

(IV) HIGH-SPEED COMPUTATION

After the setting of the potentiometer is completed, turn the computation mode switch to RO, and the high-speed computation state is assumed. Introduce the solution voltages into the Oscilloscope, and the solution waveforms can be observed. If the output of the TRIG terminal of the Computation Control Unit is used as the horizontal synchronizing signal of the Oscilloscope, stationary waveforms can be obtained. If the time constant of the Summing Integrator is set at 0.1S, waveforms, which are made slower, as if the computation time were elongated ten times, can be obtained. Therefore, you can analyze the initial state in detail at the setting of 1S and find the general trend at the setting of 0.1S.



At 1S　　　At 0.1S

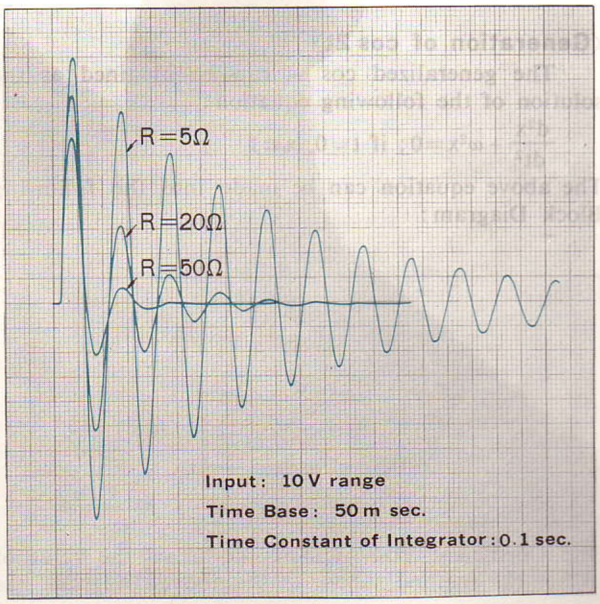
(V) SOLUTION RECORDING BY LOW-SPEED COMPUTATION

Introduce the solution voltage into the input terminal of the pen recorder. Set the computation mode switch first to RS. Select the proper sensitivity of the pen-recorder and start feeding the recording paper. Then change over the computation mode switch to OP, and the low-speed computation will start and the solution waveform will be obtained on the recording paper. The waveforms on the cathode-ray oscilloscope naturally disappear during low-speed computation.

(VI) SOLUTION RECORDING BY WAVEFORM TRANSLATOR

Introduce the solution voltage into the input terminal of the Waveform Translator and connect its output terminal with the X-Y Recorder. Set TIME BASE ordinarily to 50 ms, and set PEN SPEED to FAST if the waveforms are simple ones, to SLOW if the waveforms are complicated ones, and to MEDIUM in ordinary cases. Short the holes of SHORT RESET beforehand with a bottle plug. While maintaining the state of high-speed computation, lower the pen of the X-Y Recorder, remove the bottle plug, and the waveform will be recorded from left to right. Lift the pen and insert the bottle plug, and the pen will return to its original position.

SOLUTION WAVEFORM



B

Let us analyze the following Mathieu's equation*:

$$\frac{d^2y}{dt^2}+\lambda^2(1+\varepsilon\cos 2t)\,y=0;$$

if $t=0,\ y=2$

*Mathieu's equation is used when Laplace's equation is analyzed by means of cylindrical coordinates and when vortex movement in an elliptical cylinder or attenuation of magnetic force in a metallic cylinder is analyzed. It is one of the most important equations in electrical and mechanical engineering.

If we assume that coefficients λ and ε have the following values, we can proceed with programming immediately without scaling:

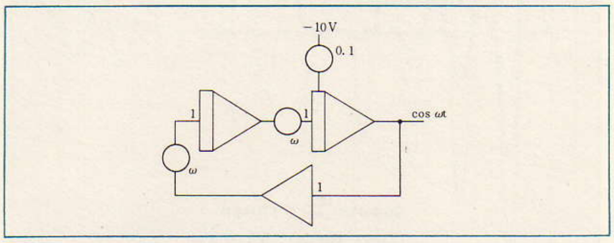
$10\geqq\lambda>0,\ 1\geqq\varepsilon>0$

〈Generation of cos 2t〉

The generalized cos ωt can be obtained as the solution of the following equation:

$$\frac{d^2x}{dt^2}+\omega^2x=0;\ \text{if } t=0,\ x=1$$

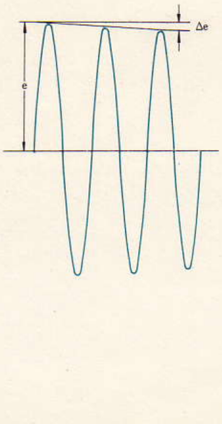
The above equation can be made into the following Block Diagram:



One Coefficient Potentiometer could set the value of ω^2 but the method shown in the above Diagram has been adopted, because ω can be directly read out and the unbalance among the computation voltages of the respective computing elements can be diminished.

〈Circle Test〉

A trigonometrical function is generated by setting the above-mentioned ω to 1, and the quantity of attenuation of its amplitude is used as a guide in judgement of the characteristics of the analog computing element (see the specifications on p. 20).



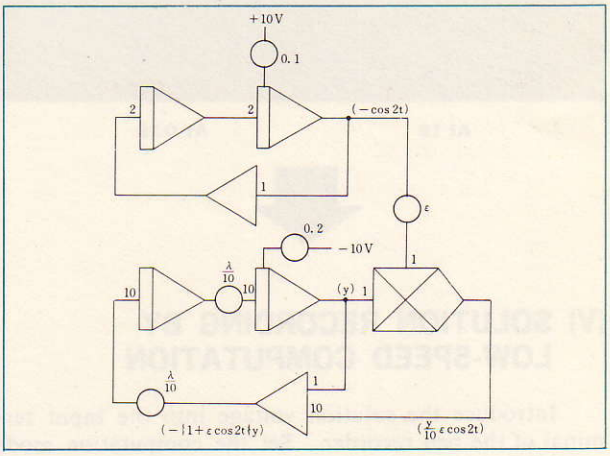
Circle Test:

$$\frac{\Delta e}{e}\times 100\%$$

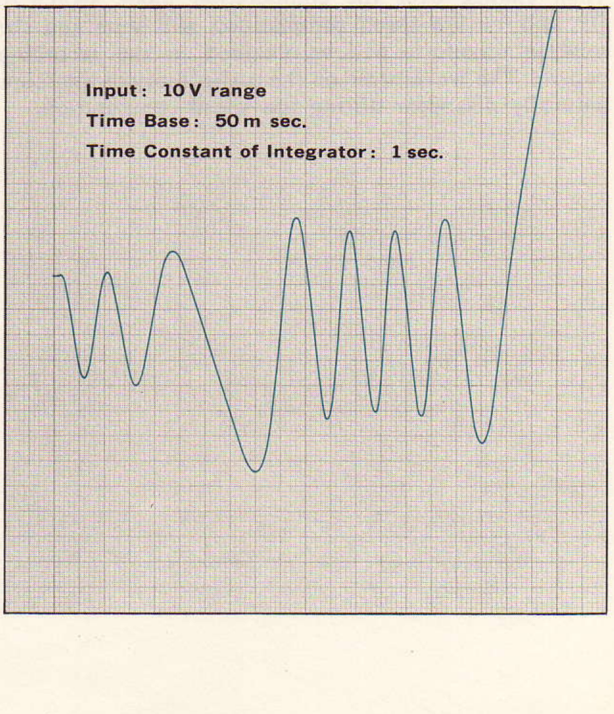
〈Programming〉

Let us proceed with programming by modifying the given equation.

$$\frac{d^2y}{dt^2}=-\lambda^2\{y+\varepsilon\cos 2t\cdot y\};\ \text{if } t=0,\ y=2$$



EXAMPLE OF SOLUTION WAVEFORM (λ=10, ε=1.0)



C

Let us analyze the following simultaneous differential equations with two unknowns:

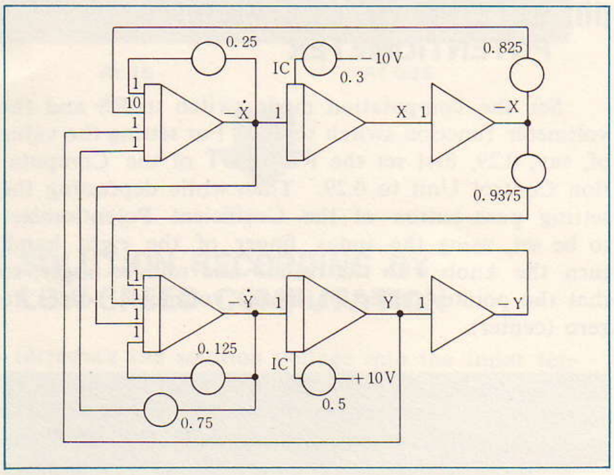
$$2\ddot{x}+\dot{x}+3\dot{y}+66x-8y=0$$
$$4\ddot{y}+\dot{y}+8\dot{x}+16y+15x=0$$
$$\text{If } t=0,\ x=3,\ y=-5,\ \dot{x}=\dot{y}=0$$

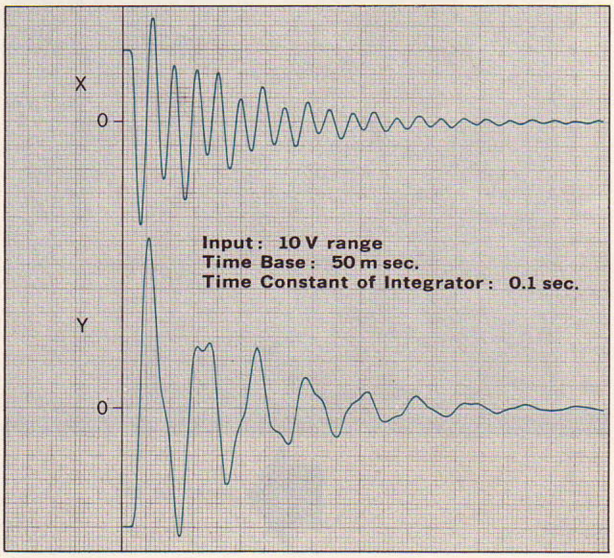
First we divide the above equations respectively with the coefficients of $\ddot{x}$ and $\ddot{y}$, and obtain

$$\ddot{x}+0.5\dot{x}+1.5\dot{y}+33x-4y=0$$
$$\ddot{y}+0.25\dot{y}+2\dot{x}+4y+3.75x=0$$

Then we assume that T=2t and perform the time scaling of the above equations to obtain

$$\ddot{X}=-0.25\dot{X}-0.75\dot{Y}-8.25X+Y$$
$$\ddot{Y}=-0.125\dot{Y}-\dot{X}-Y-0.9375X$$
$$\text{If } T=0,\ X=3,\ Y=-5,\ \dot{X}=\dot{Y}=0$$





D

Let us solve the following algebraic equation:

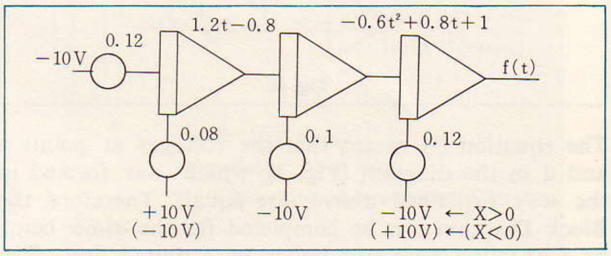
$$x^3-2x^2-5x+6=0$$

The analysis of differential equations is the specialty of an analog computer, but various studies have been carried on to solve algebraic equations also with an analog computer. The following is one of the examples of this type application:

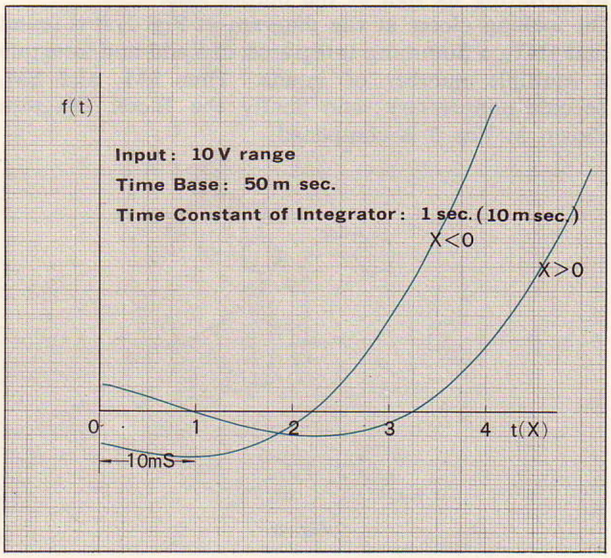
We divide the above-mentioned equation by 5 to facilitate setting the coefficient, and obtain

$$0.2x^3-0.4x^2-x+1.2=0$$

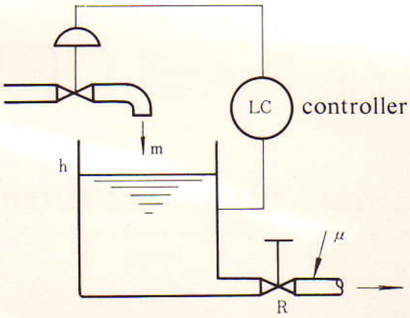
We use x=t and consider $f(t)=0.2t^3-0.4t^2-t+1.2$. By programming this equation, we obtain the Block Diagram as shown below. We are going to obtain the value of t just when the output f(t) has passed through 0 in its downward curve. In case of $x<0$, we use $-x=t$ (because t cannot be a negative value) and repeat the same procedure after re-writing the equation accordingly.



SOLUTION WAVEFORM



E

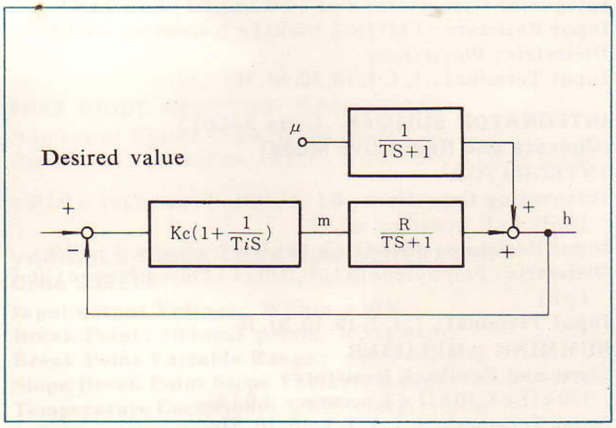


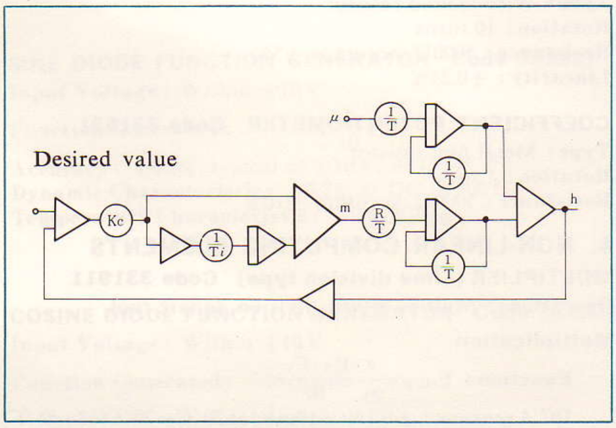
Suppose there is an automatic control system that maintains a constant level of water in a tank. Let us analyze the level variations that may occur when the piping undergoes pressure changes (external disturbances).
The transfer function of the water level system can be expressed by the following equation:

$$h=\frac{R}{TS+1}m+\frac{1}{TS+1}\mu$$

where h: Level change component of the tank
R: Piping resistance
μ: Change component of pressure head of piping
m: Change component of flow rate
T: Time constant of the tank

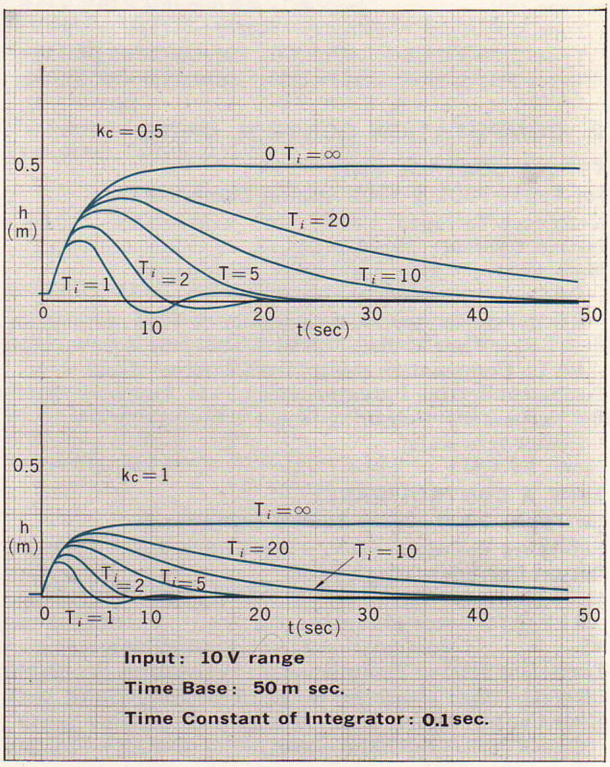
If we assume that the controller performs PI (proportional + integral) control, this system can be expressed by the following Block Diagram:





Now we will find the variation of h when we assume
T=12 sec
R=6.8 m^3/sec
μ=1 m (=+10 V)
and cause the constants Kc and Ti to change.
Since we are dealing with analysis of the change component, the desired value will be 0.

SOLUTION WAVEFORM



SPECIFICATIONS

1. GENERAL SPECIFICATIONS

Reference Voltage: +10 V, −10 V with accuracy ±0.1%
Circle Test: High Precision High Speed type; ±0.05%/cycle ($\tau=10^{-3}$, coefficient=1). High-Speed/Low-Speed Computations Selectable type; ±1.0 %/cycle ($\tau=1$, coefficient=1)
Normal Operating Condition: Temperature; 5~35°C (41~95°F) Humidity; 80% Max.
Power Supply: AC 220V ±10%, 50~60 Hz. Other Voltages are also available upon request.
Dimensions:
Type 3301............... 166×497×400 mm (6½×19¾×15¾″)
Type 3302............... 316×497×400 mm (12½×19¾×15¾″)
Types 3303 & 3304...... 992×570×550 mm (39×22½×20⅝″)
Types 3305 & 3306......992×1100×550 mm (39×43¼×20⅝″)

2. COMPUTATION CONTROL UNITS

TYPE A CONTROL UNIT
for Types 3301 & 3302 Analog Computers

Reference Voltage: +10 V, −10 V with accuracy ±0.1%.
Output Current: 50 mA Max.
Mode Control: OFF; power off. RS; reset. OP; operate. HD; hold.
RO; repetitive operation. Computation Time; 55ms ±3ms. Rest Time; 5 ms ±3 ms at 50 Hz, 12 ms ±3 ms at 60Hz.
EXT; Computation control from external signal
Coefficient Setting Potentiometer: 5 kΩ. Linearity; ±0.1%
DC Voltmeter: Measuring range; 0.1/0.3/1/3/10/30 V (center-zero scale)

TYPE A CONTROL PANEL
for Types 3303~3306 Analog Computers

Reference Voltage: +10V, −10V with accuracy ±0.05%
Output Current: 200 mA Max.
Mode Control: RS; reset. COM; operate. HLD; hold. REP COM; repetitive operation.
Computation Time; 10/20/50/100 msec
Coefficient Setting Potentiometer: 5k Ω. Linearity; ±0.05%
DC Voltmeter: Measuring range; 0.1/0.3/1/3/10/30 V
Mode Control Signal Distribution:
C_1; COMPUTE/RESET signal
C_2; τ/100 signal
C_3; HOLD signal
Sampling Type Waveform Translator:
Number of Channels; 2
Input; ±1/2/5/10 V
Time Base; 5/10/20/50/100 msec
Output Voltage; ±1 V
Recording Speed; 30~120 sec/trace
Accuracy: ±0.5%

3. LINEAR COMPUTING ELEMENTS

DUAL SUMMING AMPLIFIER Code 331611

Input and Feedback Resistors: 100 kΩ×5, 10 kΩ×2, accuracy ±0.1%
Input Terminal: 1, 1, 1, 1, 1, 10, 10, SJ
Coefficient: 0.1, 1, 10

DUAL SUMMING INTEGRATOR Code 331711
(Repetitive Mode only)

Integrating Capacitors: 0.1 μF, 0.01 μF, accuracy ±0.1%
Input Resistors: 100 kΩ×3, 10 kΩ×2, accuracy ±0.1%
Dielectric: Polystyrene
Input Terminal: 1, 1, 1, 10, 10, SJ, IC

DUAL SUMMING INTEGRATOR Code 331751
(Operate Mode only)

Integrator Capacitors: 1 μF (±0.3%), 0.1 μF (±0.1%)
Input Resistors: 1 MΩ×3, 100 kΩ×2, accuracy ±0.1%
Dielectric: Polystyrene
Input Terminal: 1, 1, 1, 10, 10, SJ, IC

INTEGRATOR SUMMER Code 331811
(Operate and Repetitive Mode)

INTEGRATOR
Integrating Capacitors: 0.1 μF, 0.01 μF, accuracy ±0.1%; 10 μF, 1 μF, accuracy ±0.5%
Input Resistors: 100 kΩ×3, 10 kΩ×2, accuracy ±0.1%
Dielectric: Polystyrene (0.1μF, 0.01μF) Polycarbonate (10μF, 1 μF)
Input Terminal: 1, 1, 1, 10, 10, SJ, IC
SUMMING AMPLIFIER
Input and Feedback Resistors: 100 kΩ×5, 10 kΩ×2, accuracy ±0.1%
Input Terminal: 1, 1, 1, 1, 1, 10, 10, SJ

COEFFICIENT POTENTIOMETER Code 331511

Type: Wire-wound resistor
Rotation: 10 turns
Resistance: 5000Ω, accuracy ±5%
Linearity: ±0.25%

COEFFICIENT POTENTIOMETER Code 331521

Type: Metal film resistor
Rotation: 1 turn
Resistance: 5000Ω, accuracy ±10%

4. NON-LINEAR COMPUTING ELEMENTS

MULTIPLIER (Time division type) Code 331911

Operations: Multiplication, division, square root

Multiplication

Function: $E_{OUT} = -\frac{Ex \cdot Ey}{10}$

DC Accuracy: ±0.1% (±10mV) at 20°C~30°C (68~86°F)

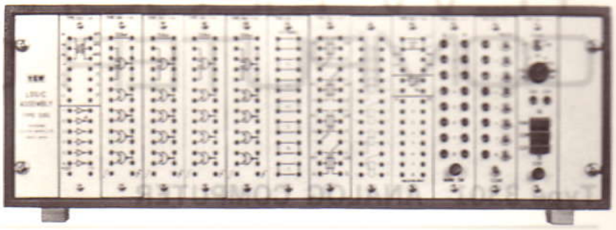
Frequency Characteristic

	DC~150Hz	1 kHz	5.5 kHz	10 kHz
Amplitude	±0.1%	+3.5%	+13.5 dB	−4.5 dB
Phase	0.05%			

Division

Function: $E_{OUT} = -10\frac{Ez}{Ey}$

DC Accuracy: ±0.1% (±10 mV), (Ey=Ez=10 V, at 25°C or 77°F)



Type 3351 Logic Assembly

Frequency Characteristic

	20 Hz	100 Hz	10 kHz	20 kHz
Amplitude			+4 dB	−12 dB
Phase	0.5%	2%		

Square Root
Function: $E_{OUT} = \sqrt{-10\,Ez}$
DC Accuracy: ±0.1% (±10 mV) (Ez = −10 V, at 25°C or 77°F)

FREE DIODE RESISTOR Code 332111
Number of Silicon High Speed Diode: 2 pcs.
Resistance: 100 kΩ×4, 10 kΩ×2, accuracy 0.1% or 0.5%

VARIABLE DIODE FUNCTION GENERATOR Code 332212
Input/output Voltage: Within ±10 V
Break Point: 10 break points. 10 segments
Break Point Variable Range: −10 V～+10 V
Slope/Break Point Slope Variable Range: −5～+5 V/V
Temperature Coefficient: ±0.05%/deg. typical
±0.1%/deg. maximum
Frequency Characteristic: Within ±1% (DC to 500 Hz)

SINE DIODE FUNCTION GENERATOR Code 332221
Input Voltage: Within ±10 V
Function Generated: $-10 \sin \frac{X}{10}\pi$
Accuracy: ±0.2%, typical at ±10 V, 20°C (68°F)
Dynamic Characteristic: ±0.2% at DC to 500 Hz
Temperature Characteristic: ±0.01%/deg.

COSINE DIODE FUNCTION GENERATOR Code 332231
Input Voltage: Within ±10 V
Function Generated: $-10 \cos \frac{X}{10}\pi$
Accuracy: ±0.2%, typical at ±10 V, 20°C (68°F)
Dynamic Characteristic: ±0.2% at DC to 500 Hz
Temperature Characteristic: ±0.01%/deg.

X^2 DIODE FUNCTION GENERATOR Code 332241
Input Voltage: Within ±10 V
Function: $-\frac{X^2}{10}$ or $\sqrt{-10\,Z}$, selected with bottle plug
Static Accuracy: ±0.1%, typical, at 20°C (68°F)
Dynamic Accuracy: ±0.2%, up to 500 Hz
Temperature Characteristic: ±0.01%/deg.

2-LOG Z DIODE FUNCTION GENERATOR Code 332251
Input Voltage and Function:
$10 \log_{10}(-Z)\ (-10 \leq Z \leq -0.1)$
$-10^{\frac{X}{10}}(10 \leq X \leq +10)$ selected with bottle plug
Static Accuracy: ±0.2%, typical, 20°C
Dynamic Accuracy: ±0.2%, up to 500 Hz
Temperature Characteristic: ±0.01%/deg.

6-COMPARATOR (Electronic) Code 332411
Input Signal Voltage: $-10\,V \leqq A,\ B \leqq +10\,V$
Output Signal Level: +15 V, $A+B>0$
(C Output) 0 V, $A+B<0$
Hysteresis: ±10 mV
Frequency Characteristic: −3 dB at 10 kHz

8-ANALOG SWITCH Code 332511
8-ELECTRONIC SWITCH Code 332521
Computing Resistance in ON State: 100 kΩ ±0.1%
Leakage Voltage in OFF State: ±0.1% at DC to 500 Hz, ±1% at DC to 10 kHz
Response Time: 1 μs to 2 μs
Spike (when used with Type 3316 Dual Summing Amplifier): 20 μs to 30 μs
Input Signal Level: "1" state; +10 V to +15 V (or open)
"0" state; 0 V (or short)

5. WAVEFORM TRANSLATOR
Code 332611
Number of Channel: 1
Input: ±1/2/5/10 V
Time Base: Synchronized with the control signal generator
Output Voltage: 0 to ±1 V
Recording Speed: 30/60/120 sec/trace
Frequency: DC to 20 kHz
Accuracy: ±0.5%

6. MONITORING OSCILLOSCOPE
Number of Channels: 4
Size: 9 inches
Position Sensitivity: 1/2/5 V/div.
Accuracy: ±5%
Time Base: Synchronized with the control signal generator

7. DIGITAL VOLTMETER
(Refer to the separate catalog Cat. YEW 2800F)

YEW RECOMMENDED COMPUTER COMPOSITION

Type 3301 ANALOG COMPUTER

Code	Name	Number of Unit
331311	Type-A Control Unit	1
331521	Coefficient Potentiometer (1-turn)	8
331811	Integrator Summer	4
332111	Free Diode Resistor	1
332611	Waveform Translator	1
339811	Pre-wired Console for Type 3301	1
—	Accessories	1 set

Type 3302 ANALOG COMPUTER

Code	Name	Number of Unit
331311	Type-A Control Unit	1
331511	Coefficient Potentiometer (10-turn)	4
331521	Coefficient Potentiometer (1-turn)	12
331611	Dual Summing Amplifier	2
331811	Integrator Summer	5
331911	Multiplier	2
332111	Free Diode Resistor	2
332212	Variable Diode Function Generator	1
332411	6-Comparator	1
332521	8-Electronic Switch	1
332611	Waveform Translator	1
339821	Pre-wired Console for Type 3302	1
—	Accessories	1 set

Type 3304 ANALOG COMPUTER

Code	Name	Number of Unit
331511	Coefficient Potentiometer (1-turn)	12
331521	Coefficient Potentiometer (10-turn)	24
331611	Dual Summing Amplifier	2
331811	Integrator Summer	8
331911	Multiplier	2
332111	Free Diode Resistor	3
332212	Variable Diode Function Generator	1
332221	Sine Diode Function Generator	1
332231	Cosine Diode Function Generator	1
332241	X^2 Diode Function Generator	1
332411	6-Comparator	1
332521	8-Electronic Switch	1
	(Type A Control Panel)	
334311	Reference Voltage Source	1
334411	Control Signal Generator (High-speed)	1
334421	Control Signal Generator (Low-speed)	1
334511	Signal Distributor	3
334611	Waveform Translator	1
3391	Pre-patch Board	1
339841	Pre-wired Console for Type 3304	1
—	Monitoring Oscilloscope	1
—	Accessories	1 set

Remarks:

1. Each Pre-wired Console is provided with alarm, DC power supply and reference voltage source.
2. For recommended computer compositions of larger scale than Type 3304, correspondence is invited.

Represented by:

A & D MESSTECHNIK GEORG KOCH
2000 HAMBURG 13, PARKALLEE 7
TELEFON (0411) 44 32 33

YEW

YOKOGAWA ELECTRIC WORKS, LTD.

2-9 Nakacho, Musashino-shi, Tokyo, 180 Japan
Phone: Tokyo 0422-51-8111 Telex: 02822-327 YOKOGAWA MUS
Cable Address: TLX2822-327 YOKOGAWA TOKYO

YEW EUROPÄISCHES VERBINDUNGSBURO
2000 Hamburg 26, Hammer Landstrasse, 76 I.O.G., Germany.
Phone: Hamburg 2191310 Cable Address: YOKOGAWA HAMBURG

YEWTEC CORPORATION
1995-Palmer Ave., Larchmont, New York, 10538 U.S.A.
Phone: 914-834-3550 Telex: 710-566-1104

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