

CAPACITOR CHARGING METHOD

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to capacitor charging methods used for measuring the insulation resistance of a capacitor and for determining whether a capacitor is acceptable.

2. Description of the Related Art

To determine whether a capacitor is acceptable, there is generally known a method for measuring the insulation resistance of the capacitor, in which a DC voltage is applied to the capacitor and the leakage current (charging current) of the capacitor is measured after the capacitor is sufficiently charged. As a matter of course, the leakage current is low in an acceptable capacitor.

The measurement method specified in Japanese Industrial Standard (JIS) No. C5102 has been known as this type of insulation-resistance measuring method. This measuring method requires a measurement time of about 60 seconds because a current needs to be measured when a capacitor is sufficiently charged. As the cost of an electronic unit has been reduced and it has been demanded to increase reliability, however, it has been also required that the manufacturing capacity and the quality of electronic components such as capacitors be increased. Such a request cannot be satisfied by the conventional measuring method,

which requires such a long measurement time period for each capacitor.

In addition to the above method, which continuously applies a DC voltage, there has been known a capacitor charging method in which a DC voltage is intermittently applied (Japanese Unexamined Patent Publication No. 4-254769). This charging method is suited to a case in which a characteristic is measured with the use of a turn table which is intermittently rotated.

This method can be used for continuous characteristic measurement for a number of capacitors supplied from a parts feeder. In such an insulation-resistance measuring method employing a turn table, there are a continuous type in which the insulation resistance of each capacitor is measured one by one when capacitors have been charged at a plurality of charging areas, and a batch type in which a specified number of capacitors are supplied to a turn table, the turn table is stopped, and charging and insulation-resistance measurement are performed at the same time for a plurality of capacitors. Both types require a long time period for charging and have not good charging efficiency.

The inventors of this application found after intensive research on intermittent application of a DC voltage to a capacitor that even intermittent voltage application has the same effect as continuous voltage application, under a certain condition. In other words, the intermittent voltage application has the same charging characteristic as the continuous voltage

application. Even if voltage application is stopped for a moment, if it is a short period, charging advances.

Fig. 1 and Fig. 2 show the relationship between the current and the time in each of cases in which a DC voltage was continuously applied to a ceramic capacitor and a DC voltage was intermittently applied to the ceramic capacitor, with coordinates in a logarithmic current scale and a logarithmic time scale and with correct measurement of current changes. In the continuous voltage application, as shown in Fig. 1, an almost constant, high current flowed in a short period① from the application start t_0 , the current rapidly decreased in a transition period② following it, and then the current was reduced with a linear charging characteristic③ having a certain gradient. This linear charging characteristic③ continued until one to two minutes elapsed after the charging start.

In the intermittent voltage application, as shown in Fig. 2, characteristics①,②, and③ in a first voltage application were the same as those in the continuous voltage application. The voltage application was stopped at a time t_a and the capacitor was discharged to the ground. And then a second voltage application was performed at a time t_b . The current rapidly increased with a characteristic④ and rapidly decreased to be stable with a linear charging characteristic⑤. Although the top section of the characteristic④ cannot be clearly seen because the horizontal axis is a logarithmic time scale in Fig. 2, the

section was actually formed of a level part which was the same as the characteristic^① and a transition period which was the same as the characteristic^②. It was found that the linear charging characteristic^⑤ was positioned on an extended line of the linear charging characteristic^③, which was obtained in the first voltage application. When the intermittent voltage application was repeated, the same characteristics as those^④ and ^⑤ were repeated and the current curve became stable on an extended line of the linear charging characteristics^③ and ^⑤. The same voltage was applied in the above continuous and intermittent voltage applications.

A current i_t was measured at a time t , when a constant time T elapsed from the application start in both continuous voltage application and intermittent voltage application. The same current i_t was measured. In other words, even when a DC voltage is intermittently applied, if an OFF period (t_a to t_b) in the intermittent application is short (equal to or less than several hundred milliseconds, for example), the same result is obtained as when charging is performed with continuous voltage application.

According to an experiment performed by the inventors of this application, the same result was obtained as when continuous application was performed, for a capacitor having a capacitance of $0.01 \mu F$ or less if the OFF time period of intermittent application was 500 ms or less.

With an examination of the above charging characteristics, the following fact was found. An equivalent circuit of the capacitor is formed of a capacitor C_0 , an internal resistor r , an insulation resistor R_0 , and a dielectric polarization component D , as shown in Fig. 3. It was found that the non-linear characteristics ① and ④ shown in Figs. 1 and 2 correspond to the charging stage of the capacitor C_0 , whereas the linear charging characteristics ③ and ⑤ correspond to the charging stage of the dielectric polarization component D .

It was found that the above intermittent voltage application causes the same result as continuous voltage application. The charging speed of the capacitor is the same.

The inventors of this application found with further research on intermittent application of a DC voltage to a capacitor that higher-speed charging can be performed in intermittent application under a certain condition than in continuous application of a constant voltage. According to this fact, charging can be performed at a higher speed than in continuous application of a constant voltage, and the measurement of capacitor insulation resistance or the determination of whether a capacitor is acceptable can be performed in a short period.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to

provide a capacitor charging method in which a high-speed charging is allowed with a DC voltage being intermittently applied to a capacitor.

The foregoing object is achieved according to the present invention through the provision of a capacitor charging method in which a DC voltage is intermittently applied to a capacitor, wherein a precedingly applied voltage E_1 is set higher than a subsequently applied voltage E_2 .

The inventors of the present invention obtained the result shown in Fig. 4 with a voltage applied in intermittent application being changed variously. In the continuous voltage application shown in Fig. 1 and the intermittent voltage application shown in Fig. 2, a rated voltage E_0 was applied. In Fig. 4, a first applied voltage E_1 was set higher than the rated voltage and a second applied voltage E_2 was set to the rated voltage.

In Fig. 4, characteristics ① to ③ in the first voltage application are substantially the same as those shown in Figs. 1 and 2. In the second voltage application, the current rises with a characteristic ④ and then drastically decreases to become stable with a linear charging characteristic ⑦. The current on the linear characteristic ⑦ is lower than that on the linear characteristic ⑤ shown in Fig. 2. Namely, the characteristic ⑦ is not on an extended line of the characteristic ③. When a third voltage application (at a voltage of E_2) is performed, the current becomes stable on an extended line of the linear characteristic

⑦.

The charging characteristics ⑥ and ⑦ shown in Fig. 4 are obtained when the capacitor is discharged to the ground in a time period (t_a to t_b) between the first voltage application to the second voltage application. A charge accumulated into the capacitor C_0 (see Fig. 3) becomes almost zero, and with the voltage E_2 being applied, the capacitor is charged with the characteristics ⑥ and ⑦, which are similar to the characteristics ①, ②, and ③. On the other hand, when the capacitor is set open in the period (t_a to t_b) between the first voltage application to the second voltage application, charging characteristics ⑥' and ⑦' shown in Fig. 5 appear. This is because the charge accumulated into the capacitor C_0 flows in reverse when the voltage E_2 is applied since E_1 is higher than E_2 . Therefore, the current changes from a negative value through the vicinity of zero to a charging value to form the characteristics ⑥' and ⑦'.

It is clear from Figs. 4 and 5 that the charging characteristic ⑦ is obtained earlier when the capacitor is discharged and, on the other hand, a process for connecting the capacitor to the ground can be omitted when the capacitor is set open.

As described above, the charging characteristics ① to ③ obtained by the first voltage application are substantially the same as those obtained by the rated voltage application, but the charging current in the second voltage application (voltage E_2)

is greatly reduced as compared with that obtained by the rated voltage application. Namely, this type of voltage application implements faster charging than continuous voltage application.

Therefore, the intermittent voltage application with the foregoing voltages reduces the charging time to a time t_1 , whereas continuous voltage application or intermittent voltage application with the rated voltage needs the time t_2 until the certain current i_1 is reached.

With an examination of the ratio of the precedingly applied voltage E_1 and the subsequently applied voltage E_2 , it was found that a conspicuous effect is obtained when $E_1/E_2 \geq 1.2$. Especially when E_1/E_2 was set to two or more, charging proceeded at a speed several times higher than when E_1 was equal to E_2 , reducing the charging time greatly.

In a third voltage application (with the voltage E_2), when the capacitor is discharged to the ground in a time period from t_0 to t_d , a characteristic shown in Fig. 4 is obtained in which a high current drastically decreases. When the capacitor is set open in the time period t_0 to t_d , the current changes from a lower initial value than when the capacitor is discharged, in the same curve to become stable in the characteristic (1), as shown in Fig. 5. This can be considered to be because the charge accumulated into the capacitor C_0 is released when the capacitor is discharged whereas the charge accumulated into the capacitor C_0 moves to the capacitors C_1 to C_n when the capacitor C_0 is set open. Therefore,

the current changes earlier to the charging characteristic^⑦ when the capacitor is set open than when the capacitor is discharged.

In the present invention, when the capacitor is discharged during the time periods, t_a to t_b and t_c to t_d , a voltage lower than E_2 may be applied instead of being discharged to the ground.

Alternatively, a negative voltage is applied so that the current flows in reverse. In either case, the same effect is obtained as when the capacitor is discharged to the ground.

A period of discharging (discharged to the ground, a lower voltage than E_2 being applied, or a negative voltage being applied) is not necessarily match the whole periods, t_a to t_b and t_c to t_d , and needs to be included in the whole periods.

$$0 < \text{period of discharging} \leq t_a \text{ to } t_b, t_c \text{ to } t_d$$

According to the present invention, since it is unnecessary to stop a measuring apparatus (such as a turn table) for a long period, which is required in the continuous voltage application type, and insulation resistance can be measured while a capacitor is intermittently carried, facility capacity is increased.

Especially when a measuring apparatus having a turn table is used, a charging area can be reduced and the number of measurement terminals can also be reduced.

When the precedingly applied voltage E_1 is set to a high value, if the application period T_1 of the voltage E_1 is reduced, the same effect is obtained. In other words, when the application

period T_1 of the precedingly applied voltage E_1 is reduced to be shorter than the period T_2 of the subsequently applied voltage E_2 , the same effect is obtained, further reducing the charging time period. This effect is effective in that processing capacity is increased in the batch type, in which a specified number of capacitors are supplied to a turn table, the turn table is stopped, and charging and insulation-resistance measurement are performed at the same time for a plurality of capacitors.

In this case, the preceding-application time period T_1 needs to be the sum of the charging period^① and the transition period^② of the capacitor C_0 or more. It is preferred that this time period T_1 be set to 100 milliseconds or less so as to measure a capacitor in a short period.

It is clear from the above descriptions that according to the present invention, since DC voltages are intermittently applied to a capacitor such that the precedingly applied voltage E_1 is higher than the subsequently applied voltage E_2 , charging rapidly advances during a period in which a voltage is not applied, and charging is performed at a higher speed than in a case when the same voltage is continuously applied. As a result, insulation-resistance measurement and the determination of whether a capacitor is acceptable can be performed at a high speed, and measuring capacity is greatly improved.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a graph of charging characteristics in a case in which a DC voltage is continuously applied to a capacitor.

Fig. 2 is a graph of charging characteristics in a case in which a DC voltage is intermittently applied to a capacitor.

Fig. 3 is an equivalent circuit diagram of a capacitor.

Fig. 4 is a graph of charging characteristics in a case in which DC voltages are intermittently applied (with discharging) to a capacitor according to a method of the present invention.

Fig. 5 is a graph of charging characteristics in a case in which DC voltages are intermittently applied (with open state) to a capacitor according to a method of the present invention.

Fig. 6 is a circuit diagram of a current measuring apparatus.

Fig. 7 is a waveform chart of voltages intermittently applied.

Fig. 8 is a graph of actual charging characteristics in a case in which the voltages shown in Fig. 7 are intermittently applied.

Fig. 9 is a flowchart of a method for determining whether a capacitor is acceptable, which uses a charging method according to the present invention.

Fig. 10 is a plan of a characteristic measuring and selecting apparatus using a method of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fig. 6 is a block diagram of a current measuring apparatus with which a method according to the present invention is implemented. The inventors of the present application has proposed this measuring apparatus in Japanese Unexamined Patent Publication No. 7-293442.

This measuring apparatus is provided with DC-current measurement power sources 10a and 10b, a switch 11, a capacitor 12 under measurement, a limiting resistor 13, a logarithmic amplifier 14, a measurement amplifier 15, A/D converters 16 and 18, and a calculation processing circuit (CPU) 17. The current is measured with the use of the measurement amplifier 15 in an early charging stage, the amplifier is switched to the logarithmic amplifier 14 at a certain threshold, and the current is measured by the use of the logarithmic amplifier 14 since then. Since this measuring apparatus correctly measures the charging current of the capacitor 12 even if the current changes in a wide range, it can continuously measure the current from the early charging stage to the late charging stage, which is difficult with the use of the conventional measuring apparatus.

The switch 11 is switched by the CPU 17 at a certain interval.

A DC voltage is intermittently applied to the capacitor 12 from either one of the DC-current measuring power sources 10a and 10b.

The voltage E_2 of the power source 10b is set to the rated voltage (25 volts in this embodiment) and the voltage E_1 of the power source

10a is set higher than E_2 . To discharge the capacitor to the ground at a period between the applications of the voltages E_1 and E_2 , it is necessary to provide a contact point 11c connected to the ground, between the contact points 11a and 11b. The contact point 11c is unnecessary if the capacitor is set open at the period between the applications of the voltages E_1 and E_2 .

The time interval when the switch 11 is turned on and off is not necessarily constant. For example, a second ON time period T_2 may be set longer than a first ON time period T_1 . Alternatively, the first ON time period T_1 may be set longer than the second ON time period T_2 . When a voltage is applied three times or more, each ON time period may be changed.

A measuring apparatus with which a method according to the present invention is implemented is not limited to the measuring apparatus shown in Fig. 6. Any other apparatuses can be used if different voltages can be intermittently applied to a capacitor.

Fig. 8 shows charging characteristics in a case A in which the rated voltage (25 volts) was intermittently applied twice as shown in Fig. 2 and in cases B and C in which different DC voltages E_1 and E_2 were intermittently applied as shown in Fig. 7. A laminated ceramic capacitor was used with an initial charging current of 50 milliamperes. In the experiments A to C, the (ON) time period T_1 of a first voltage application was set to 20 milliseconds, a discharging time period T_{off} was set to 20



milliseconds, the (ON) time period T_2 of a second voltage application was set to 20 milliseconds, and each applied voltage was set as follows:

Experiment	A	B	C
First applied voltage (E_1)	25 V	30 V	50 V
Second applied voltage (E_2)	25 V	25 V	25 V

It is clearly understood from Fig. 8 that the cases A to C show nearly the same charging characteristic in the first voltage application and the charging current is higher in the order of the case A, the case B, and the case C in the second voltage application. Charging is performed the fastest in the case C. Charging is performed faster in the case B than in the case A. The time required for the charging current to be reduced to 1×10^{-7} amperes or less is about 0.8 seconds in the case A, about 0.4 seconds in the case B, and about 0.16 seconds in the case C. Higher-speed charging is performed in the cases B and C than in the case A.

The inventors of the present application found from further experiments on cases in which E_1/E_2 was set more than 2 that the charging speed increases as E_1/E_2 increases. The inventors also found that even when the voltages applied in the

first and second applications are set higher than the rated voltage, if the same voltage is applied in the first and second applications, just the same characteristics as those shown in Fig. 2 are obtained.

The inventors confirmed that the same effect was obtained when the time period T_1 of the first voltage application was set shorter than the time period T_2 of the second voltage application.

Therefore, the charging time can further be reduced. The time period T_1 depends on the capacitance of a capacitor to be measured and must ensure the following condition.

Charging time period ① + transition time period ② of $C_0 \leq T_1$

To respond to the demand for short insulation-resistance measurement of a laminated ceramic capacitor, it is preferred that the time period T_1 satisfy the following condition.

$$T_1 \leq 100 \text{ ms}$$

The time period T_2 is set to any value according to the required processing capability for a capacitor under measurement.

Fig. 9 is a flowchart of a method for determining whether a capacitor is acceptable, which uses a method according to the present invention.

Different voltages $E_1, E_2, \dots$ are intermittently applied in a step S1.

It is determined whether the elapsing time t from the

voltage application start reaches the specified time t_0 in a step S2. This time t_0 is the reference time for the charging current to reach a threshold value i_0 by intermittent voltage application, and is set, for example, to 1 to 10 seconds. If the elapsing time t has not yet reached the specified time t_0 , intermittent voltage application is repeated.

When the specified time t_0 elapses, the current $i(t)$ is measured in a step S3. This current $i(t)$ is compared with the threshold value i_0 , used for determining whether the capacitor is acceptable in a step S4.

When $i(t)$ is lower than i_0 , it is determined that the capacitor is acceptable since charging has advanced sufficiently in a step S5. If $i(t)$ is not lower than i_0 , the capacitor is determined to be unacceptable since charging has not yet sufficiently advanced in a step S6.

When a capacitor has been charged according to a method of the present invention, either the insulation resistance thereof is measured or it is determined whether the capacitor is acceptable by comparing the current obtained after charging for the specified time with the threshold. The operation following the charging is not specified.

Fig. 10 is a characteristic measuring and selecting apparatus employing a method of the present invention.

A turn table 20 rotates intermittently in the direction indicated by an arrow by one step. On the circumference of the

turn table 20, a plurality of holding sections 21 each of which can hold one chip-type capacitor to be measured are provided at an equal interval. There are provided around the turn table 20 a supply section 22 for supplying capacitors to the turn table 20, a capacitance measuring section 23, a charging section 24 in which the present invention is applied, an IR measuring section 25 for measuring a charging current, a discharging section 26, and a taking-out section 27. In the supply section 22, a supply unit 28 such as a parts feeder for supplying capacitors to the turn table 20 one by one is disposed.

The charging section 24 is divided into a plurality of stages. For example, the first-half stage 24a applies a voltage E_1 and the second-half stage 24b applies a voltage E_2 . Each of the stages 24a and 24b is formed of a plurality of portions for a plurality of voltage applications. Each of the stages may be formed of one portion for one voltage application.

Since a capacitor needs to be charged for a long time on a turn table in the conventional method, a charging area must be large and thereby the turn table itself becomes large. Conversely, with the method of the present invention, since a capacitor can be charged at a high speed, it is unnecessary to make the charging section 24 large and thereby the turn table 20 can be made compact. In addition, the number of measurement terminals can be reduced and cost is also reduced. A part of the charging area used in the conventional method can be used

for other purposes such as characteristic measurement.

The present invention can also be applied to charging of an electrolytic capacitor, a film capacitor, and other capacitors as well as to that of a ceramic capacitor.

In the present invention, various types of voltage applications can be considered. The number of times each of the preceding voltage E_1 and the subsequent voltage E_2 is applied is not limited to one, and may be a plurality of times. For example, high and low voltages may be applied a plurality of times, such as a first application of a voltage E_1 , a second application of a voltage E_2 ($E_1 > E_2$), a third application of the voltage E_1 , and a fourth application of the voltage E_2 . The relationship among the voltages applied may be $E_1 > E_2 > E_3$, where E_1 indicates the voltage of a first application, E_2 indicates that of a second application, and E_3 indicates that of a third application. In any cases, since charging is accelerated by applying a high voltage first and then a low voltage, it is necessary to include a stage in which a high voltage is applied first and then a low voltage is applied.

WHAT IS CLAIMED IS:

1. A capacitor charging method in which a DC voltage is intermittently applied to a capacitor,

wherein a preceedingly applied voltage E_1 is set higher than a subsequently applied voltage E_2 ;

the capacitor is discharged to the ground in a period between the application time period T_1 of the preceedingly applied voltage E_1 and the application time period T_2 of the subsequently applied voltage E_2 .

2. A capacitor charging method in which a DC voltage is intermittently applied to a capacitor,

wherein a preceedingly applied voltage E_1 is set higher than a subsequently applied voltage E_2 ;

a voltage lower than the subsequently applied voltage E_2 or a negative voltage is applied to the capacitor in a period between the preceding-application time period T_1 and the subsequent-application time period T_2 .

3. A capacitor charging method in which a DC voltage is intermittently applied to a capacitor,

wherein a preceedingly applied voltage E_1 is set higher than a subsequently applied voltage E_2 ;

the capacitor is set open in a period between the



preceding-rapidly advances during a period in which a voltage is not applied, and higher-speed charging is performed than in a case in which the same voltage is continuously applied.



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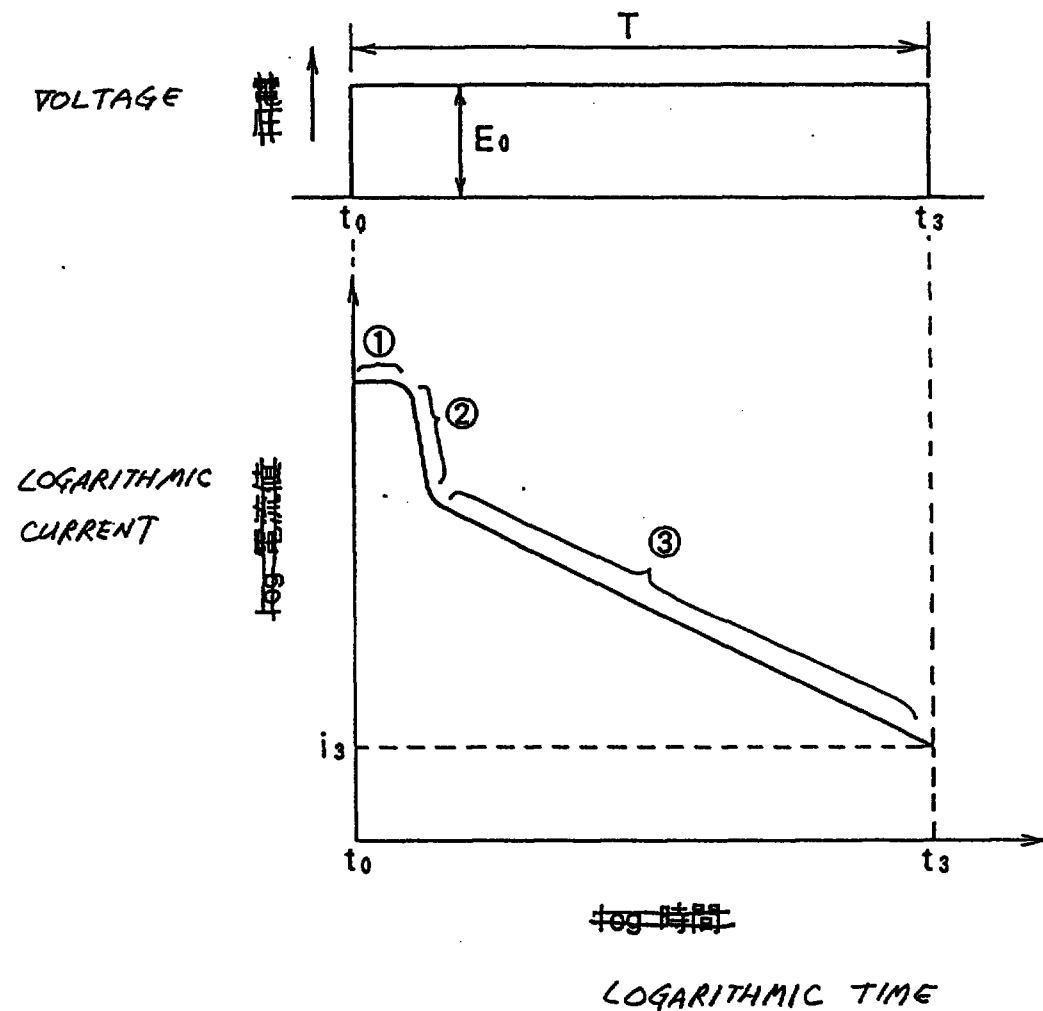
ABSTRACT OF THE DISCLOSURE

When DC voltages are intermittently applied to a capacitor such that a precedingly applied voltage E_1 is higher than a subsequently applied voltage E_2 , charging rapidly advances during a period in which a voltage is not applied, and higher-speed charging is performed than in a case in which the same voltage is continuously applied.

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~~図1~~ FIG. 1

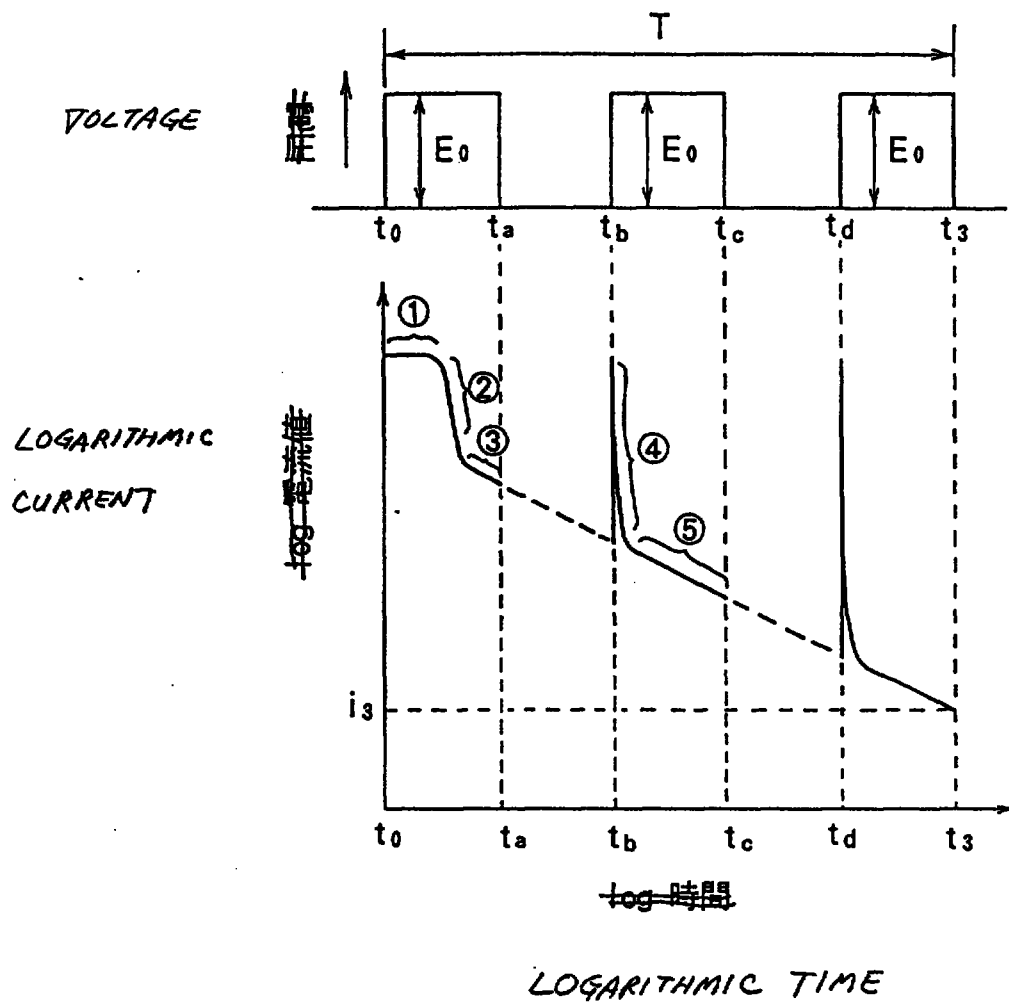


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FIG. 2

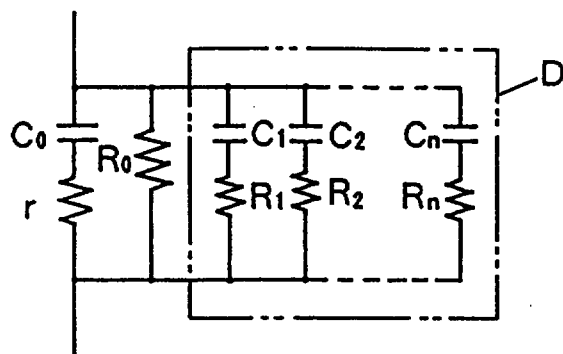


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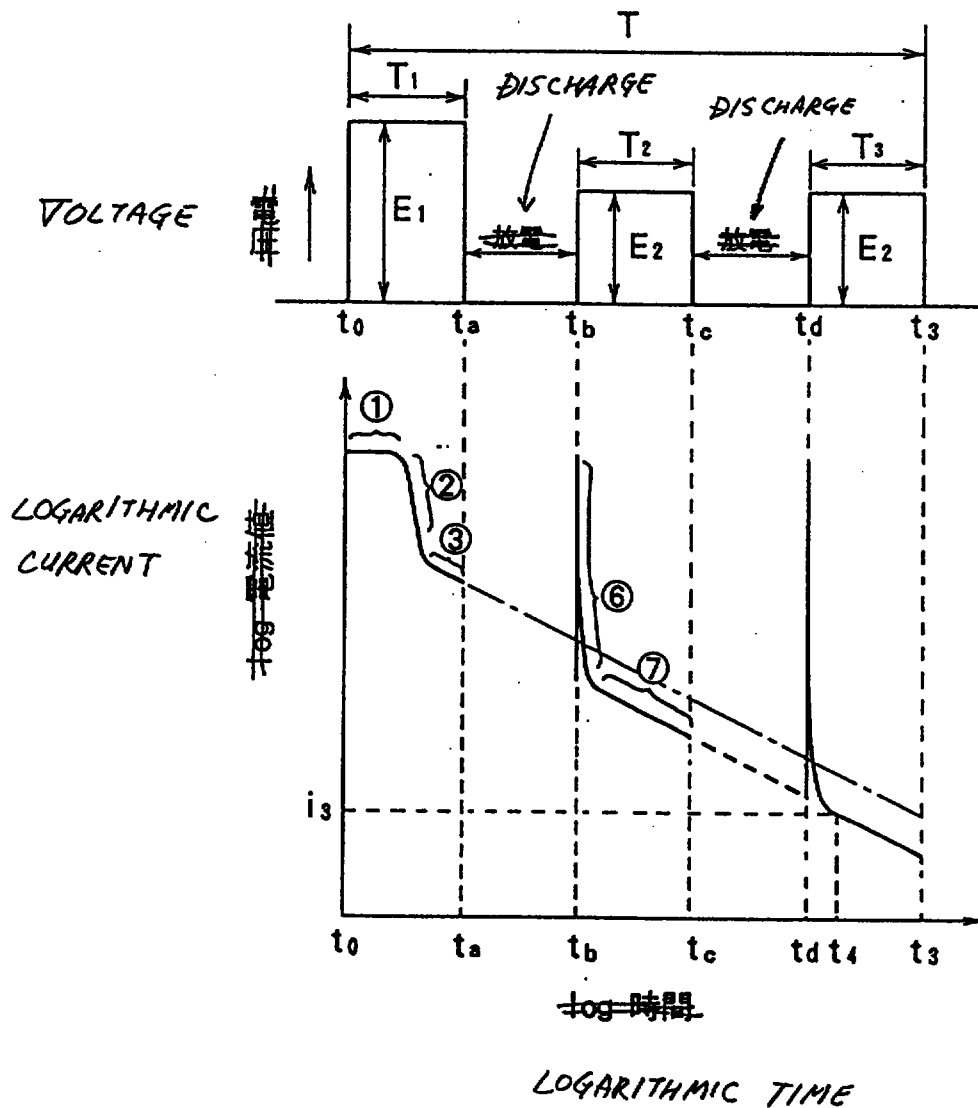


~~【図3】~~ FIG. 3



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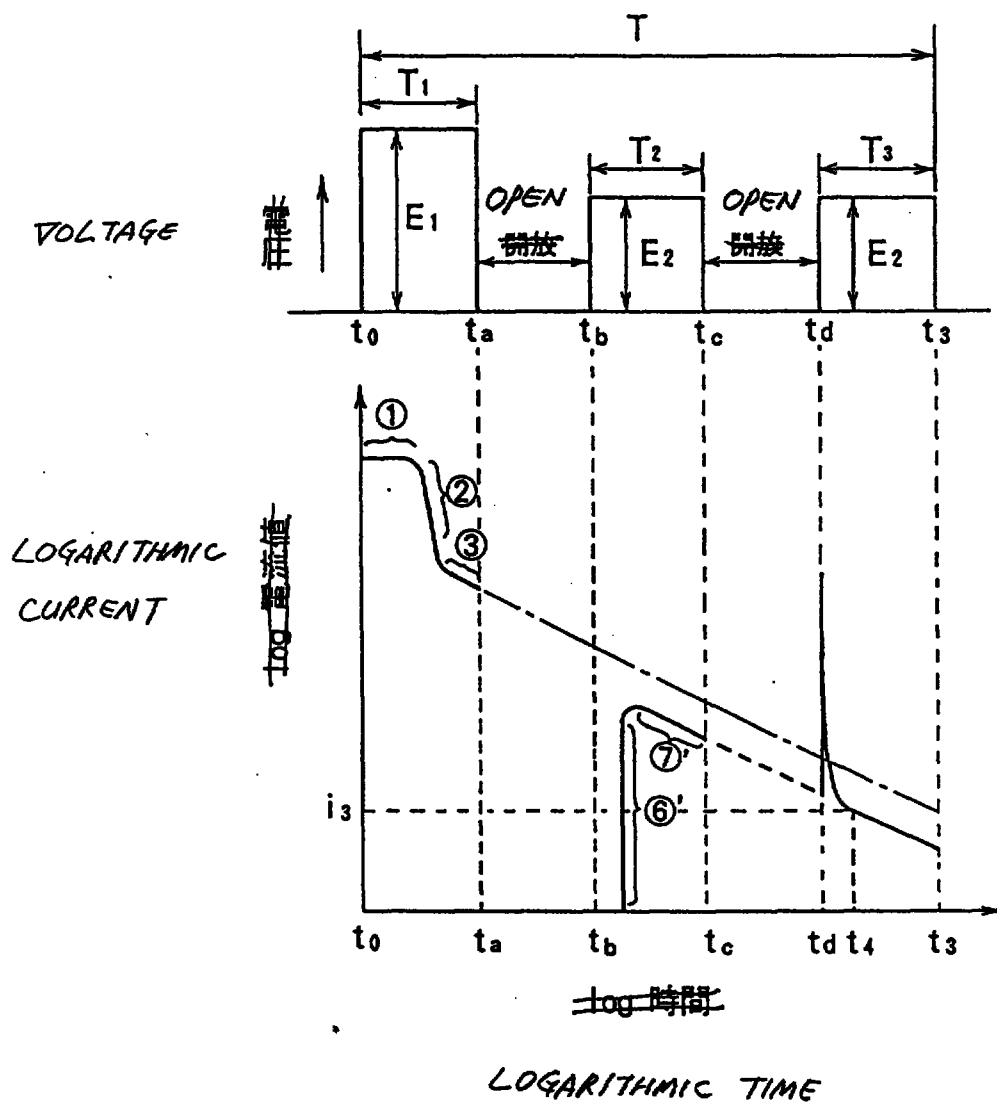
~~【図4】~~ FIG. 4



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~~【図5】~~ FIG. 5

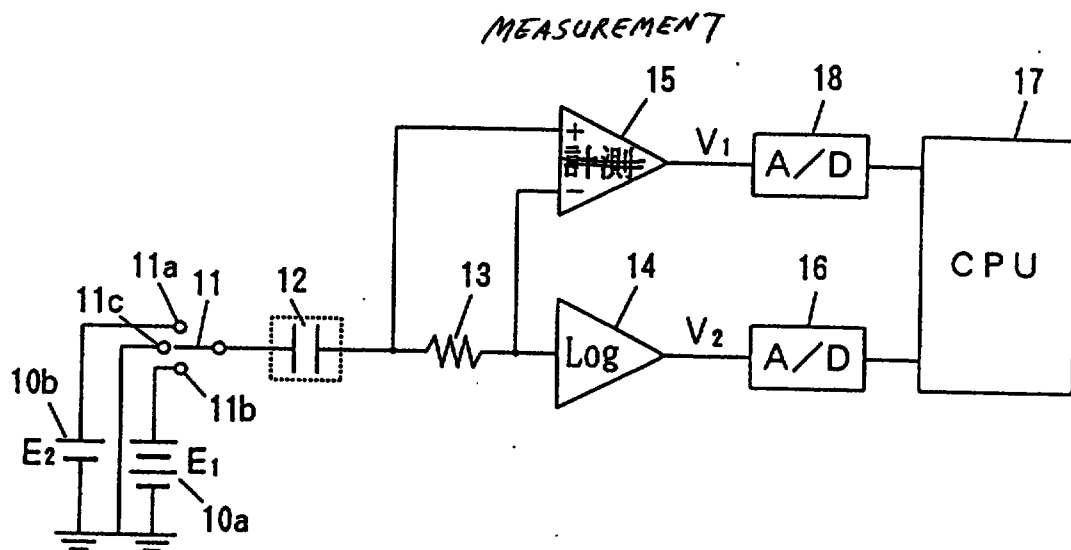


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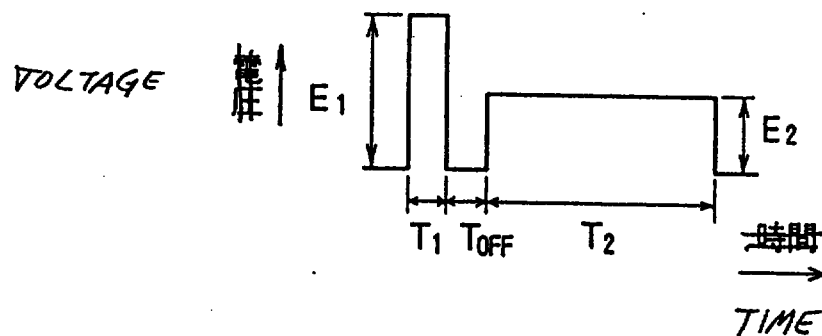


~~【図6】~~ FIG. 6



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~~【図7】~~ FIG. 7

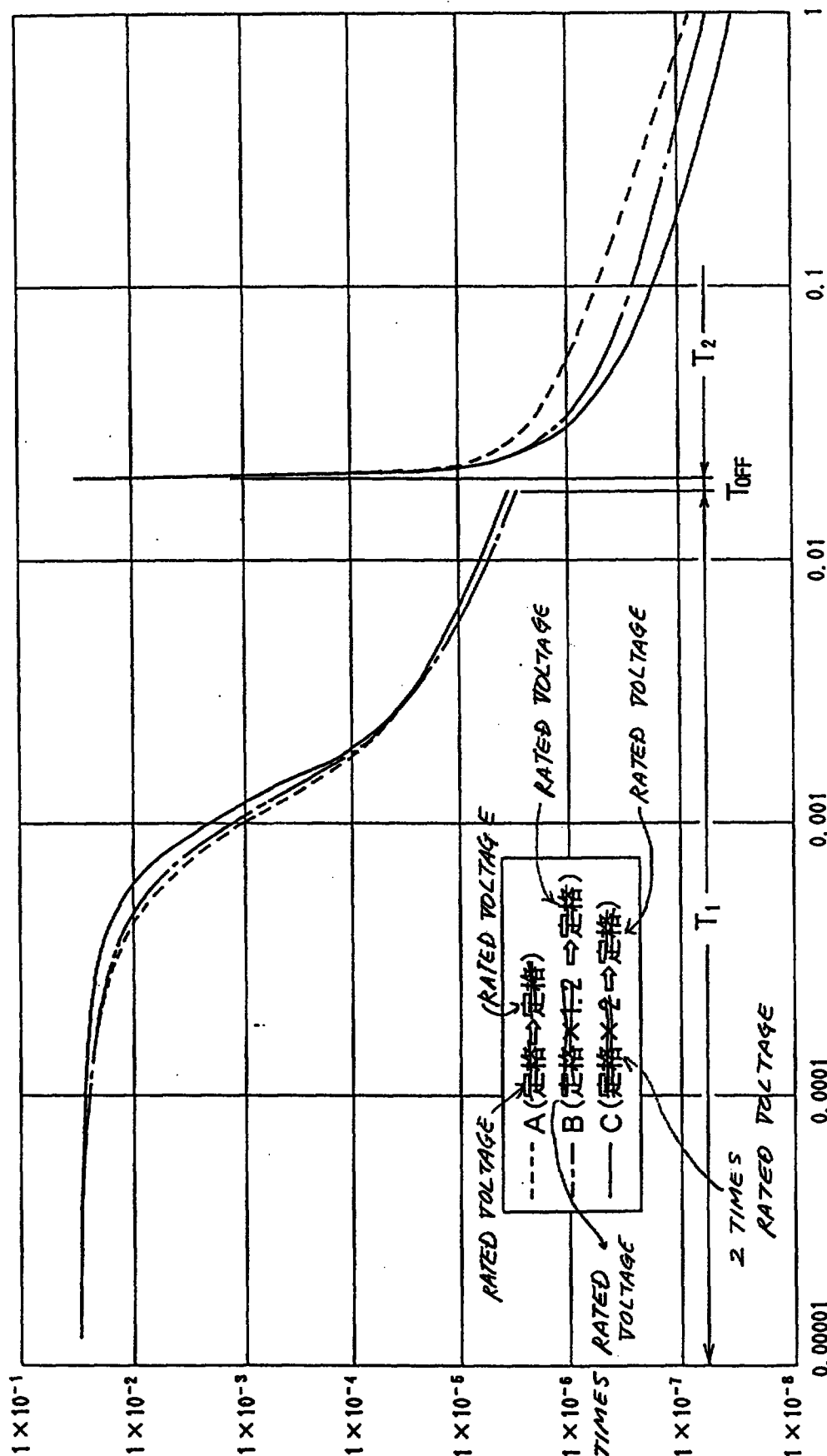


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【図8】 FIG. 8



CHARGING CURRENT (AMPERE)

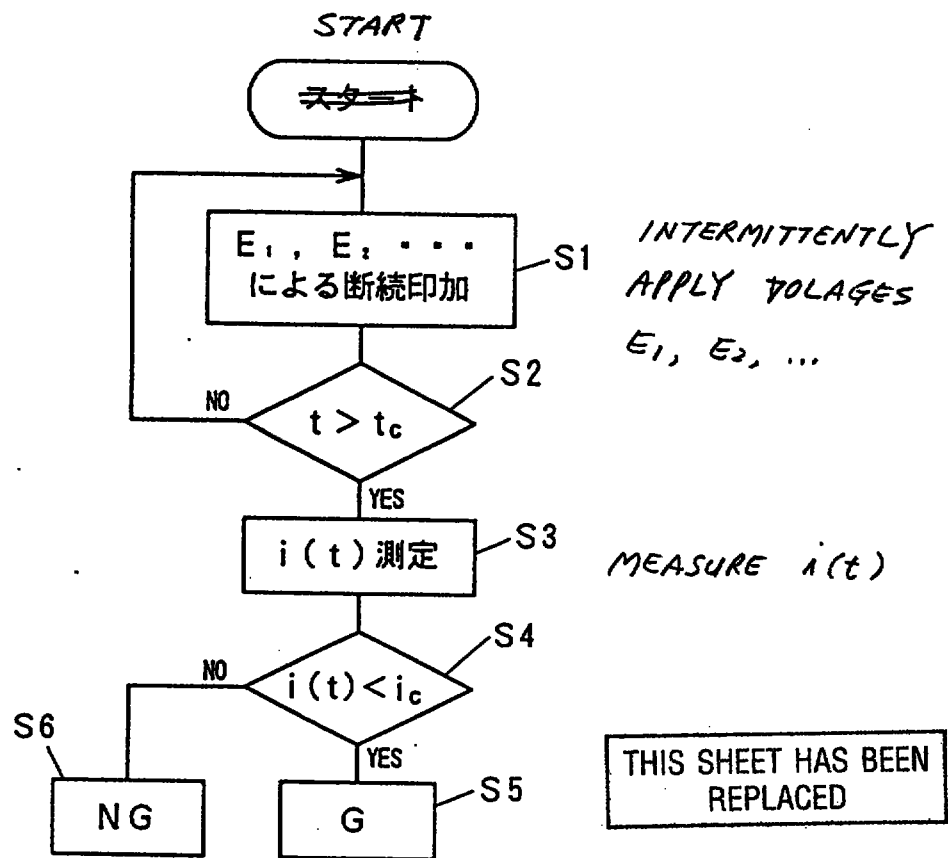
充電電流 (アンペア)

印加時間 (秒)

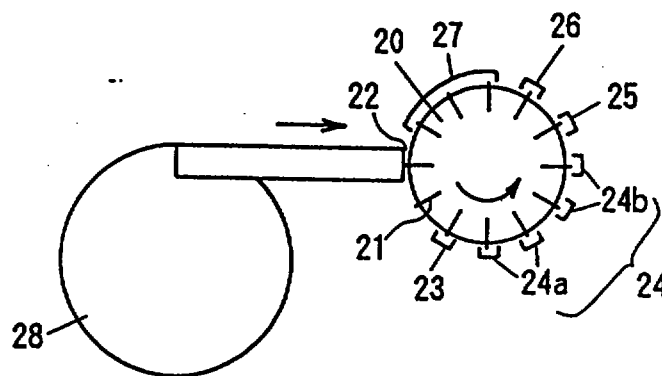
VOLTAGE APPLICATION TIME (SECOND)

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~~【図9】~~ FIG. 9



~~【図10】~~ FIG. 10

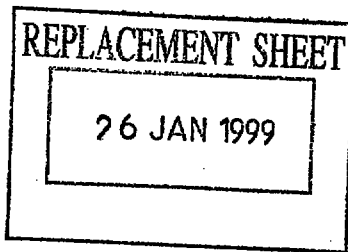


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milliseconds, the (ON) time period T_1 of a second voltage application was set to 1 second, and each applied voltage was set as follows:

Experiment	A	B	C
First applied voltage (E1)	25 V	30 V	50 V
Second applied voltage (E2)	25 V	25 V	25 V

It is clearly understood from Fig. 8 that the cases A to C show nearly the same charging characteristic in the first voltage application and the charging current is higher in the order of the case A, the case B, and the case C in the second voltage application. Charging is performed the fastest in the case C. Charging is performed faster in the case B than in the case A. The time required for the charging current to be reduced to 1×10^{-7} amperes or less is about 0.8 seconds in the case A, about 0.4 seconds in the case B, and about 0.16 seconds in the case C. Higher-speed charging is performed in the cases B and C than in the case A.

The inventors of the present application found from further experiments on cases in which E_1/E_2 was set more than 2 that the charging speed increases as E_1/E_2 increases. The inventors also found that even when the voltages applied in the

CAPACITOR CHARGING METHOD

ABSTRACT OF THE DISCLOSURE

When DC voltages are intermittently applied to a capacitor such that a precedingly applied voltage E_1 is higher than a subsequently applied voltage E_2 , charging rapidly advances during a period in which a voltage is not applied, and higher-speed charging is performed than in a case in which the same voltage is continuously applied.

Fig. 4

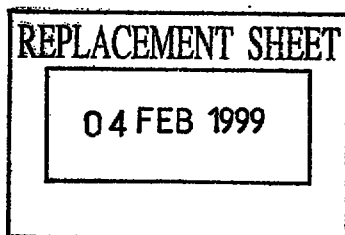
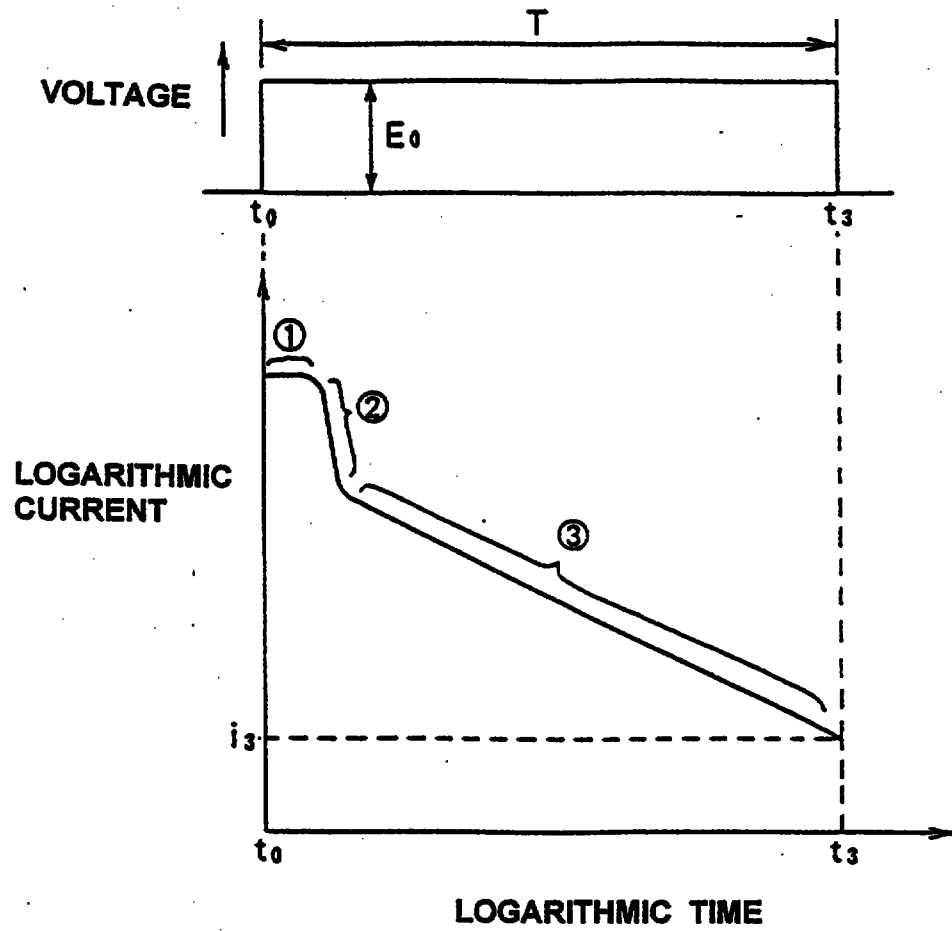


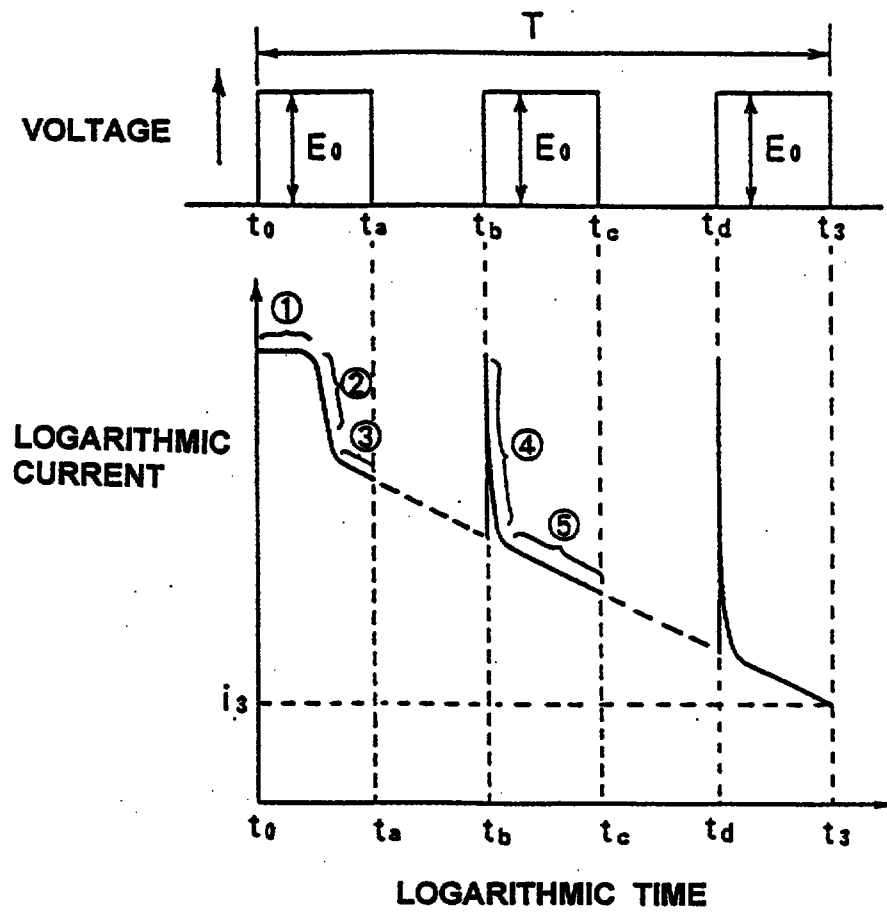
Fig. 1



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Fig. 2



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Fig. 3 3

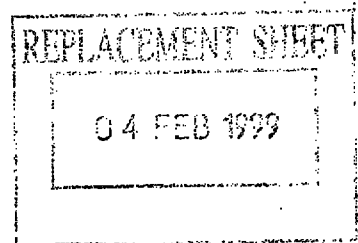
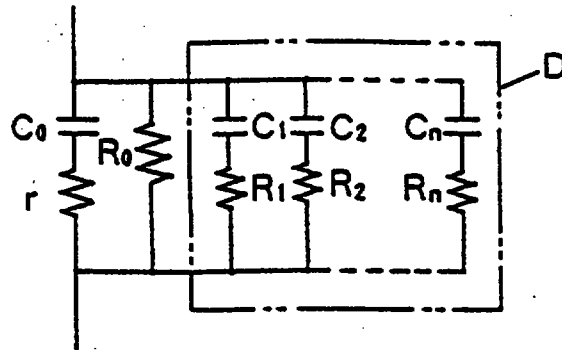


Fig. 4

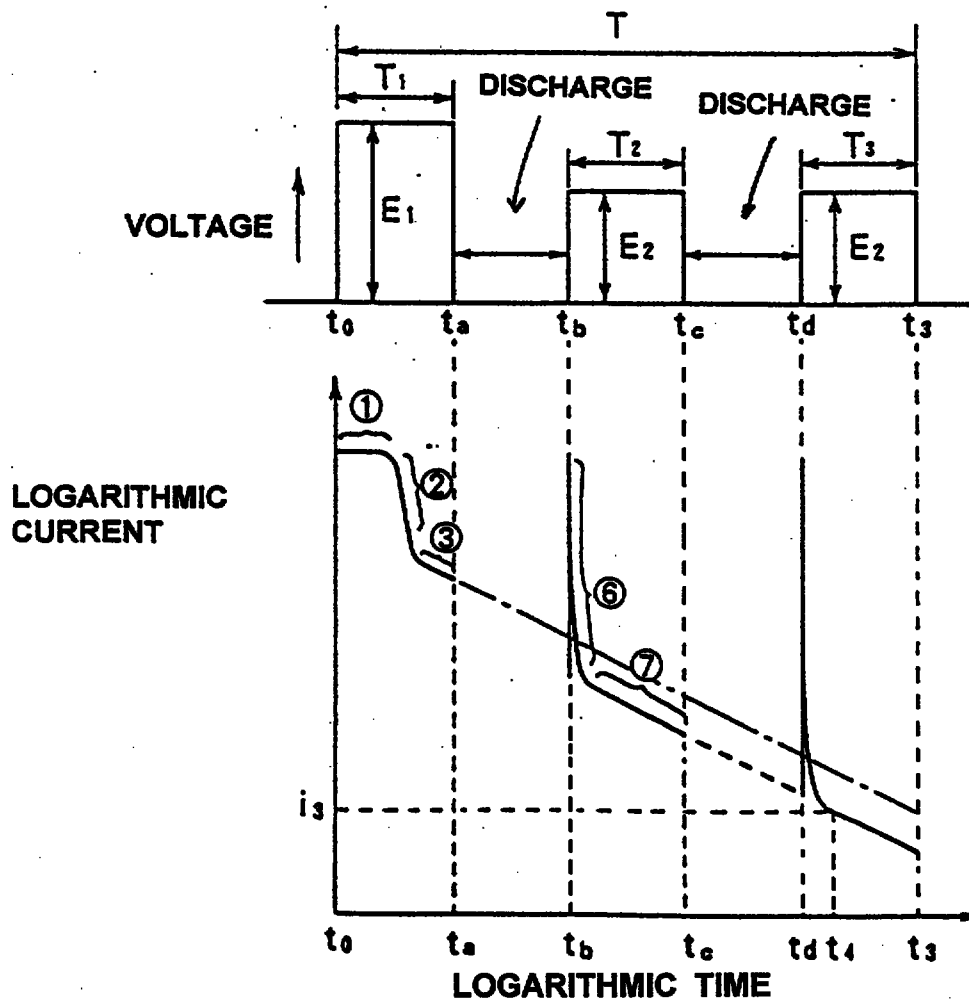
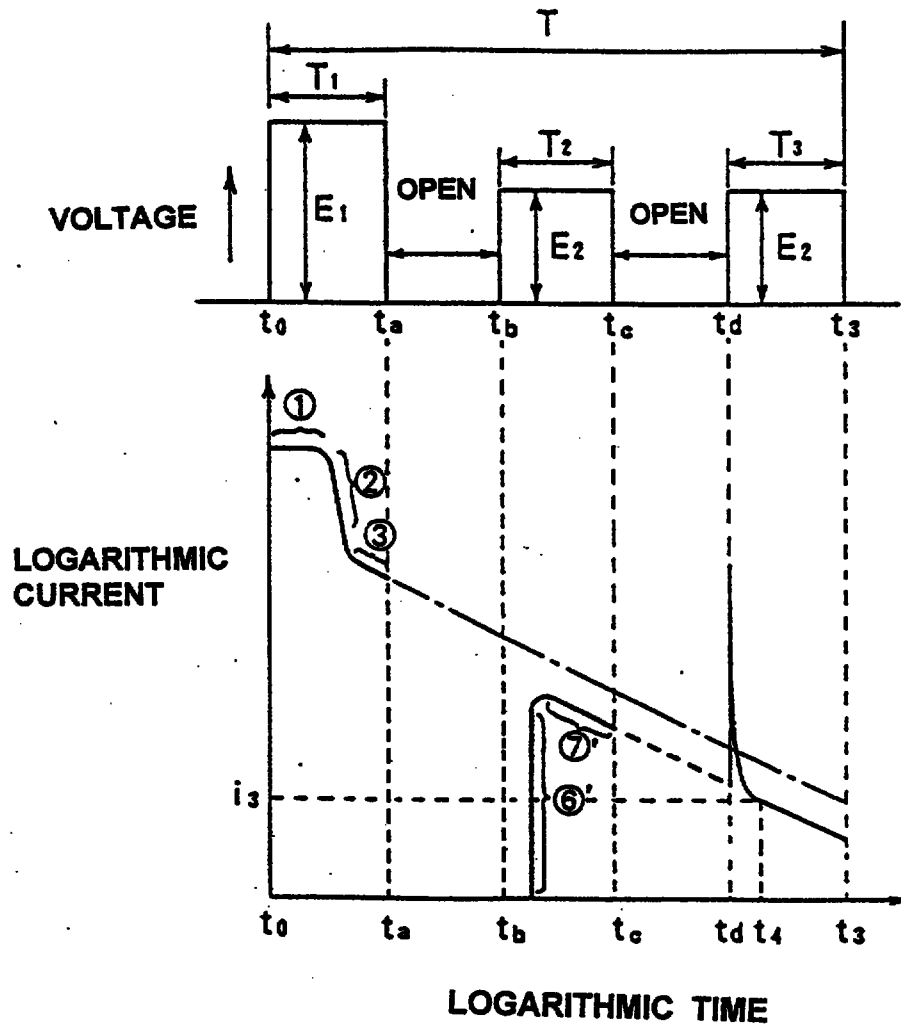


FIG. 5



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Fig. 6

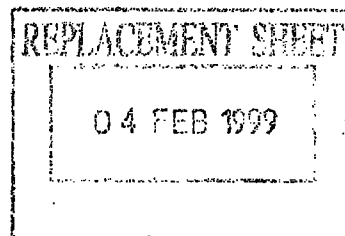
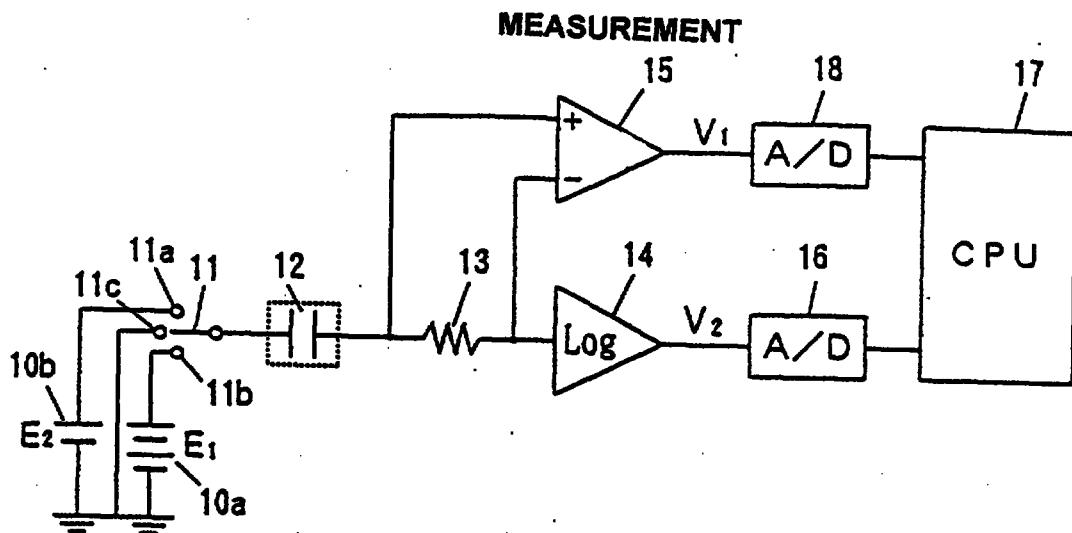


Fig. 7

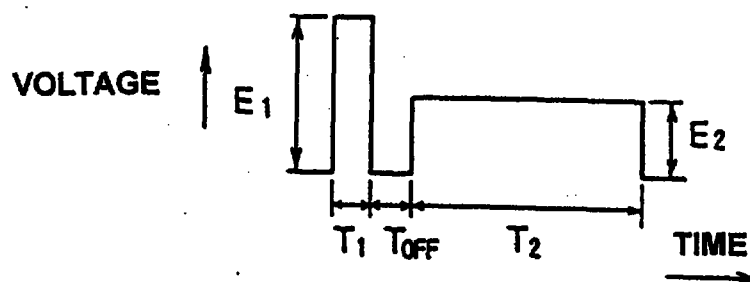


FIG. 8

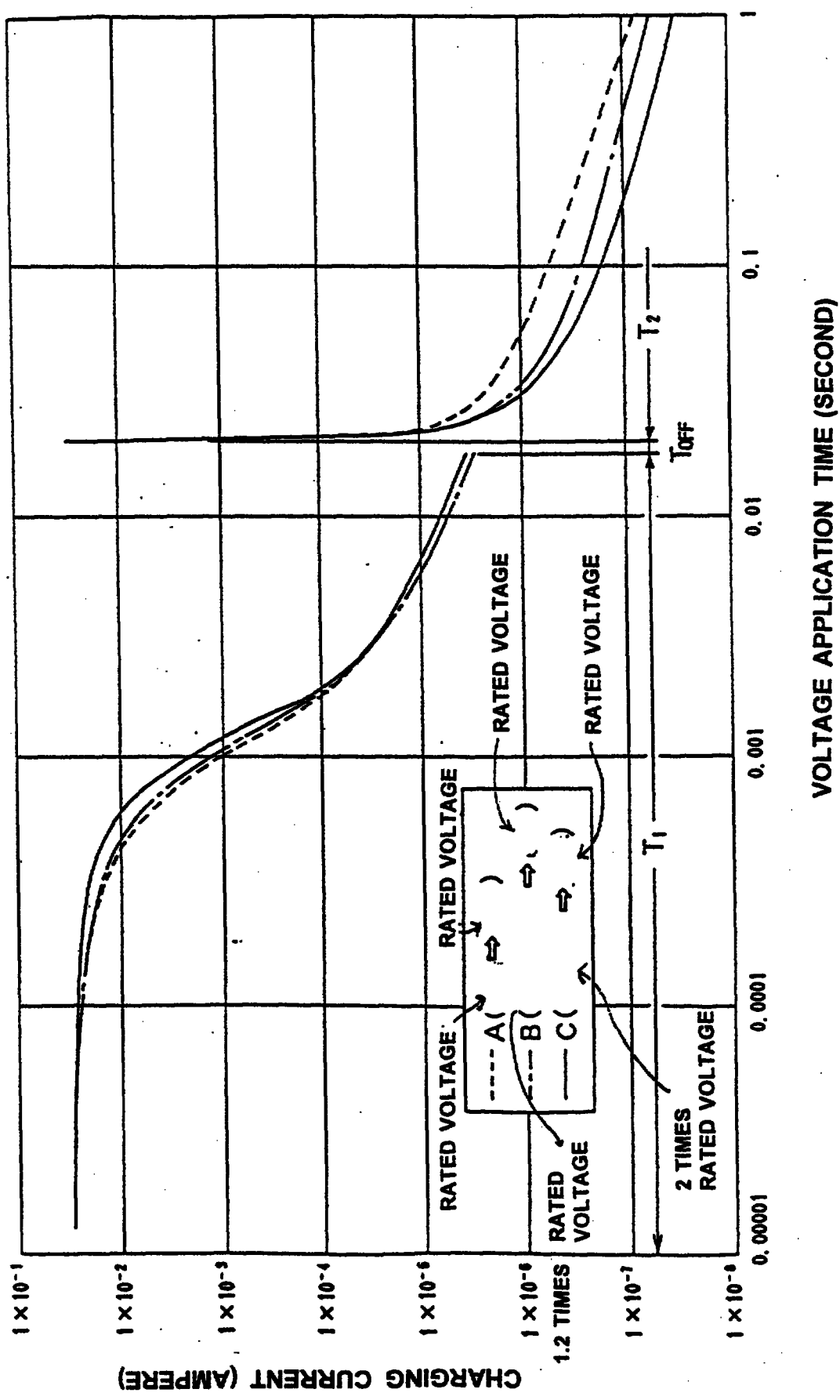


FIG. 9

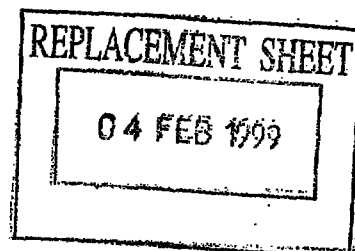
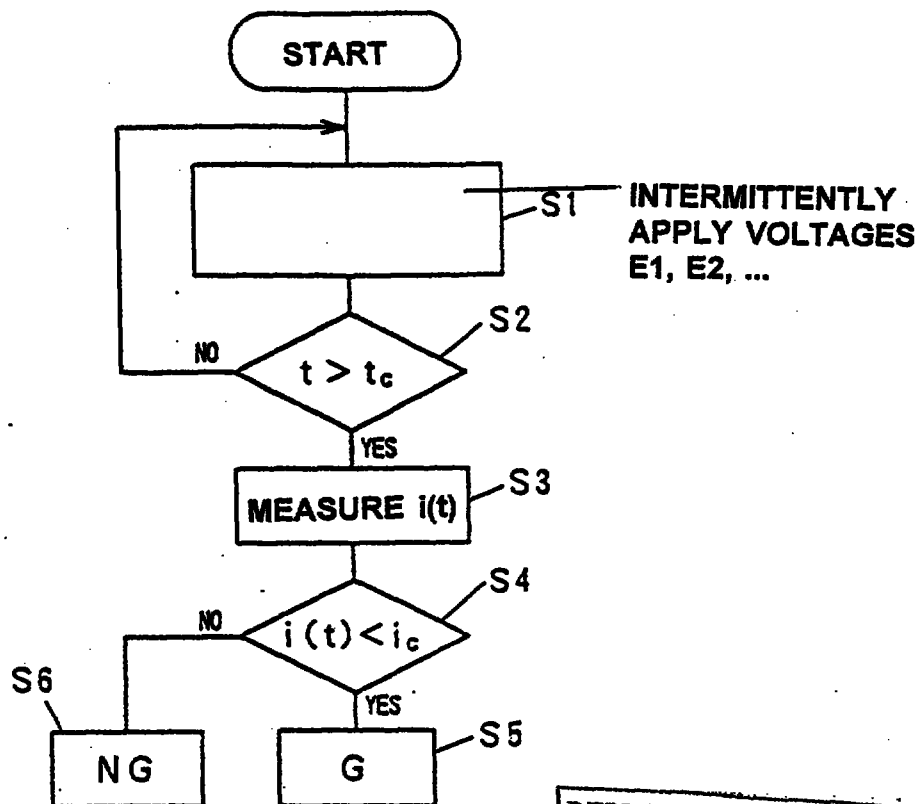


FIG. 10

