

ELECTRIC DISCHARGE MACHINING APPARATUS

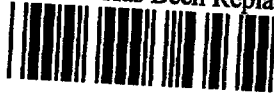
The present invention relates to an electroerosion machine. More specifically, the present invention relates to an electric discharge machine ("EDM") for performing electric discharge machining on a workpiece using a tool electrode in which a train of successive power pulses are supplied from a power supply to a machine body including a machining gap formed between the tool electrode and the workpiece.

In general, an electric discharge machine includes a machine body having a machining gap formed between a tool electrode and a workpiece being machined, a power supply for supplying electric energy to the machining gap and a dielectric supply device for supplying a dielectric fluid, such as kerosine or water, to the machining gap. The power supply is necessarily positioned with a physical spacing from the machine body and connected to the machine body by means of appropriate conductors.

A train of successive voltage pulses from the power supply are applied across the machining gap to induce electric discharges across the machining gap so that a current starts to flow through the machining gap, thereby resulting in the machining of the workpiece.

It is well known to use a coaxial cable, which has an inner-conductor and a conductive shield insulated from the inner-conductor, to reduce the undesirable self-inductance of the

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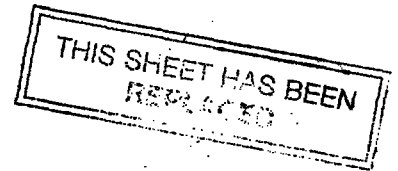
conductors connected between the power supply and the machine body. However, the stray capacitance between the inner-conductor and the shield adversely affects the quality of the machined surface of the workpiece particularly when a relatively long cable is used.

An object of the present invention is to provide an electric discharge machine which can pass current pulses having a steep slope leading edge through a machining gap, thereby increasing machining speed even when a power supply is positioned at a long distance from a machine body.

Another object of the present invention is to provide an electric discharge machine which prevents damages on the machined surface of a workpiece due to the stray capacitance between conductors connected between a power supply and a machine body.

Additional objects, advantages and novel features of the invention will be set forth in part in the description which follows, and in part will become apparent to those skilled in the art upon examination of the following, or may be learned by practice of the invention. The objects and advantages of the invention may be realized and attained by means of the instrumentalities and combinations particularly pointed out in the appended claims.

A general aspect of the present invention is the provision of an electric discharge machining apparatus for machining a workpiece by means of electric discharges having a



tool electrode spaced from the workpiece and defining therewith a machining gap and a power supply for supplying a machining current to the machining gap and comprising: a first conductor having a first ampacity connected between the power supply and the tool electrode; a second conductor connected between the power supply and the workpiece; wherein the first and second conductors are so arranged to reduce the stray capacitance therebetween; a third conductor connected in parallel to the first conductor having a second ampacity smaller than the first ampacity; and a fourth conductor connected in parallel to the second conductor; wherein the third and fourth conductors are so arranged to reduce the inductance thereof.

Another aspect of the present invention is the provision of a method of machining a workpiece using a tool electrode spaced from the workpiece and defining therewith a machining gap a power supply from which a machining current is intermittently supplied to the machining gap and comprising the steps of: connecting a first conductor between the power supply and the tool electrode; connecting a second conductor between the power supply and the workpiece in such a manner as to reduce the stray capacitance between the first and second conductors; connecting a third conductor in parallel to the first conductor; connecting a fourth conductor in parallel to the second conductor in such a manner as to reduce the inductance of the third and fourth conductors; passing a first current pulse from the power supply through the first conductor, the machining gap and the second conductor; and passing a second current pulse having a



steep slope leading edge from the power supply through the third conductor, the machining gap and the fourth conductor during at least a portion of a leading edge of the first current pulse.

The accompanying drawings, which are incorporated in and form a part of the specification, illustrate embodiments of the present invention and, together with the description, serve to explain the principles of the invention. In the drawings:

FIG. 1 is a block diagram illustrating an embodiment of the invention as used in an electric discharge machine;

FIG. 2 is a block diagram illustrating another embodiment of the invention as used in an electric discharge machine;

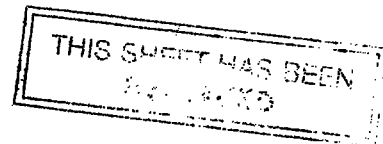
FIGS. 3A to 3E are timing charts illustrating the operation of the machine of FIG. 1; and

FIGS. 4A to 4F are timing charts illustrating the operation of the machine of FIG. 2.

An embodiment of the invention is described hereinafter in detail with reference to the drawings.

FIG. 1 illustrates an embodiment of an electric discharge machine comprising a power supply 10 and a machine body, which includes a tool electrode 1 and a workpiece 2 being machined.

The tool electrode 1 is positioned spaced from the workpiece 2 and defining therewith a machining gap G. The workpiece 2 is securely mounted on an appropriate work table (not



illustrated) and submerged in a work tank (not illustrated) filled with a dielectric fluid. The machine body further includes a terminal 3A, which is connected to the tool electrode 1, and a terminal 3B which is connected to the workpiece 2. It is preferable that each of terminals 3A and 3B are positioned close to the gap G.

The power supply 10 is provided for intermittently supplying a train of successive machining current pulses having a predetermined ON time to the gap G. The power supply 10 includes a d.c. power source 11, current limiting resistors R1 and R2 and switching transistors TR1 and TR2, all of which are connected in series with the gap G. Each one of the resistors R1 and R2 have different magnitudes of resistance, and each is connected in series with a respective one of the transistors TR1 and TR2. The series combinations of the resistors R1 and R2 and the transistors TR1 and TR2 are connected in parallel to each other between the power source 11 and the tool electrode 1. Though an additional combination of a current limiting resistor and a switching transistor may be provided, they have been omitted from FIG. 1 in the interest of clarity and simplicity. The power supply 10 further includes a pulse generator 12 for generating a gating pulse signal GP1 having an ON time and an OFF time. The power supply 10 further includes a discharge detector 13 for monitoring a voltage VG at the gap G and supplying an output signal SP representative of an occurrence of electric discharges to the pulse generator 12. The pulse generator 12 supplies the gating pulse signal GP1 to the transistors TR1 and TR2 so that a



voltage from the power source 11 is applied across the gap G to induce electric discharges and then a current flows through the gap G for a predetermined period of time. The power supply 10 includes a terminal 5A, which is connected to the positive terminal of the power source 11 through the transistors TR1 and TR2 and the resistors R1 and R2, and a terminal 5B which is connected to the negative terminal of the power source 11.

Cables L1 and L2 are provided for carrying a current between the power supply 10 and the machine body. In the illustrated embodiment, the cable L1 is connected to the terminal 5A of the power supply 10 at one end and connected to the terminal 3A of the machine body at the other end. The cable L2 is connected to the terminal 5B of the power supply 10 at one end and connected to the terminal 3B of the machine body at the other end. Each of the cables L1 and L2 are constituted as individual stranded conductors, which are composed of a group of copper wires of small diameters, to reduce the stray capacitance between the cables L1 and L2.

Additionally, a coaxial cable is provided for carrying a current between the power supply 10 and the machine body. The coaxial cable includes an inner-conductor L3 and a conductive shield L4 which is arranged coaxially with the inner-conductor L3 and insulated therefrom by an appropriate insulator. Each of the conductors L3 and L4 are smaller in cross-sectional area than the cables L1 and L2, for example, about half to reduce the stray inductance of the conductors L3 and L4. In other words, each of the conductors L3 and L4 are smaller in ampacity than the cables



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L1 and L2. In the illustrated embodiment, the inner-conductor L3 is connected to the terminal 5A at one end and connected to the terminal 3A at the other end. The conductive shield L4 is connected to the terminal 5B at one end and connected to the terminal 3B at the other end. In other words, the conductors L3 and L4 are connected in parallel with the cables L1 and L2, respectively.

As will now be appreciated by the artisan, the coaxial cable is used to reduce the inductance of the conductors L3 and L4. Alternatively, a twisted pair, which is composed of two insulated conductors twisted together without a common covering, may be used.

Operation of the machine shown in FIG. 1 will now be described with reference to FIGS. 3A, 3B, 3C, 3D and 3E. FIGS. 3A, 3B, 3C, 3D and 3E are illustrative of waveforms of the gating pulse signal GP1, a voltage VG, a current  $i_1$  flowing through the cables L1 and L2, a current  $i_2$  flowing through the conductors L3 and L4, and a total current IG, i.e., a combination of currents  $i_1$  and  $i_2$ .

At the time  $t_1$ , when the gating pulse signal GP1 goes high, the transistors TR1 and TR2 are turned on. A voltage from the power source 11 is applied across the gap G. Thereby, at the time  $t_2$ , electric discharges are caused to start in the gap G and a current  $i_2$  starts to flow through the gap G. As shown in FIG. 3D, a current  $i_2$  suddenly increases due to low inductance of the conductors L3 and L4. As shown in FIG. 3C, a current  $i_1$  gradually increases to its steady value while a current  $i_2$



decreases to its steady value, as shown in FIG. 3C. The steady value of current  $i_1$  is inversely proportional to the total resistance of the cables  $L_1$  and  $L_2$  and the gap  $G$ . The steady value of current  $i_2$  is inversely proportional to the total resistance of the conductors  $L_3$  and  $L_4$  and the gap  $G$ . In the illustrated embodiment, the cables  $L_1$  and  $L_2$  are larger in cross-sectional area than the conductors  $L_3$  and  $L_4$  so that the steady value of current  $i_1$  is larger than that of current  $i_2$ . The cables  $L_1$  and  $L_2$  and the conductors  $L_3$  and  $L_4$  are only sufficiently large to pass mean currents  $i_1$  and  $i_2$ , respectively. The gating pulse signal  $GP_1$  is in an ON state a predetermined time after the generation of the signal  $SP$ . At the time  $t_3$ , when the gating pulse signal  $GP_1$  is turned off, a current  $i_2$  suddenly drops. While, a current  $i_1$  gradually decreases. As shown in FIG. 3E, a total current  $I_G$  flowing through the gap  $G$  has a steep slope on its leading edge.

FIG. 2 illustrates another embodiment of an electric discharge machine, which is suitable, for example, for the machining of a cemented carbide workpiece by means of a copper tungsten electrode or the machining of a steel workpiece by means of a steel electrode. Similar elements are labelled with similar reference numerals as used in FIG. 1.

In FIG. 2, a power supply 10A includes a first series combination consisting of the d.c. power source 11, a diode  $D_1$  for reverse-current protection, the current limiting resistor  $R_1$  and the switching transistor  $TR_1$ , all of which are connected in series to the terminal 5A. Though an additional combination of a



diode, a current limiting resistor and a switching transistor may be provided, they have been omitted from FIG. 2 in the interest of clarity and simplicity.

The power supply 10A further includes a second series combination consisting of a variable voltage, d.c. power source 11B, adjustable between approximately 100 volts and 300 volts, and a switching transistor DTR. In addition, the power supply 10A includes a terminal 5C to which the inner-conductor L3 is connected at one end. The power source 11B is connected to the terminal 5C through the transistor DTR at its positive terminal and connected to the terminal 5B at its negative terminal. The first and second series combinations are connected in parallel to each other. The power supply 10A further includes a pulse generator 14, which is provided connected to the discharge detector 13 for generating a gating pulse signal GP2 having an ON time and an OFF time. For example, each of the pulse generators 12 and 14 may include appropriate clock oscillator and counter. The pulse generator 14 turns on the transistor DTR so that a high peak current flows through the gap G a predetermined short time after an occurrence of electric discharges. A diode DR is provided between the cable L1 and the conductor L3 for preventing a voltage from the power source 11 from being applied across a spacing between the conductors L3 and L4.

Operation of the machine shown in FIG. 2 will now be described with reference to FIGS. 4A, 4B, 4C, 4D 4E and 4F. FIGS. 4A, 4B, 4C, 4D, 4E and 4F are illustrative of waveforms of



the gating pulse signal GP1, a voltage VG, the signal SP, a current i1, a current i2, and a total current IG.

At the time t1, when the gating pulse signals GP1 and GP2 go high, the transistors TR1 and DTR are turned on. The power sources 11 and 11B apply a voltage across the gap G. Thereby, at the time t2, electric discharges are caused to start in the gap G and a current i2 starts to flow through the gap G. At the time t2, a discharge detector detects drop of a voltage VG and supplies the signal SP to the pulse generators 12 and 14. After a predetermined short time upon receipt of the signal SP the pulse generator 14 turns off the transistor DTR. Preferably, the transistor DTR is closed at least about a half of the time during which a current i1 does not reach its steady value though a current flows through the gap G. A peak value of current i2 can be set to a desired value by adjusting a voltage of the power source 11B. Alternatively, it may be set by varying an ON time of the gating pulse signal GP2.

The foregoing description of a preferred embodiment of the invention has been presented for purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed, and obviously many modifications and variations are possible in the light of the above teaching. For example, a voltage may be applied across the gap G with the tool electrode 1 being negatively poled and the workpiece 2 being positively poled. It is intended that the scope of the invention be defined by the claims appended hereto.



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CLAIMS

1. An electric discharge machining apparatus for machining a workpiece by means of electric discharge having a tool electrode (1) spaced from said workpiece (2) and defining therewith a machining gap (G) and a power supply (10) for supplying a machining current to said machining gap, said apparatus comprising:
- a first conductor (L1) having a first ampacity (current carrying capacity) connected between said power supply and said tool electrode;
- a second conductor (L2) connected between said power supply and said workpiece;
- wherein said first and second conductors are so arranged to reduce the stray capacitance therebetween;
- a third conductor (L3) connected in parallel to said first conductor and having a second ampacity (current carrying capacity) smaller than said first ampacity (current carrying capacity); and
- a fourth conductor (L4) connected in parallel to said second conductor;
- wherein said third and fourth conductors are so arranged to reduce the inductance thereof.
2. An electric discharge machining apparatus according to Claim 1, wherein said third and fourth conductors form a coaxial cable having an inner-conductor and a shield insulated from said inner-conductor said inner-conductor being connected between said power supply and one of said tool electrode and said workpiece, said shield being connected between said power supply and the other of said tool electrode and said workpiece.
3. An electric discharge machining apparatus according to Claim 1 or Claim 2, wherein said power supply includes a first power source (11), a first switching means (TR1, TR2) connected in series with said first power source and said machining gap for controlling the flow of

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current through said first and second conductors and said machining gap, a second power source (11b) and a second switching means (DTR) connected in series between said second power source and said machining gap for controlling the flow of current through said third and fourth conductors and said machining gap.

4. An electric discharge machining apparatus according to Claim 3, wherein said power supply further includes a discharge detector (13) for detecting the occurrence of electric discharges, a first pulse generator (12) for supplying to said first switching means a first gating pulse signal having an ON time and an OFF time and a second pulse generator (14) responsive to said discharge detector for supplying a second gating pulse signal to said second switching means, said second pulse signal having an ON time a predetermined time after an occurrence of electric discharges.

5. A method of machining a workpiece using a tool electrode (1) spaced from said workpiece (2) and defining therewith a machining gap (G) and a power supply (10) from which a machining current is intermittently supplied to said machining gap, comprising the steps of:

connecting a first conductor (L1) between said power supply and said tool electrode;

25 connecting a second conductor (L2) between said power supply and said workpiece in such a manner as to reduce the stray capacitance between said first and second conductors;

connecting a third conductor (L3) in parallel to said first conductor;

connecting a fourth conductor (L4) in parallel to said second conductor in such a manner as to reduce the inductance of said third and fourth conductors;

passing a first current pulse from said power supply through said first conductor, said machining gap

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and said second conductor; and

5            passing a second current pulse having a steep  
slope leading edge from said power supply through said  
third conductor, said machining gap and said fourth  
conductor during at least a portion of a leading edge of  
said first current pulse.

6.            The method of Claim 6, wherein the step of  
connecting further comprising arranging said third  
conductor coaxially with said fourth conductor.

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ABSTRACTELECTRIC DISCHARGE MACHINING APPARATUS

An electric discharge machining apparatus for machining a workpiece by means of electric discharges using a tool electrode (1) spaced from the workpiece (2) and defining therewith a machining gap (G), comprising a pair of individual cables (L1,L2) with a low capacitance and a coaxial cable (L3,L4) with a low inductance to carry a train of successive current pulses from a power supply to the machining gap. The pair of cables are larger in current-carrying capacity than the coaxial cable. A current pulse flowing through the pair of cables is combined with that flowing through the coaxial cable to thereby obtain a total current pulse of a steep slope leading edge while preventing undesirable stray capacitance.

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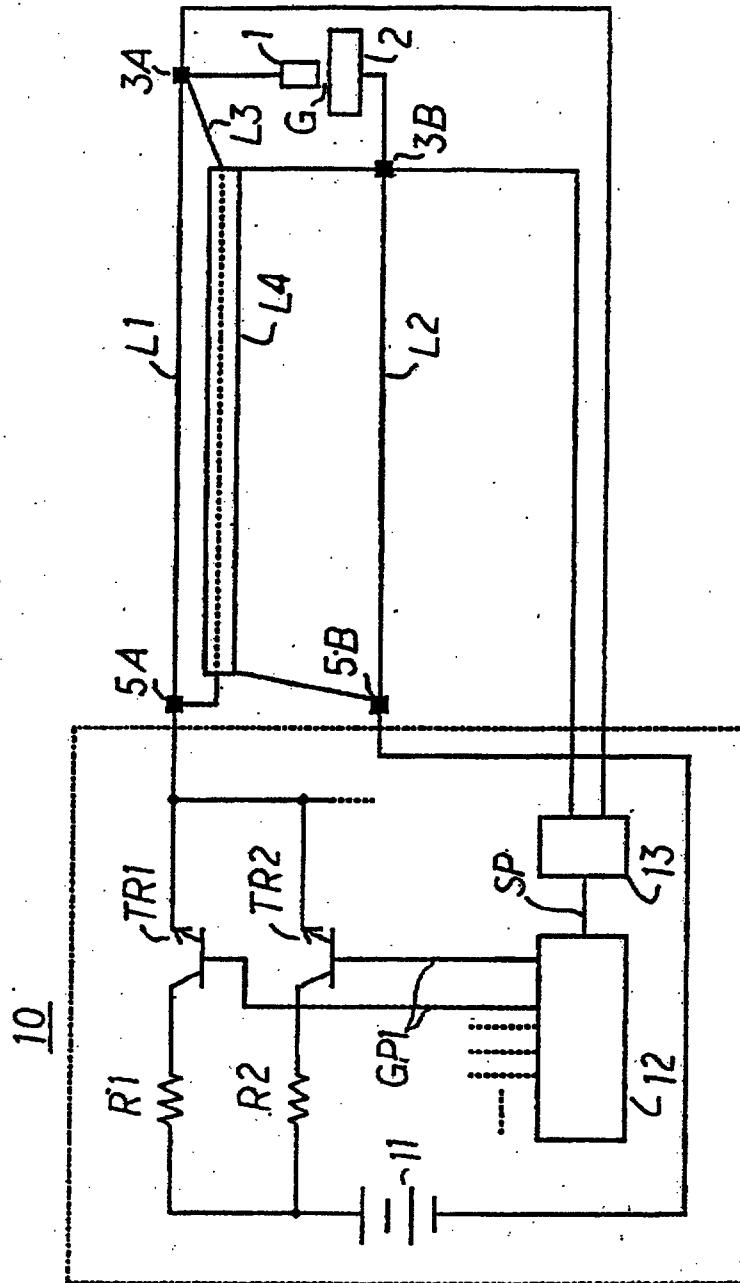
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FIG. 1



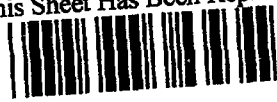
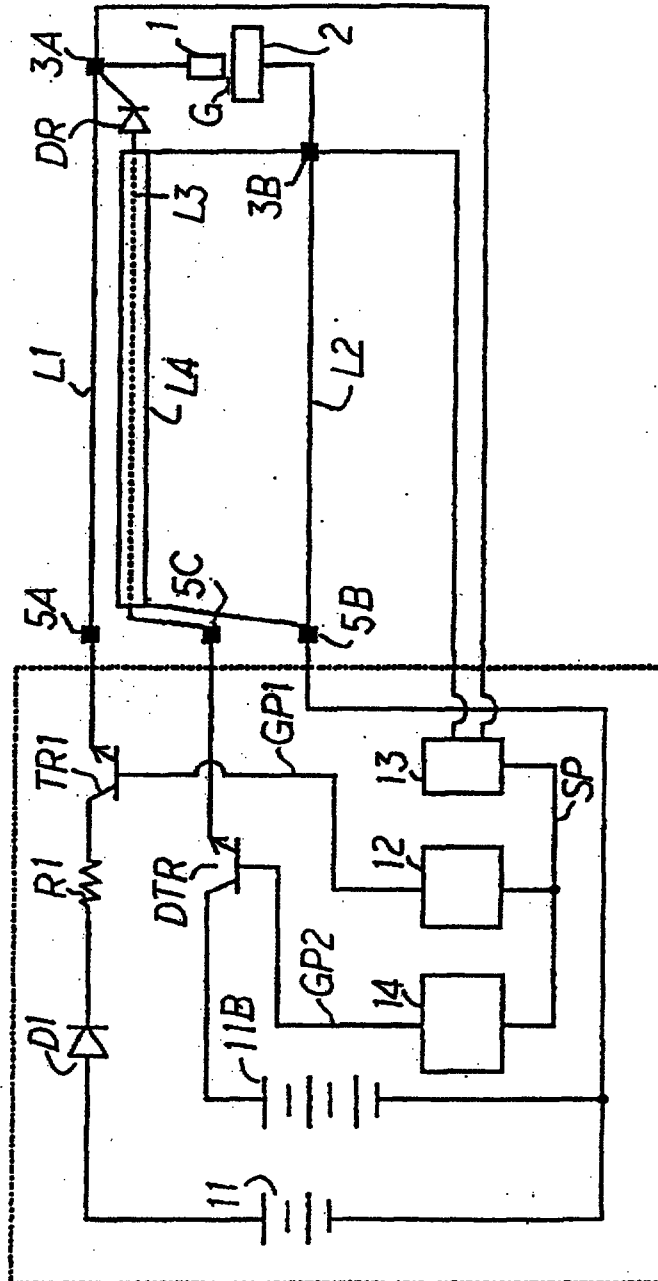
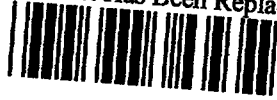


FIG. 2

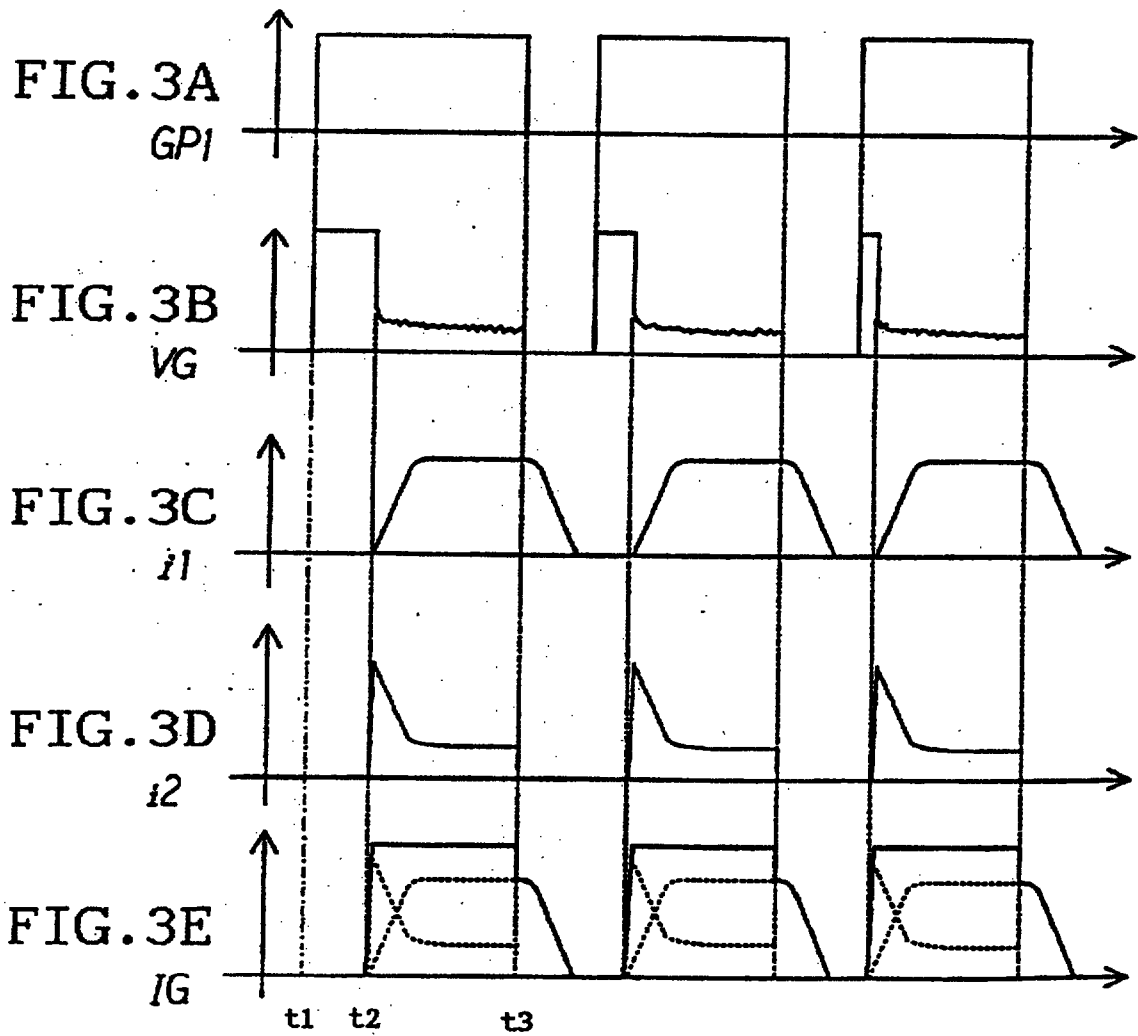
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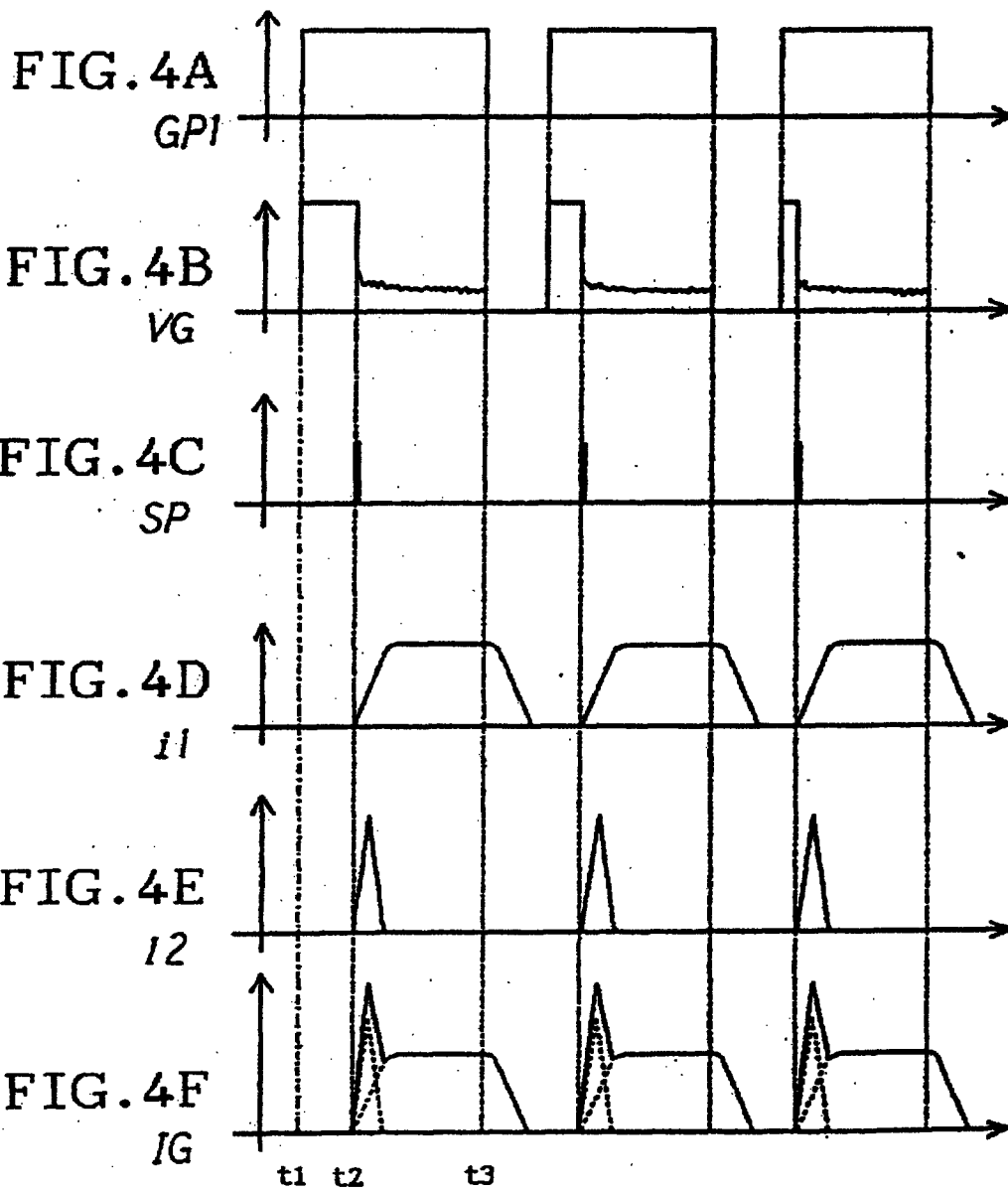


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### ELECTRIC DISCHARGE MACHINING APPARATUS

The present invention relates to an electroerosion machine. More specifically, the present invention relates to an electric discharge machine ("EDM") for performing electric discharge machining on a workpiece using a tool electrode in which a train of successive power pulses are supplied from a power supply to a machine body including a machining gap formed between the tool electrode and the workpiece.

In general, an electric discharge machine includes a machine body having a machining gap formed between a tool electrode and a workpiece being machined, a power supply for supplying electric energy to the machining gap and a dielectric supply device for supplying a dielectric fluid, such as kerosine or water, to the machining gap. The power supply is necessarily positioned with a physical spacing from the machine body and connected to the machine body by means of appropriate conductors.

A train of successive voltage pulses from the power supply are applied across the machining gap to induce electric discharges across the machining gap so that a current starts to flow through the machining gap, thereby resulting in the machining of the workpiece.

It is well known to use a coaxial cable, which has an inner-conductor and a conductive shield insulated from the inner-conductor, to reduce the undesirable self-inductance of the

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conductors connected between the power supply and the machine body. However, the stray capacitance between the inner-conductor and the shield adversely affects the quality of the machined surface of the workpiece particularly when a relatively long cable is used.

An object of the present invention is to provide an electric discharge machine which can pass current pulses having a steep slope leading edge through a machining gap, thereby increasing machining speed even when a power supply is positioned at a long distance from a machine body.

Another object of the present invention is to provide an electric discharge machine which prevents damages on the machined surface of a workpiece due to the stray capacitance between conductors connected between a power supply and a machine body.

Additional objects, advantages and novel features of the invention will be set forth in part in the description which follows, and in part will become apparent to those skilled in the art upon examination of the following, or may be learned by practice of the invention. The objects and advantages of the invention may be realized and attained by means of the instrumentalities and combinations particularly pointed out in the appended claims.

A general aspect of the present invention is the provision of an electric discharge machining apparatus for machining a workpiece by means of electric discharges having a

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tool electrode spaced from the workpiece and defining therewith a machining gap and a power supply for supplying a machining current to the machining gap and comprising: a first conductor having a first ampacity connected between the power supply and the tool electrode; a second conductor connected between the power supply and the workpiece; wherein the first and second conductors are so arranged to reduce the stray capacitance therebetween; a third conductor connected in parallel to the first conductor having a second ampacity smaller than the first ampacity; and a fourth conductor connected in parallel to the second conductor; wherein the third and fourth conductors are so arranged to reduce the inductance thereof.

Another aspect of the present invention is the provision of a method of machining a workpiece using a tool electrode spaced from the workpiece and defining therewith a machining gap a power supply from which a machining current is intermittently supplied to the machining gap and comprising the steps of: connecting a first conductor between the power supply and the tool electrode; connecting a second conductor between the power supply and the workpiece in such a manner as to reduce the stray capacitance between the first and second conductors; connecting a third conductor in parallel to the first conductor; connecting a fourth conductor in parallel to the second conductor in such a manner as to reduce the inductance of the third and fourth conductors; passing a first current pulse from the power supply through the first conductor, the machining gap and the second conductor; and passing a second current pulse having a

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steep slope leading edge from the power supply through the third conductor, the machining gap and the fourth conductor during at least a portion of a leading edge of the first current pulse.

The accompanying drawings, which are incorporated in and form a part of the specification, illustrate embodiments of the present invention and, together with the description, serve to explain the principles of the invention. In the drawings:

FIG. 1 is a block diagram illustrating an embodiment of the invention as used in an electric discharge machine;

FIG. 2 is a block diagram illustrating another embodiment of the invention as used in an electric discharge machine;

FIGS. 3A to 3E are timing charts illustrating the operation of the machine of FIG. 1; and

FIGS. 4A to 4F are timing charts illustrating the operation of the machine of FIG. 2.

An embodiment of the invention is described hereinafter in detail with reference to the drawings.

FIG. 1 illustrates an embodiment of an electric discharge machine comprising a power supply 10 and a machine body, which includes a tool electrode 1 and a workpiece 2 being machined.

The tool electrode 1 is positioned spaced from the workpiece 2 and defining therewith a machining gap G. The workpiece 2 is securely mounted on an appropriate work table (not

illustrated) and submerged in a work tank (not illustrated) filled with a dielectric fluid. The machine body further includes a terminal 3A, which is connected to the tool electrode 1, and a terminal 3B which is connected to the workpiece 2. It is preferable that each of terminals 3A and 3B are positioned close to the gap G.

The power supply 10 is provided for intermittently supplying a train of successive machining current pulses having a predetermined ON time to the gap G. The power supply 10 includes a d.c. power source 11, current limiting resistors R1 and R2 and switching transistors TR1 and TR2, all of which are connected in series with the gap G. Each one of the resistors R1 and R2 have different magnitudes of resistance, and each is connected in series with a respective one of the transistors TR1 and TR2. The series combinations of the resistors R1 and R2 and the transistors TR1 and TR2 are connected in parallel to each other between the power source 11 and the tool electrode 1. Though an additional combination of a current limiting resistor and a switching transistor may be provided, they have been omitted from FIG. 1 in the interest of clarity and simplicity. The power supply 10 further includes a pulse generator 12 for generating a gating pulse signal GP1 having an ON time and an OFF time. The power supply 10 further includes a discharge detector 13 for monitoring a voltage VG at the gap G and supplying an output signal SP representative of an occurrence of electric discharges to the pulse generator 12. The pulse generator 12 supplies the gating pulse signal GP1 to the transistors TR1 and TR2 so that a

voltage from the power source 11 is applied across the gap G to induce electric discharges and then a current flows through the gap G for a predetermined period of time. The power supply 10 includes a terminal 5A, which is connected to the positive terminal of the power source 11 through the transistors TR1 and TR2 and the resistors R1 and R2, and a terminal 5B which is connected to the negative terminal of the power source 11.

Cables L1 and L2 are provided for carrying a current between the power supply 10 and the machine body. In the illustrated embodiment, the cable L1 is connected to the terminal 5A of the power supply 10 at one end and connected to the terminal 3A of the machine body at the other end. The cable L2 is connected to the terminal 5B of the power supply 10 at one end and connected to the terminal 3B of the machine body at the other end. Each of the cables L1 and L2 are constituted as individual stranded conductors, which are composed of a group of copper wires of small diameters, to reduce the stray capacitance between the cables L1 and L2.

Additionally, a coaxial cable is provided for carrying a current between the power supply 10 and the machine body. The coaxial cable includes an inner-conductor L3 and a conductive shield L4 which is arranged coaxially with the inner-conductor L3 and insulated therefrom by an appropriate insulator. Each of the conductors L3 and L4 are smaller in cross-sectional area than the cables L1 and L2, for example, about half to reduce the stray inductance of the conductors L3 and L4. In other words, each of the conductors L3 and L4 are smaller in ampacity than the cables

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L1 and L2. In the illustrated embodiment, the inner-conductor L3 is connected to the terminal 5A at one end and connected to the terminal 3A at the other end. The conductive shield L4 is connected to the terminal 5B at one end and connected to the terminal 3B at the other end. In other words, the conductors L3 and L4 are connected in parallel with the cables L1 and L2, respectively.

As will now be appreciated by the artisan, the coaxial cable is used to reduce the inductance of the conductors L3 and L4. Alternatively, a twisted pair, which is composed of two insulated conductors twisted together without a common covering, may be used.

Operation of the machine shown in FIG. 1 will now be described with reference to FIGS. 3A, 3B, 3C, 3D and 3E. FIGS. 3A, 3B, 3C, 3D and 3E are illustrative of waveforms of the gating pulse signal GP1, a voltage VG, a current  $i_1$  flowing through the cables L1 and L2, a current  $i_2$  flowing through the conductors L3 and L4, and a total current IG, i.e., a combination of currents  $i_1$  and  $i_2$ .

At the time  $t_1$ , when the gating pulse signal GP1 goes high, the transistors TR1 and TR2 are turned on. A voltage from the power source 11 is applied across the gap G. Thereby, at the time  $t_2$ , electric discharges are caused to start in the gap G and a current  $i_2$  starts to flow through the gap G. As shown in FIG. 3D, a current  $i_2$  suddenly increases due to low inductance of the conductors L3 and L4. As shown in FIG. 3C, a current  $i_1$  gradually increases to its steady value while a current  $i_2$

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decreases to its steady value, as shown in FIG. 3C. The steady value of current  $i_1$  is inversely proportional to the total resistance of the cables L1 and L2 and the gap G. The steady value of current  $i_2$  is inversely proportional to the total resistance of the conductors L3 and L4 and the gap G. In the illustrated embodiment, the cables L1 and L2 are larger in cross-sectional area than the conductors L3 and L4 so that the steady value of current  $i_1$  is larger than that of current  $i_2$ . The cables L1 and L2 and the conductors L3 and L4 are only sufficiently large to pass mean currents  $i_1$  and  $i_2$ , respectively. The gating pulse signal GP1 is in an ON state a predetermined time after the generation of the signal SP. At the time  $t_3$ , when the gating pulse signal GP1 is turned off, a current  $i_2$  suddenly drops. While, a current  $i_1$  gradually decreases. As shown in FIG. 3E, a total current IG flowing through the gap G has a steep slope on its leading edge.

FIG. 2 illustrates another embodiment of an electric discharge machine, which is suitable, for example, for the machining of a cemented carbide workpiece by means of a copper tungsten electrode or the machining of a steel workpiece by means of a steel electrode. Similar elements are labelled with similar reference numerals as used in FIG. 1.

In FIG. 2, a power supply 10A includes a first series combination consisting of the d.c. power source 11, a diode D1 for reverse-current protection, the current limiting resistor R1 and the switching transistor TR1, all of which are connected in series to the terminal 5A. Though an additional combination of a

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diode, a current limiting resistor and a switching transistor may be provided, they have been omitted from FIG. 2 in the interest of clarity and simplicity.

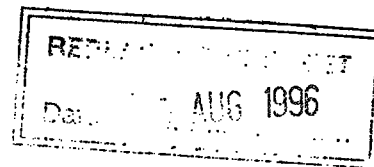
The power supply 10A further includes a second series combination consisting of a variable voltage, d.c. power source 11B, adjustable between approximately 100 volts and 300 volts, and a switching transistor DTR. In addition, the power supply 10A includes a terminal 5C to which the inner-conductor L3 is connected at one end. The power source 11B is connected to the terminal 5C through the transistor DTR at its positive terminal and connected to the terminal 5B at its negative terminal. The first and second series combinations are connected in parallel to each other. The power supply 10A further includes a pulse generator 14, which is provided connected to the discharge detector 13 for generating a gating pulse signal GP2 having an ON time and an OFF time. For example, each of the pulse generators 12 and 14 may include appropriate clock oscillator and counter. The pulse generator 14 turns on the transistor DTR so that a high peak current flows through the gap G a predetermined short time after an occurrence of electric discharges. A diode DR is provided between the cable L1 and the conductor L3 for preventing a voltage from the power source 11 from being applied across a spacing between the conductors L3 and L4.

Operation of the machine shown in FIG. 2 will now be described with reference to FIGS. 4A, 4B, 4C, 4D 4E and 4F. FIGS. 4A, 4B, 4C, 4D, 4E and 4F are illustrative of waveforms of

the gating pulse signal GP1, a voltage VG, the signal SP, a current i1, a current i2, and a total current IG.

At the time t1, when the gating pulse signals GP1 and GP2 go high, the transistors TR1 and DTR are turned on. The power sources 11 and 11B apply a voltage across the gap G. Thereby, at the time t2, electric discharges are caused to start in the gap G and a current i2 starts to flow through the gap G. At the time t2, a discharge detector detects drop of a voltage VG and supplies the signal SP to the pulse generators 12 and 14. After a predetermined short time upon receipt of the signal SP the pulse generator 14 turns off the transistor DTR. Preferably, the transistor DTR is closed at least about a half of the time during which a current i1 does not reach its steady value though a current flows through the gap G. A peak value of current i2 can be set to a desired value by adjusting a voltage of the power source 11B. Alternatively, it may be set by varying an ON time of the gating pulse signal GP2.

The foregoing description of a preferred embodiment of the invention has been presented for purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed, and obviously many modifications and variations are possible in the light of the above teaching. For example, a voltage may be applied across the gap G with the tool electrode 1 being negatively poled and the workpiece 2 being positively poled. It is intended that the scope of the invention be defined by the claims appended hereto.



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# CLAIMS

1. An electric discharge machining apparatus for machining a workpiece by means of electric discharge having a tool electrode (1) spaced from said workpiece (2) and defining therewith a machining gap (G) and a power supply (10) for supplying a machining current to said machining gap, said apparatus comprising:
  - a first conductor (L1) having a first ampacity (current carrying capacity) connected between said power supply and said tool electrode;
  - a second conductor (L2) connected between said power supply and said workpiece;
  - wherein said first and second conductors are so arranged to reduce the stray capacitance therebetween;
  - a third conductor (L3) connected in parallel to said first conductor and having a second ampacity (current carrying capacity) smaller than said first ampacity (current carrying capacity); and
  - a fourth conductor (L4) connected in parallel to said second conductor;
  - wherein said third and fourth conductors are so arranged to reduce the inductance thereof.
2. An electric discharge machining apparatus according to Claim 1, wherein said third and fourth conductors form a coaxial cable having an inner-conductor and a shield insulated from said inner-conductor said inner-conductor being connected between said power supply and one of said tool electrode and said workpiece, said shield being connected between said power supply and the other of said tool electrode and said workpiece.
3. An electric discharge machining apparatus according to Claim 1 or Claim 2, wherein said power supply includes a first power source (11), a first switching means (TR1, TR2) connected in series with said first power source and said machining gap for controlling the flow of



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current through said first and second conductors and said machining gap, a second power source (11b) and a second switching means (DTR) connected in series between said second power source and said machining gap for controlling the flow of current through said third and fourth conductors and said machining gap.

4. An electric discharge machining apparatus according to Claim 3, wherein said power supply further includes a discharge detector (13) for detecting the occurrence of electric discharges, a first pulse generator (12) for supplying to said first switching means a first gating pulse signal having an ON time and an OFF time and a second pulse generator (14) responsive to said discharge detector for supplying a second gating pulse signal to said second switching means, said second pulse signal having an ON time a predetermined time after an occurrence of electric discharges.

5. A method of machining a workpiece using a tool electrode (1) spaced from said workpiece (2) and defining therewith a machining gap (G) and a power supply (10) from which a machining current is intermittently supplied to said machining gap, comprising the steps of:

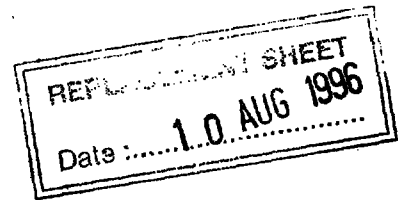
connecting a first conductor (L1) between said power supply and said tool electrode;

connecting a second conductor (L2) between said power supply and said workpiece in such a manner as to reduce the stray capacitance between said first and second conductors;

connecting a third conductor (L3) in parallel to said first conductor;

connecting a fourth conductor (L4) in parallel to said second conductor in such a manner as to reduce the inductance of said third and fourth conductors;

passing a first current pulse from said power supply through said first conductor, said machining gap



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and said second conductor; and

5            passing a second current pulse having a steep  
slope leading edge from said power supply through said  
third conductor, said machining gap and said fourth  
conductor during at least a portion of a leading edge of  
said first current pulse.

6.            The method of Claim 6, wherein the step of  
connecting further comprising arranging said third  
conductor coaxially with said fourth conductor.

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ABSTRACT

ELECTRIC DISCHARGE MACHINING APPARATUS

An electric discharge machining apparatus for machining a workpiece by means of electric discharges using a tool electrode (1) spaced from the workpiece (2) and defining therewith a machining gap (G), comprising a pair of individual cables (L1,L2) with a low capacitance and a coaxial cable (L3,L4) with a low inductance to carry a train of successive current pulses from a power supply to the machining gap. The pair of cables are larger in current-carrying capacity than the coaxial cable. A current pulse flowing through the pair of cables is combined with that flowing through the coaxial cable to thereby obtain a total current pulse of a steep slope leading edge while preventing undesirable stray capacitance.

Figure 1

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FIG. 1

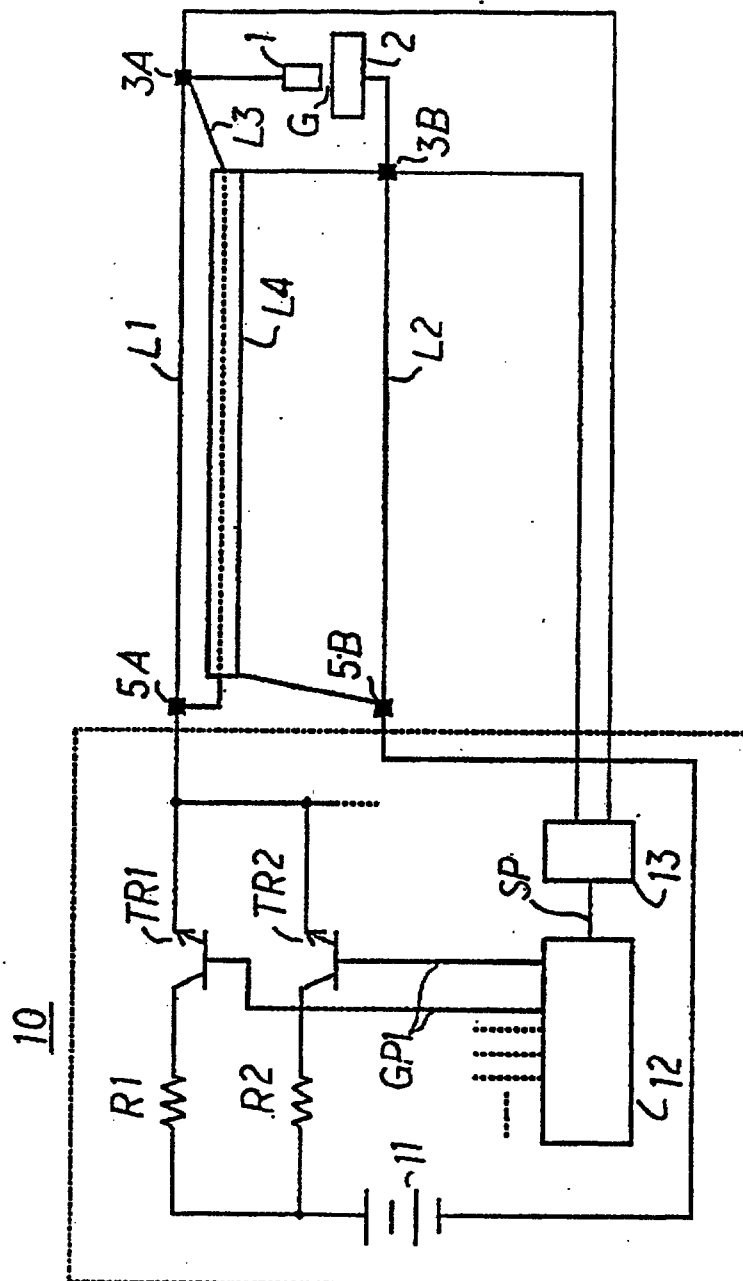
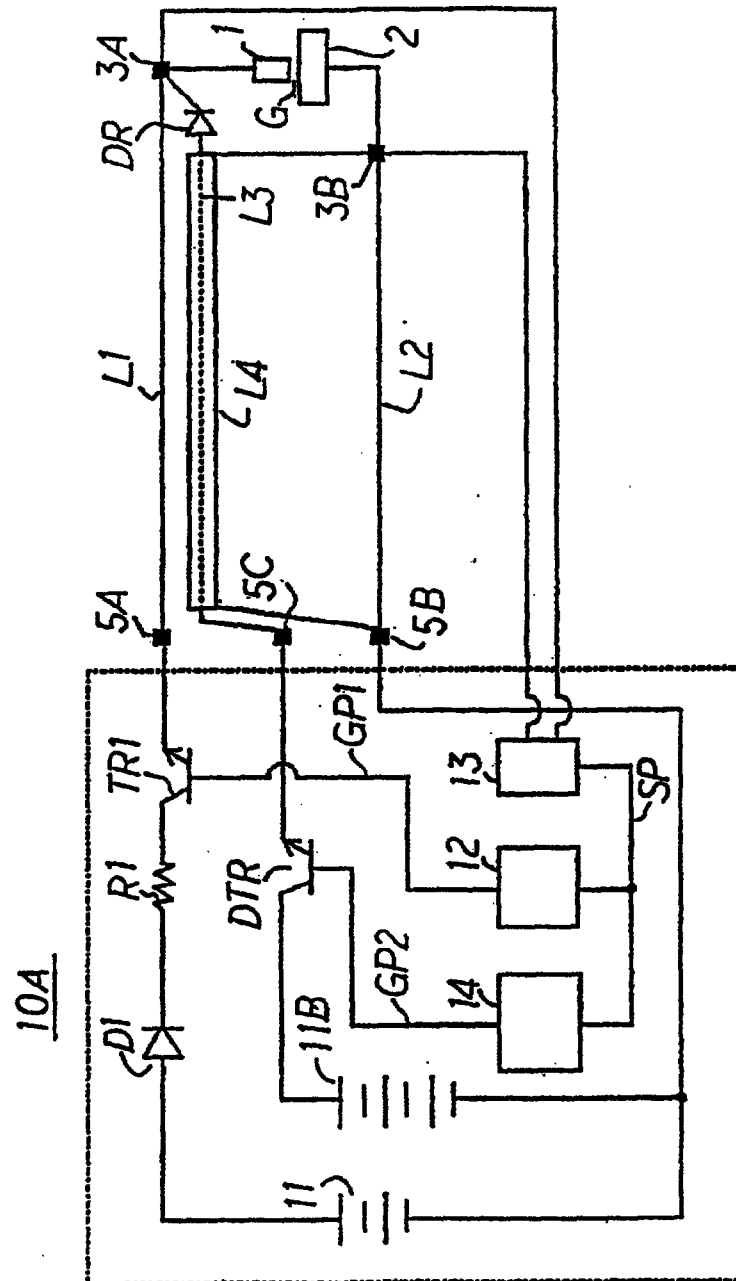
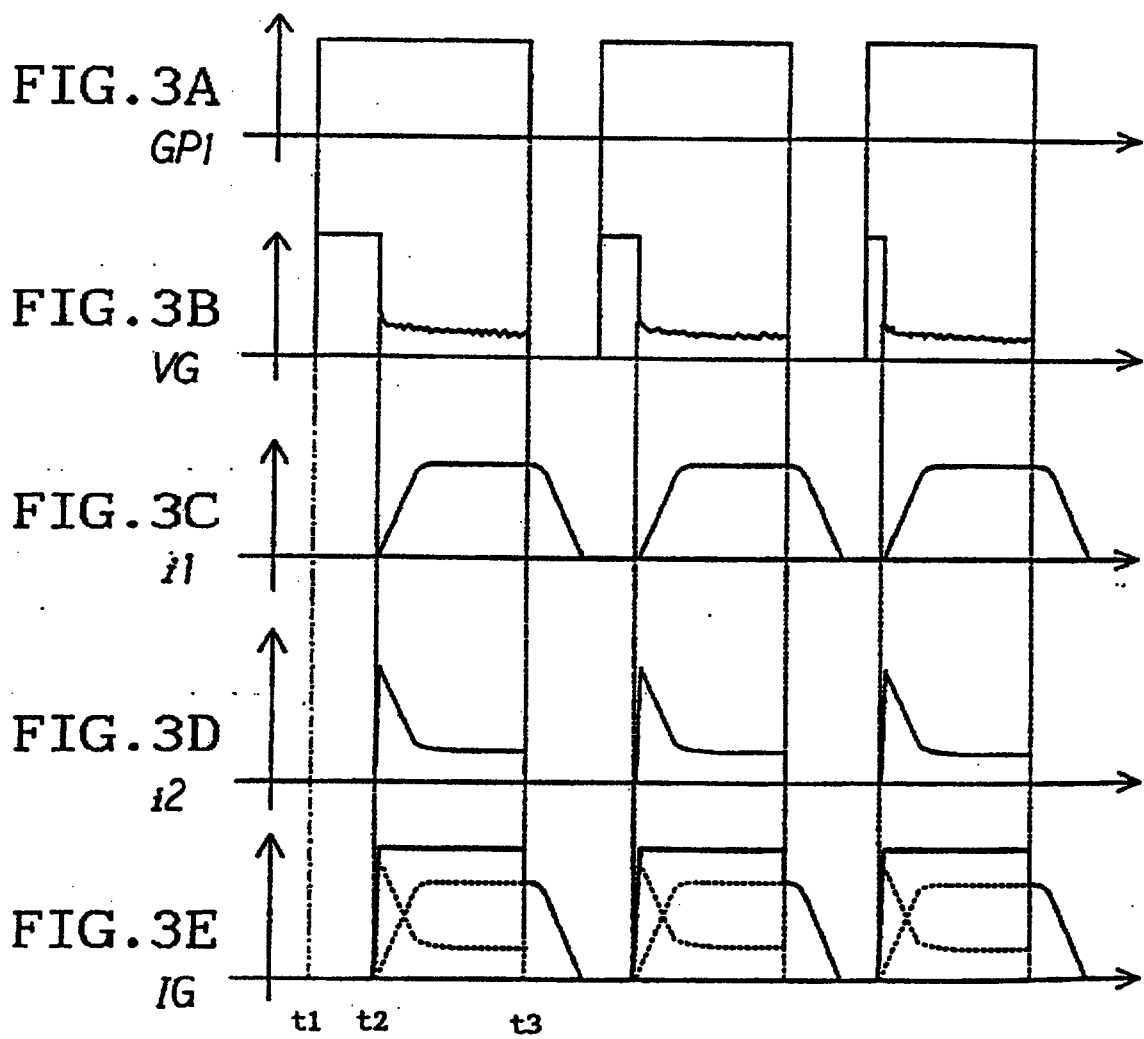


FIG. 2



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