



- (51) International Patent Classification: Not classified
- (21) International Application Number: PCT/IB2013/002503
- (22) International Filing Date: 11 November 2013 (11.11.2013)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data: 13/673,596 9 November 2012 (09.11.2012) US
- (71) Applicant: LINCOLN GLOBAL, INC. [US/US]; 17721 Railroad Street, City of Industry, CA 91748 (US).
- (72) Inventors: HEARN, James, E.; c/o Lincoln Global, Inc., 17721 Railroad Street, City of Industry, CA 91748 (US). PETERS, Steven, R.; 15565 Windmill Point Road, Huntsburg, OH 44046 (US).
- (81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM,

DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

- (84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— without international search report and to be republished upon receipt of that report (Rule 48.2(g))

(54) Title: SYSTEM AND METHOD TO DETECT DROPLET DETACHMENT

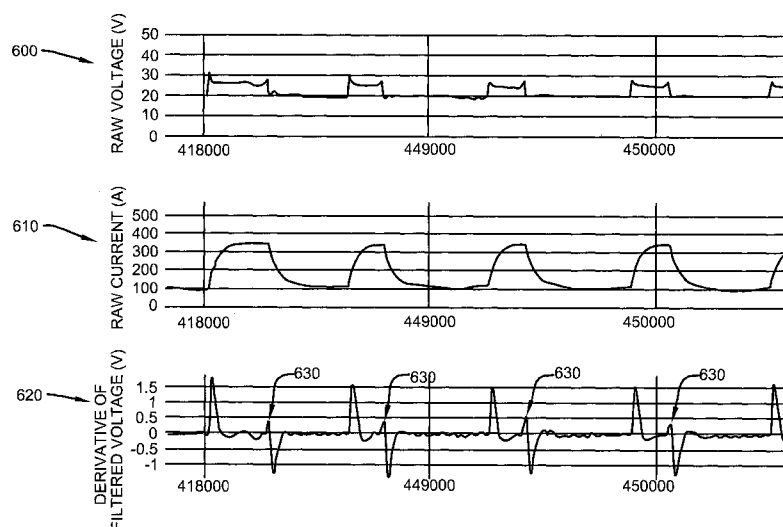


FIG. 6

(57) Abstract: The invention described herein generally pertains to a method for improved droplet detachment detection in a welding process in which a derivative of at least one welding parameter over time is used to detect droplet detachment from the wire during a welding operation based identification of a peak signature (630).



System and Method to Detect Droplet Detachment

Technical Field

The invention described herein pertains generally to a method for improved droplet detachment detection in a welding process.

Background of the Invention

Gas metal arc welding (GMAW), sometimes referred to by its subtypes metal inert gas (MIG) welding or metal active gas (MAG) welding, is a semi-automatic or automatic arc welding process in which a continuous and consumable wire electrode ("welding wire") and a shielding gas are fed through a welding gun.

Pulse spray metal transfer (GMAW-P) uses high energy of Axial Spray Metal Transfer and alternates this high energy (peak) current with a lower energy (background) current. Each cycle is referred to as a period and the period can repeat several hundred times per second. Spray or pulsed spray welding processes are free flight transfers in which a droplet formed detaches from the wire, crosses the plasma, and into the weld pool.

Pulsed energy produces desirable fusion characteristics and reduces the heat input considerably when compared to axial spray transfer or other welding processes. The dynamics of the pulse permit the use of GMAW-P for out-of-position welding. Therefore, it is easily seen that what is needed is a dynamic way to provide a more accurate method for detection of the droplet detaching (and the droplet detachment point) from a wire.

Summary of the Invention

In accordance with the present invention, there is provided a process for detecting droplet detaching from a wire during a welding operation that uses a shielding gas comprising the steps of: providing a welding signal to a welding electrode in a succession of welding cycles during a welding process, each said welding cycle including a pulsed output comprised of a background output condition with a superimposed high output pulse condition during which the welding electrode heats up to a molten droplet and is pinched off and separates from the end of the electrode measuring at least one welding parameter during said welding process, calculating a derivative over time of said at least one welding parameter, detecting a peak signature within said derivative of at least one welding parameter during an arc of the welding operation, and reducing a magnitude of at least one welding parameter of said pulsed output used with said welding process based on said step of detecting. The at least one welding parameter is selected from the group consisting of current,

voltage, resistance, and power. The process may further include the step of monitoring a duration of time from a start of the pulse to the termination of the pulse. The process may further include the steps of using the duration of time as a threshold value for a next cycle of the pulse; and terminating a next cycle of the pulse based on the step of using. The process may further include the step of using the duration of time as input for an adaptive control of the welding process for a next cycle. Moreover, process may further include the steps of using duration of time as an indicia of droplet size consistency and wire feed speed consistency between cycles of pulses.

In accordance with the present invention, there is provided a process for detecting droplet detaching from a wire during a welding operation that uses a shielding gas comprising the steps of: providing a welding signal to a welding electrode in a succession of welding cycles during a welding process, each said welding cycle a pulsed output comprised of a background output condition with a superimposed high output pulse condition during which the welding electrode heats up to a molten droplet and is pinched off and separates from the end of the electrode calculating a derivative over time of at least one characteristic selected from the group consisting of voltage, current, resistance, and power during said welding process, detecting a peak signature within said step of calculating during an arc of the welding operation, and modifying said pulsed output used with said welding process based on said step of detecting.

In accordance with the present invention, there is provided a process for detecting droplet detaching from a wire during a welding operation that uses a shielding gas comprising the steps of: providing a welding signal to a welding electrode in a succession of welding cycles during a welding process, each said welding cycle including a pulsed output comprised of a background output condition with a superimposed high output pulse condition during which the welding electrode heats up to a molten droplet and is pinched off and separates from the end of the electrode measuring at least one welding parameter during said pulse welding process, calculating a derivative over time of said at least one welding parameter, identifying a peak signature within said derivative over time of said at least one welding parameter during an arc of the welding operation, reducing a magnitude of at least one welding parameter of said pulsed output used with said pulse welding process based on said step of identifying, monitoring a duration of time from a start of said pulsed output to said reduction of magnitude of at least one welding parameter of said pulsed output, and using said duration of time as input for an adaptive control of said pulse welding process for a next cycle of said pulsed output.

These and other objects, features and embodiments of this invention will be evident when viewed in light of the drawings, detailed description and appended claims.

Brief Description of the Drawings

The invention may take physical form in certain parts and arrangements of parts, a preferred embodiment of which will be described in detail in the specification and illustrated in the accompanying drawings which form a part hereof, and wherein:

Fig. 1 is a combined block diagram and wiring diagram illustrating an electric arc welder for performing a pulse welding process employing a droplet detector circuit operating in real time to influence the waveform used on the welding event;

Fig. 2 is a graph illustrating a voltage curve and current curve of a prior art pulse welding process;

Fig. 3 is a graph illustrating the signals of various locations in the electric arc welder illustrated in *Fig. 1*;

Fig. 4 is a waveform similar to *Fig. 3* depicting current vs. time and associating it with weld bead formation, and ultimate droplet detachment from the wire;

Fig. 5 is a combined block diagram and wiring diagram illustrating droplet detector for generating a control signal to influence the waveform used on the welding event;

Fig. 6 is a group of waveforms depicting voltage vs. time, current vs. time, and derivative of voltage vs. time;

Fig. 7 is a flow diagram of the controlling a pulsed output and identifying a threshold to employ in the next cycle of the pulsed output; and

Fig. 8 is a flow diagram of the termination of a pulsed output based on detecting a peak signature in real time.

Detailed Description of the Invention

The best mode for carrying out the invention will now be described for the purposes of illustrating the best mode known to the applicant at the time of the filing of this patent application. The examples and figures are illustrative only and not meant to limit the invention, which is measured by the scope and spirit of the claims. Referring now to the drawings, wherein the showings are for the purpose of illustrating an exemplary embodiment of the invention only and not for the purpose of

limiting same, *Fig. 1* illustrates an electric arc welder **A** for performing an embodiment of a pulse welding process, as shown in *Fig. 2*. Although other welder architectures could be used, an exemplary architecture is a weld controlled by waveform technology as pioneered by The Lincoln Electric Company of Cleveland, Ohio. In this type of weld, a waveform generator produces the profile for the waveforms used in a pulse welding process. The power source creates the pulses in accordance with the shape determined from the waveform generator by using a plurality of current pulses and at high frequency such as over 18 kHz. This type of technology produces precise pulse shapes for any desired welding process. Even though the invention will be described with respect to the use of a welder employing waveform technology, the invention is broader and may be used in other welders, such as SCR (Silicon Controlled Rectifier) controlled welds and chopper based welds. A blip spike, peak, among others can be identified in a voltage trace where the droplet detached. Techniques attempt to use this blip, spike, peak, etc. as a droplet detection but the value related thereto constantly changed due to various factors such as, but not limited to, resistance drop, length of welding cables, among others. This application relates to a derivative detection technique in which a peak signature is used to detect detachment of the droplet. This technique is independent of factors such as, length of welding cables, resistance drop, among others.

As used in this application, the term "peak signature" **630** will mean a pre-defined signature, dynamically defined signature, and/or any suitable combination thereof (discussed below). Peak signature **630** is based upon a derivative of pre-defined characteristics such as, but not limited to, voltage, current, resistance, power, and the like. The physical manifestation of peak signature **630** can be influenced by: welding process used, electrode **E** composition, type of welding wire, wire feed rate, pulse width, pulse amplitude, number of pulses, duration of weld, material being welded, type of workpiece **W**, among others. Peak signature **630** can be a defined pattern or a characteristic (e.g., spike, peak, two or more spikes, two or more peaks, among others) detected in a waveform of a derivative of a welding parameter over time during the welding process, wherein the defined pattern can be based on at least one of a derivative of current reading, a derivative of voltage reading, a derivative of resistance reading, a derivative of power, among others. Moreover, peak signature **630** can be detected in real time from real time monitoring of a derivative of a welding parameter (e.g., voltage, current, resistance, power, among others). Alternatively, peak signature **630** can be identified in real time by identifying at least one defined pattern or characteristic such as, but not limited to, a spike (e.g., a positive spike, a negative spike, among others). In an example, droplet detector **64** detects droplet detection based on real time identification of peak signature **630** based on a threshold tolerance for the spike detected. The threshold tolerance can trigger

detection of peak signature **630** and, in turn, initiate a reduction in the current to control droplet detachment from the wire. In an embodiment, peak signature **630** is used in pulsed spray transfer where the droplet is pinched off the end of the wire by a current pulse (e.g., pulsed output). During this detachment from the wire, the current has to change path from through the droplet to the end of the wire above the droplet which causes the arc length increases slightly. This slight increase can be detected and be referred to as peak signature **630**.

Electric arc welder **A** shown in *Fig. 1* is used to perform a standard pulse welding process as illustrated by the curves in *Fig. 2* with a plurality of operating signals indicated at various locations in *Fig. 1* and by corresponding numbers in *Fig. 3*. Electric arc welder **A** has a power source **10** in the form of a high speed switching inverter with output leads **12**, **14** for creating the pulse welding process between electrode **E** and workpiece **W**. Power source **10** is driven by an appropriate power supply **16**, illustrated as a three phase input. The profile of the pulses and background current constituting the pulse welding process is determined by a signal on wave shape input **18**. The pulse welding process can include a pulsed output comprised of a background output condition or level with a superimposed high output pulse condition during with the welding electrode heats up to a molten droplet and is pinched off and separates from the end of the electrode **E**. Current shunt **22** communicates the arc current of the welding process by lines **24** to current sensor **26** having an output **28** used by droplet detector **64**. In a like manner, leads **30**, **32** communicate the arc voltage to voltage sensor **34** having detect output **36** and a level or amplitude output **38** used by droplet detector **64**. Level output **38** has a signal representative of the arc voltage across the electrode and workpiece.

Electric arc welder **A** performs a pulse welding process in order to provide for controlled initiation of a transfer or release pulse (e.g., superimposed high output pulse) based on droplet detector **64** for each pulse welding cycle. In this regard, the invention is directed to pulse welding processes and equipment in which power source **10** applies a welding signal (via waveform in line **56** and/or wave shape input **18**) to a consumable welding electrode **E** in a succession of welding cycles, each cycle having a melting condition during which molten metal forms at the end of electrode **E** as a result of welding current from power source **10**, and a transfer condition in which a high current pulse (e.g., superimposed high output pulse condition) in the welding signal causes the molten metal to separate from electrode **E** before contacting workpiece **W**). The invention may be implemented in DC pulse welders as well as AC pulse welding applications, and is generally applicable to any type or form of welding equipment and to any pulse welding operation.

Electric arc welder **A** includes power source **10** and a wire feeder that operates to direct a consumable welding wire or electrode **E** from spool **20** toward workpiece **W** by operation of rollers, one or more of which are driven by a motor. Any type of welding wire or electrode **E** may be used, such as solid wire electrodes, cored electrodes having an inner core and an outer sheath (e.g., flux cored electrodes), among others. Electrode **E** passes through an electrical contact, where contact is coupled to an output of current shunt **22**, wherein workpiece **W** is coupled to output lead **14**. Power source **10** provides an output welding signal that generates welding current through electrode **E** and workpiece **W** in a plurality of welding cycles according to a pulse welding waveform provided by waveform generation **50**, wherein a pulsed output comprised of a background output condition with a superimposed high output pulse condition during which the welding electrode **E** heats up to a molten droplet and is pinched off and separates from the end of the electrode **E**.

Waveform generator **50** is loaded with the particular waveform to perform the welding process. This waveform is indicated as signal **2**. Timer **52** directs a timing signal by lines **54** to waveform generator **50** for the purpose of initiating the individual pulses constituting the welding process. Generator **50** also has a control signal from line **66** to control pulse generation in accordance with droplet detector **64**. The waveform that is to be outputted by power source **10** is signal **2** in line **56**. This signal, in welder **A**, is the actual signal directed to input **18** of power converter **10**.

Droplet detector **64** identifies at least one condition representative of droplet detachment (and the droplet detachment point) from the wire using peak signature **630** as illustrated in *Fig. 6*. As discussed above, droplet detachment relates to a pulsed spray transfer where the droplet is pinched off the end of the wire by a current pulse. In an embodiment, peak signature **630** is used in pulsed spray transfer where the droplet is pinched off the end of the wire by a current pulse. During this detachment from the wire, the current has to change path from through the droplet to the end of the wire above the droplet which causes the arc length increases slightly. This slight increase can be detected and be referred to as peak signature **630**. Droplet detector **64** calculates a derivative over time for a welding parameter to detect peak signature **630**. The welding parameters, by way of example and not limitation, can be voltage of the welding process (e.g., detect output **36**, level output **38**, voltage level output, and the like), current of the welding process (e.g., output **28**, arc current, and the like), resistance of the welding process (e.g., ascertained based on equation $V = I \cdot R$, where V is voltage, I is current, and R is resistance), power of the welding process (e.g., ascertained based on equation $P = I \cdot V$, where P is power, V is voltage, and I is current), among others. Based on detecting peak signature **630**, i.e., the derivative over time of at least one welding pa-

rameter, droplet detector **64** modifies the pulse generation for the welding process via control signal **66** communicated to waveform generator **50**. The modification of the current pulse during the welding process manages the droplet detachment (and the droplet detachment point) from the wire due to detection of peak signature **630**. Although the waveform measured from the welding process is discussed as a pulse peak waveform, it is to be appreciated and understood any suitable waveform used in the pulse welding process is included within the scope of this invention.

Droplet detector **64** is illustrated in more detail in *Fig. 5*. Droplet detector **64** calculates the derivative over time for one or more welding parameters. As depicted, droplet detector **64** receives the welding parameters current (e.g., output **28**) and voltage (e.g., detect output **36**, level output **38**). Although droplet detector **64** is depicted as receiving current and voltage parameters, it is to be appreciated and understood that droplet detector **64** can receive one or more welding parameters (e.g., current, voltage, resistance, and the like). Droplet detector **64** identifies peak signature **630** in real time which is used to detect droplet detachment (and the droplet detachment point) from the wire in the welding process. Peak signature **630** can be any suitable peak or spike such as, but not limited to, negative peak, positive peak, a negative spike, a positive spike, among others. Moreover, the appearance (e.g., magnitude, amplitude, width, polarity, and the like) of peak signature **630** can vary as well as correspond to a type of material used in the welding process. For instance, material A can have peak signature A' with a first appearance, whereas material B can have peak signature B' with a second appearance. However, peak signature **630** can include generalized characteristics (e.g., a spike, positive spike, negative, spike, and the like) that may be used to detect droplet detachment (and the droplet detachment point) from the wire for two or more type of materials used in the welding process.

Droplet detector **64** can use peak signature **630** as a default setting to trigger modification of the pulse generation for the current cycle of a welding process. The default setting for peak signature **630** can be pre-defined prior to a first cycle of a pulsed output for waveform generation based on a defined pattern or characteristic such as, a spike. In a more detailed example, peak signature **630** can be defined in a more particular manner including appearance details such as, but not limited to, amplitude, magnitude, width, polarity, and the like. Such particular appearance details can be identified through experimental data from pulse welding processes with similar conditions such as, but not limited to, a type of material for the welding process. Moreover, droplet detector **64** can include peak signature **630** as a dynamic setting. A dynamic setting enables for real time detection of peak signature **630** for each pulsed output of a welding process, wherein the peak signature **630**

is identified from a derivative over time of one or more welding parameters. For example, a spike can be detected in real time upon monitoring a derivative over time of a welding parameter for a welding process which can signify a droplet detachment from the wire in a pulse spray transfer welding operation.

Droplet detector **64** detects peak signature **630** from a derivative of at least one welding parameter in real time. Upon dynamic detection of peak signature **630**, control signal **66** is generated and communicated to at least modify a pulsed output in a cycle for the welding process. For example, the current for a pulsed output cycle can be rapidly reduced upon detection of peak signature **630**. In another example, the pulsed output cycle can be modified by reducing power based on detection of peak signature **630**. In one example, the pulsed output can be for an active (e.g., on-going) cycle. Ending the pulsed output for the active cycle manages the droplet detachment from the wire due to detection of peak signature **630**. As mentioned above, droplet detector **64** detects droplet detachment based on identifying peak signature **630** within the derivative of at least one welding parameter over time. Although current and voltage are illustrated, it is to be understood that one or more welding parameters can be employed with this invention.

The welding process performed by welder **A** is illustrated in *Fig. 2* wherein current curve **100** has a series of spaced current pulses **102** separated by background current portion **104**. Voltage curve **120** is the voltage between lines **30**, **32** and constitutes the arc voltage correlated with the arc current of curve **100**. An active cycle designates a current pulse that is on-going whereas a next cycle references a current pulse that is subsequent the on-going current pulse. The peak in the dv/dt graph **600** indicates the droplet has been pinched off the end of the electrode toward the puddle. Droplet detector **64** detects peak signature **630** and sends a signal via control signal **66** to waveform generator **50** indicating the pulsed output in the active cycle is to be modified. The pulsed output in the active cycle can be modified by rapidly reducing current, rapidly reducing power, among others. Thus, waveform generator **50** manages the pulsed output for the active cycle based upon control signal **66**. Waveform generator **50** generates a pulsed output for a next cycle after controlling the pulsed output of the active cycle.

The operation of welder **A** is disclosed by the signals **2** and **7** as shown in *Fig. 3*. Signal **7** is the sensed voltage in line **36**. Under normal circumstances, voltage **120** includes a plurality of spaced pulses **130** having shapes determined by waveform generator **50** and spacing determined by timer **52**. The output of waveform generator **50** is signal **2** constituting waveform signal **150** shown in *Fig. 3*. Waveform generator **50** initiates (e.g., starts) pulses for an active cycle of the welding process

and terminates (e.g., ends) the pulsed output for the active cycle based on control signal **66** and, in turn, detection of peak signature **630** within readings related to a derivative of at least one chosen welding parameter over time. Thereafter the pulse has ended, waveform generator **50** generates a pulsed output for the next cycle of the pulse welding process.

Timer **52** monitors duration of time **410** (as seen in *Fig. 4* and defined as an amount of time from t_1 to t_1) for the pulsed output from initiation (e.g., start) to termination (e.g., end), wherein termination is based on control signal **66**. Duration of time **410** for the waveform is used as a threshold value for a next cycle of a pulsed output. Duration of time **410** can be used as the pulse width for the next cycle to accurately identify droplet detachment from the wire. Duration of time **410** is further used as an input for adaptive control of the welding process for a next cycle and/or future cycles for pulse(s). Additionally, duration of time **410** is used as an indicia of consistency of droplet size. For instance, dynamic monitoring of duration of time **410** for each waveform can indicate whether droplet size is consistent when duration of time **410** is not varying. However, varying duration of time **410** for each pulsed output can indicate inconsistent droplet size for the welding process. Furthermore, wire feed speed is detected during duration of time **410** for the pulse of an active cycle. At least one action is generated to correct a wire feed speed inconsistency based on the detected wire feed speed during duration of time **410**. For instance, the detected wire feed speed for duration of time **410** for a pulsed output can be used for the next cycle of a pulsed output in order to reduce wire feed speed inconsistency.

Fig. 4, illustrates relationships between current, voltage, and molten drop development on welder tip. At time t_1 , current is ramped to peak level and maintained essentially constant to time t_2 . During time t_1 through t_2 , molten drop **420** (e.g., also referred to as molten ball, ball, droplet, among others) is generated. At time t_3 , molten drop **420** is transferring to the puddle. At a time between t_2 and t_3 , a voltage spike occurs due to the droplet detachment (and the droplet detachment point) from the wire. The precise moment of droplet detachment (and related voltage spike) is somewhat unpredictable regardless of consistent parameters used in the welding process. However, droplet detector **64** detects the voltage spike (e.g., peak signature **630**) in order to identify droplet detachment and starts the ramp down of current of the pulsed output for an active cycle to manage the pulse spray transfer welding operation.

Fig. 4 illustrates a single pulsed output associated with a welding process. Any suitable number of pulses can follow the single pulsed output and be a next cycle of a pulse. *Fig. 6* illustrates voltage waveform **600**, current waveform **610**, and derivative voltage waveform **620**. As mentioned, the

waveform can be any suitable waveform (e.g., peak pulse waveform, among others) and include any suitable number of cycles of pulses. By way of example and not limitation, the waveforms illustrate four (4) complete pulses and one (1) incomplete pulse. In other words, the pulses in voltage waveform **500** are similar to the pulse in *Fig. 4*. Voltage waveform **500** depicts raw voltage over time illustrating pulses of various widths (e.g., corresponding to duration of time **410**). Corresponding to each width of the pulse peak is raw current depicted in current waveform **510**. Droplet detector **64** uses a derivative calculation over time on a selected welding parameter such as, but not limited to, a voltage, a current, a resistance, a power, or any suitable combination thereof. In this particular example, the derivative of voltage over time is depicted in waveform **520**. Calculating the derivative of voltage over time allows a detection of peak signature **630** (e.g., a spike) in voltage occurring between time t_2 and t_3 . At the point indicated by peak signature **630**, peak signature **630** was detected thus ending the peak segment and the waveform logic progresses to reduce the current to the background amplitude. This peak signature **630** is indicative of droplet detachment (and the droplet detachment point). Peak signature **630** can be any suitable peak such as a positive peak, a negative peak, a positive spike, or a negative spike. Moreover, peak signature **630** can vary (e.g., size, amplitude, measurement, among others) in appearance based on type of material for the welding process. Although waveform **520** indicates a range for peak signature **630**, it is to be appreciated and understood any suitable range for peak signature **630** is considered to be within the scope of this invention.

Furthermore, a peak pulse waveform is one of many waveforms that can be measured in real time in order to calculate a derivative of at least one welding parameter in the welding process and the subject application is applicable to any suitable waveform, waveform generator, and/or welding mode. Moreover, a pulse can vary dependent on a type of material used in the welding process. In other words, each type of material includes a particular pulse and/or waveform to shape such pulse in the welding process and, in turn, includes a particular peak signature **630**.

By way of example and not limitation, the droplet detachment detection by droplet detector **64** can be employed with any suitable welding mode such as, but not limited to, pulse spray transfer. Spray or pulsed spray welding is a free flight transfer in which a formed droplet detaches from the wire, crosses the plasma and into the weld pool. If the arc length is very short, the end of the electrode and the weld pool are very close, as the droplet is pinched off, the droplet can bridge the gap and short into the weld pool. This can produce a different signature in comparison to the dv/dt detected with peak signature. For example, spray or pulsed spray welding has a shorting condition

(e.g., short into the weld pool when the arc length is short) and a non-shortening condition (e.g., target condition for the welding process). Moreover, a pulse spray metal transfer welding mode includes the use of a shielding gas. The pulsed waveform for a pulse spray metal transfer can be broken into several components in which an increase to a component for a given waveform can increase energy and subsequent penetration. A ramp-up rate can allow the molten droplet to form at the end of the electrode, wherein increases to the ramp-up rate stiffen the arc while decreases soften the arc. An increase to an overshoot can overcome the influence of inductance which can vary with cable length. Another component can be peak current which can be responsible for weld penetration. Increased peak current increases penetration while a decrease in peak current reduces penetration. A peak time is another component in which a longer peak time can result in a wider bead shape. A tail-out can add energy to the molten droplet. An increase to tail-out time can increase penetration while a decrease in tail-out time can reduce penetration. A tail-out speed can add energy to the molten droplet. An increase to puddle fluidity permits a fast follow molten puddle. A stepoff can reduce the tendency for fine droplet spatter. A background current can be a component in which a low-level current can maintain the arc, whereas a superimposed high current output can transfer the droplet from the wire/electrode. An increase in frequency can narrow the arc cone whereas a decrease in frequency can broaden the arc cone.

Peak signature **630** can be used to indicate and detect separation of a droplet from the end of a wire and/or to start a change or modification of a welding parameter (e.g., start a ramp down of a current routine). Surface Tension Transfer (STT) welding uses a dv/dt technique to indicate a separation of a droplet from the end of a wire as well. However, spray or pulsed spray welding uses peak signature **630** while there is an arc. On the contrary, STT used dv/dt to detect when a short circuit is about to break into an arc. Within STT it is critical to identify a period before the short broke so the current can be adjusted (e.g., reduced) quickly to prevent an explosive transition from a short to an arc. The detection in STT happened during the short circuit condition (e.g., before an arc). Peak signature **630** is used with spray or pulsed spray welding while there is an arc. Although a short circuiting condition may occur (e.g., droplet bridges the gap) and logic is used during such short circuit condition (e.g., a short clearing routine), peak signature **630** is not used in such a short circuit condition in spray or pulsed spray welding processes. If there is not a short circuiting condition, peak signature **630** is used to detect droplet detachment from the wire. Peak signature **630** is detected during a high output peak condition within the welding process. Peak signature **630** is not a predictive tool but rather indicates when the droplet has detached from the wire. Once peak signature **630** is detected, there is no need to pull the output down quickly to pre-

vent spatter during the transition from a short to an arc since the welding process is already in an arc (e.g., peak signature is detected and used while in an arc). In an example, a time (e.g., 0 to 3 milliseconds) that can be paused before reducing current. The ramp down can be consistent with regards to the exact time the droplet transfers based on the use of peak signature **630**.

Sequentially, the following occurs as illustrated in the decision tree flow diagram **700** of *Fig. 7*. Generation of pulsed output for an active cycle in a welding process can start (e.g., initiate) (reference block **710**). Based on detecting a peak signature within a derivative of at least one selected welding parameter, droplet detachment from the wire is identified (reference block **720**). Based on the identification, the pulsed output for the active cycle is modified (reference block **730**). A duration of time from the start of the pulsed output to the modification of the pulsed output is used as a threshold value for a next cycle (reference block **740**). The next cycle for a pulsed output is generated using the duration of time (e.g., waveform width) (reference block **750**).

The following occurs as illustrated in the flow diagram **800** of *Fig. 8*. At least one chosen welding parameter during a welding process is measured (reference block **810**). A derivative over time of said at least one selected welding parameter is calculated (reference block **820**). The derivative of said at least one welding parameter is monitored to detect a peak signature (reference block **830**). A pulsed output used with the welding process is modified based on detecting the peak signature (reference block **840**).

The best mode for carrying out the invention has been described for purposes of illustrating the best mode known to the applicant at the time. The examples are illustrative only and not meant to limit the invention, as measured by the scope and merit of the claims. The invention has been described with reference to preferred and alternate embodiments. Obviously, modifications and alterations will occur to others upon the reading and understanding of the specification. It is intended to include all such modifications and alterations insofar as they come within the scope of the appended claims or the equivalents thereof.

Reference numbers:

2	signal	410	time
7	signal	420	molten drop
10	power source	500	voltage waveform
12	output lead	510	current waveform
14	output lead	520	waveform
16	appropriate power supply	600	dv/dt graph
18	wave shape input	610	current waveform
20	spool	620	voltage waveform
22	current shunt	630	peak signature
24	lines	700	tree flow diagram
26	current sensor	710	reference block
28	output	720	reference block
30	lead	730	reference block
32	lead	740	reference block
34	voltage sensor	750	reference block
36	detect output	800	flow diagram
38	amplitude output	810	reference block
50	waveform generator	820	reference block
52	timer	830	reference block
54	lines	840	reference block
56	line		
64	droplet detector	A	electric arc welder
66	line/control signal	E	electrode
100	current curve	W	workpiece
102	current pulses	t ₁	time
104	current portion	t ₂	time
120	voltage curve	t ₃	time
130	spaced pulses		

CLAIMS

1. A process for detecting detachment of a droplet (420) from a wire during a welding operation that uses a shielding gas comprising the steps of:

providing a welding signal to a welding electrode (E) in a succession of welding cycles during a welding process, each said welding cycle including a pulsed output comprised of a background output condition with a superimposed high output pulse condition during which the welding electrode (E) heats up to a molten droplet (420) and is pinched off and separates from the end of the electrode (E);

measuring (810) at least one welding parameter during said welding process;

calculating (820) a derivative over time of at least one welding parameter;

detecting (830) a peak signature (630) within said derivative of at least one welding parameter during an arc of the welding operation; and

reducing a magnitude of at least one welding parameter of said pulsed output used with said welding process based on said step of detecting.
2. The process of claim 1 wherein

said at least one welding parameter is selected from the group consisting of current, voltage, resistance, and power.
3. The process of claim 1 or 2 wherein

said peak signature is a positive peak or a negative peak.
4. The process of one of the claims 1 to 3 wherein

said peak signature is based on a type of material used in the welding process.
5. The process of one of the claims 1 to 4 which further comprises the step of

monitoring a duration of time from a start of said pulse to said termination of said pulse.
6. The process of claim 5 which further comprises the step of

using said duration of time as a threshold value for a next cycle of said pulse.

7. The process of claim 6 which further comprises the step of terminating a next cycle of said pulse based on said step of using, said duration of time is a threshold value for said next cycle of said pulse.
8. The process of claim 5 which further comprises the step of using said duration of time as input for an adaptive control of the welding process for a next cycle.
9. The process of claim 5 which further comprises the step of using said duration of time as an indicia of consistency of a droplet size.
10. The process of claim 5 which further comprises the step of detecting a wire feed speed during said duration of time, and preferably further comprising the step of generating at least one action to correct a wire feed speed inconsistency based upon said step of detecting, wherein said action is preferably using said wire feed speed for a next cycle of said pulse.
11. The process of one of the claims 1 to 10 which further comprises the step of managing said welding signal in said welding process based on said step of reducing.
12. A process for detecting droplet (420) detachment and a droplet (420) detachment point from a wire during a welding operation that uses a shielding gas, in particular according to one of the preceeding claims, comprising the steps of:

providing a welding signal to a welding electrode (E) in a succession of welding cycles during a welding process, each said welding cycle a pulsed output comprised of a background output condition with a superimposed high output pulse condition during which the welding electrode (E) heats up to a molten

- droplet (420) and is pinched off and separates from the end of the electrode (E);
- calculating (820) a derivative over time of at least one characteristic selected from the group consisting of voltage, current, resistance, and power during said welding process;
- detecting (830) a peak signature within said step of calculating (820) during an arc of the welding operation; and
- modifying (840) said pulsed output used with said welding process based on said step of detecting.
13. The process of claim 12 which further comprises the step of monitoring a duration of time from a start of said pulse to said termination of said pulse.
14. The process of claim 13 which further comprises the steps of using said duration of time as a threshold value for a next cycle of said pulse; and terminating said next cycle of said pulse based on said duration of time.
15. The process of claim 13 or 14 which further comprises the steps of detecting a wire feed speed during said duration of time; and using said wire feed speed for a next cycle to correct a wire feed speed inconsistency.
16. A process, in particular according to one of the preceeding claims, for detecting droplet detachment and a droplet detachment point from a wire during a welding operation that uses a shielding gas comprising the steps of:
- providing a welding signal to a welding electrode in a succession of welding cycles during a welding process, each said welding cycle including a pulsed output comprised of a background output condition with a superimposed high output pulse condition during which the welding electrode heats up to a molten droplet and is pinched off and separates from the end of the electrode;

measuring at least one welding parameter during said pulse welding process, said at least one welding parameter preferably selected from the group of consisting of current, voltage, resistance, and power;

calculating a derivative over time of said at least one welding parameter;

identifying a peak signature within said derivative over time of said at least one welding parameter during an arc of the welding operation;

reducing a magnitude of at least one welding parameter of said pulsed output used with said pulse welding process based on said step of identifying;

monitoring a duration of time from a start of said pulsed output to said reduction of magnitude of at least one welding parameter of said pulsed output; and

using said duration of time as input for an adaptive control of said pulse welding process for a next cycle of said pulsed output.

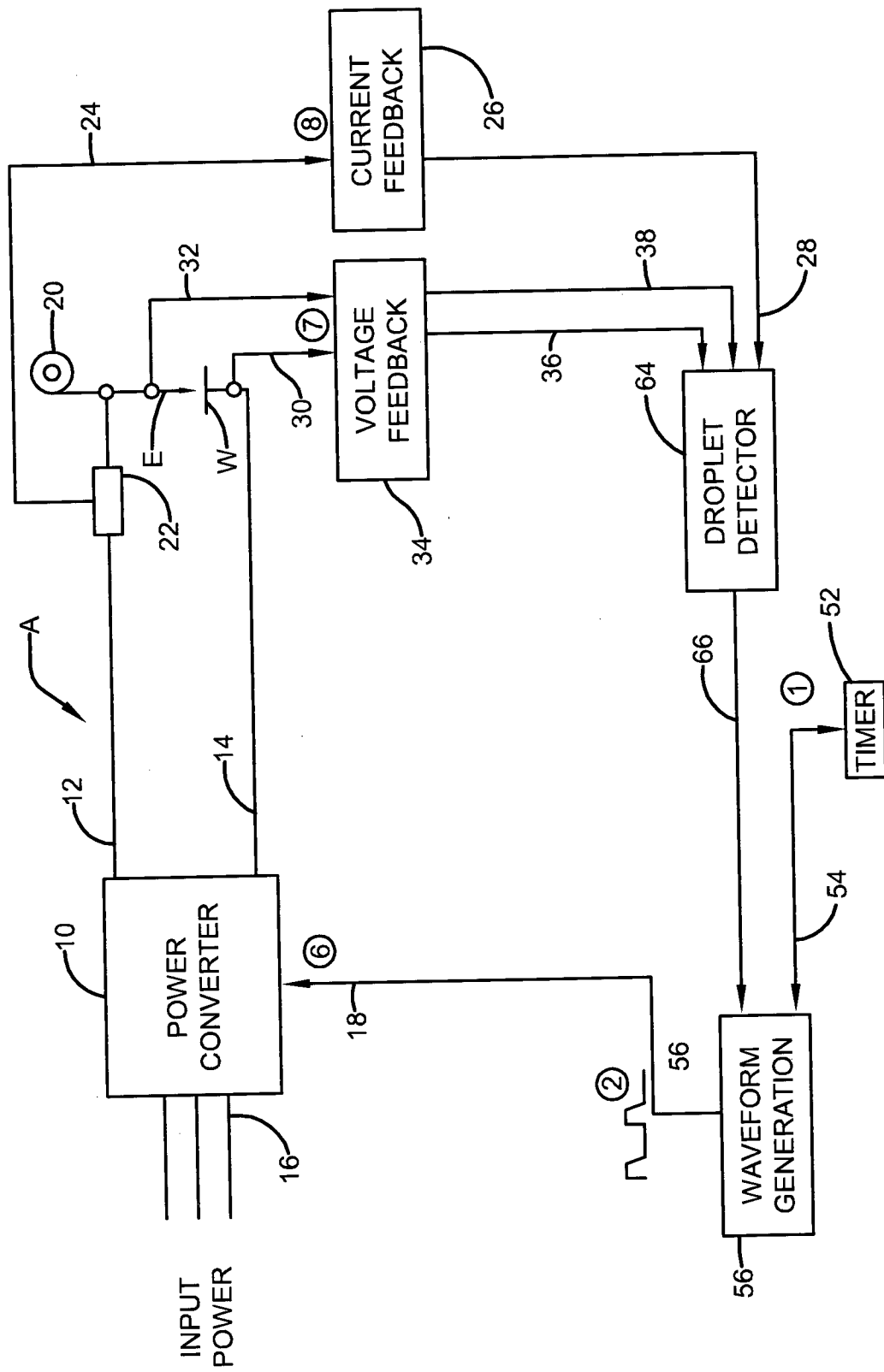


FIG. 1

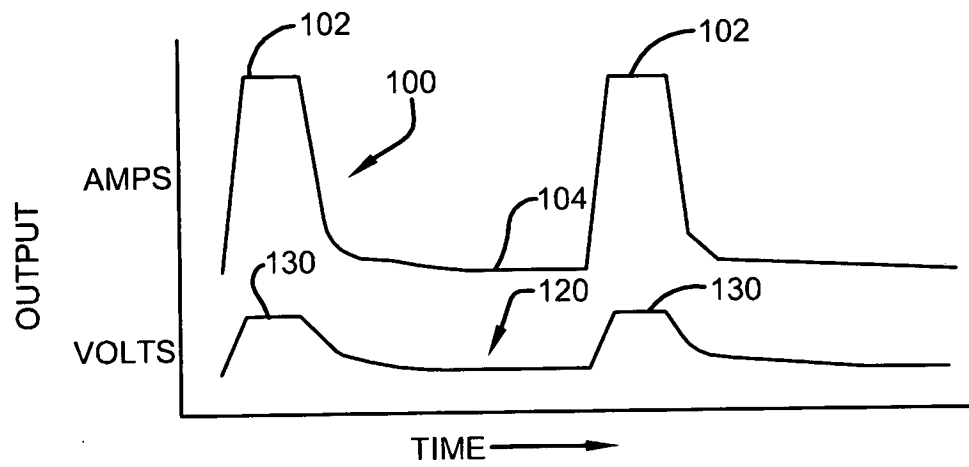


FIG. 2

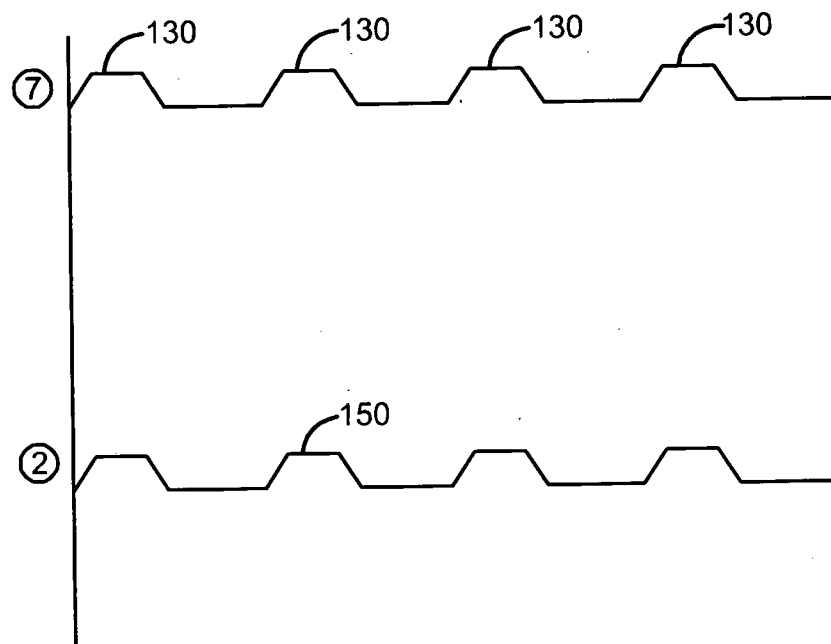


FIG. 3

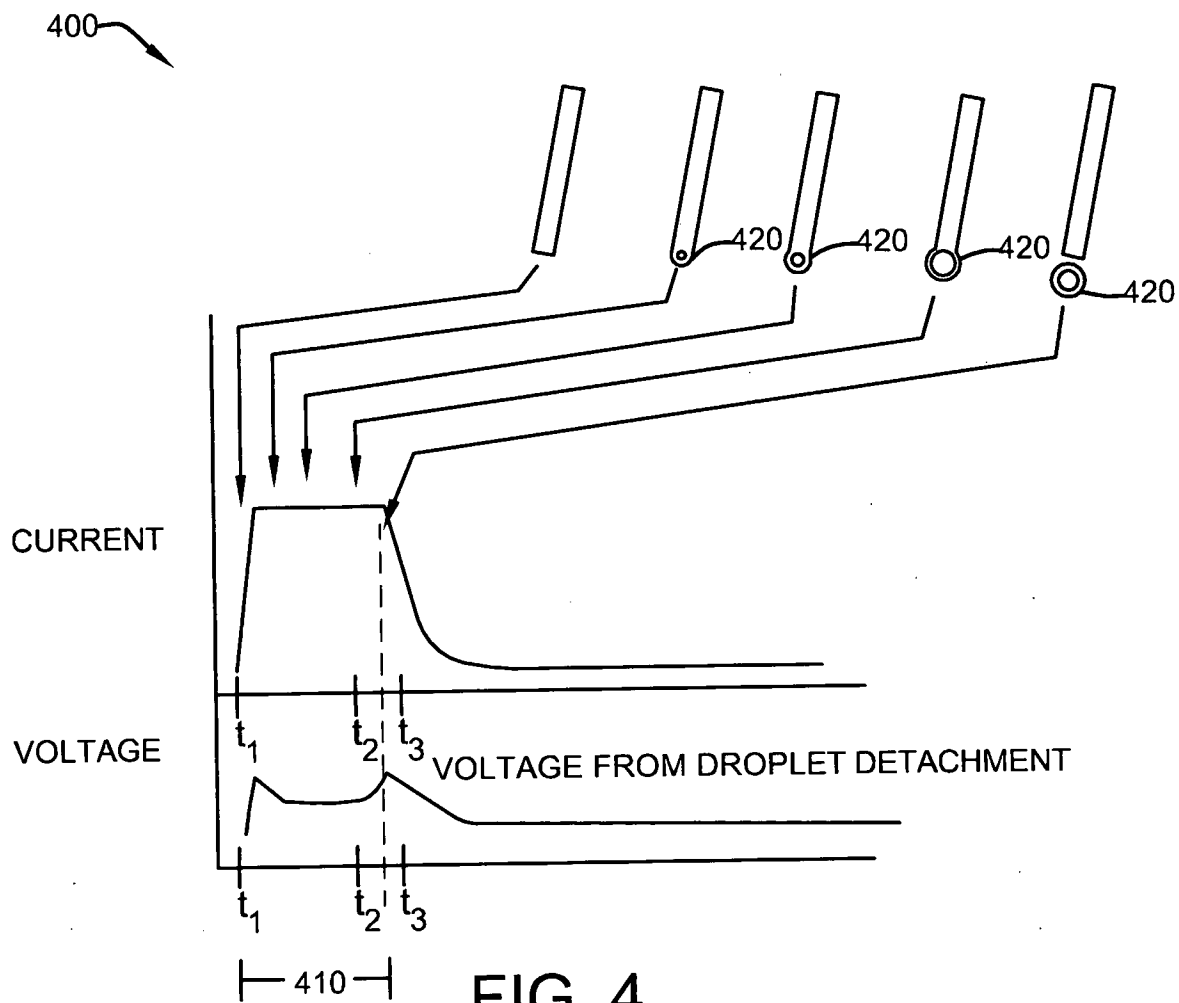


FIG. 4

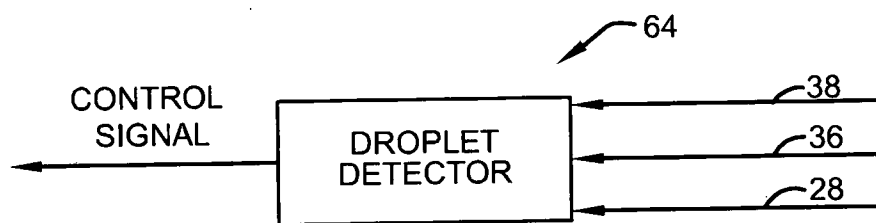


FIG. 5

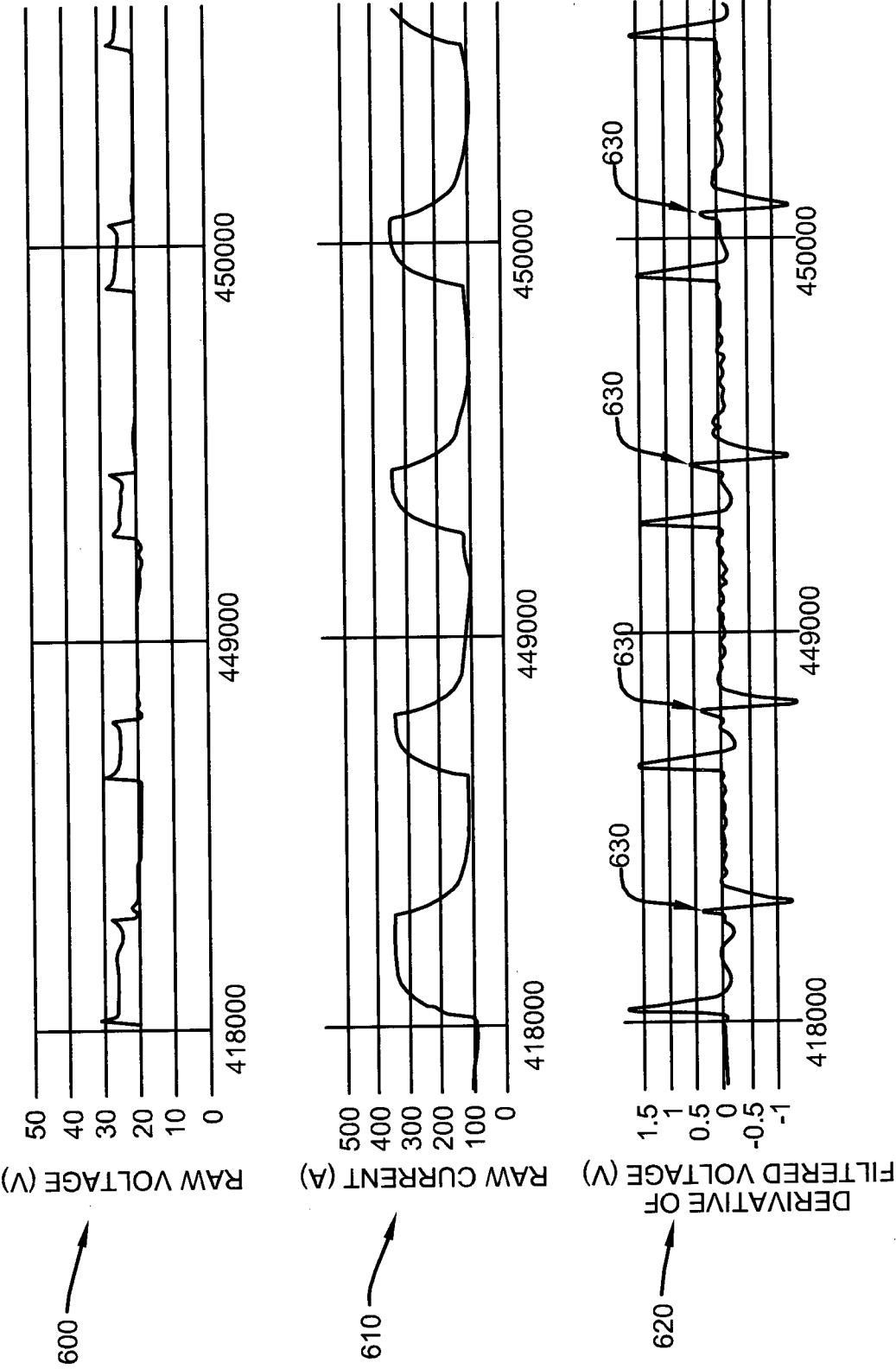


FIG. 6

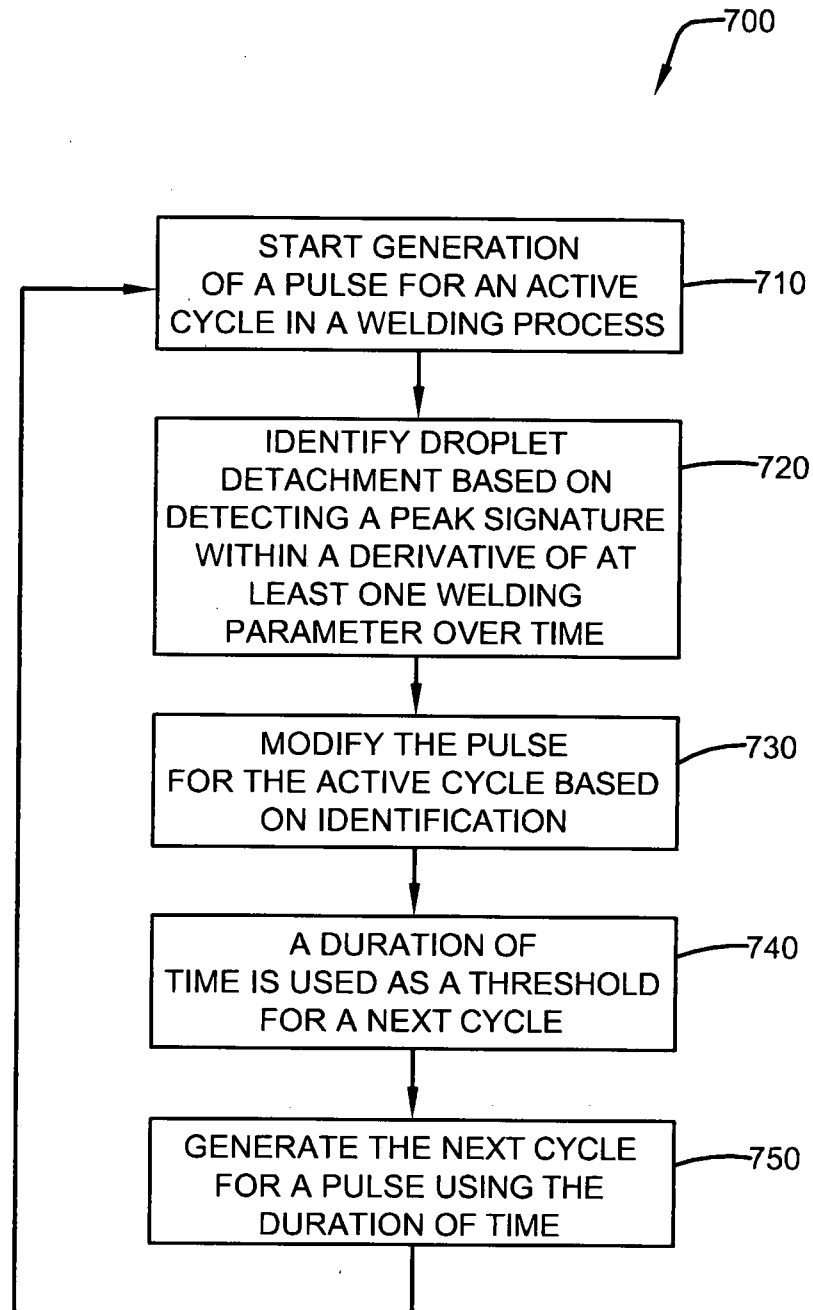


FIG. 7

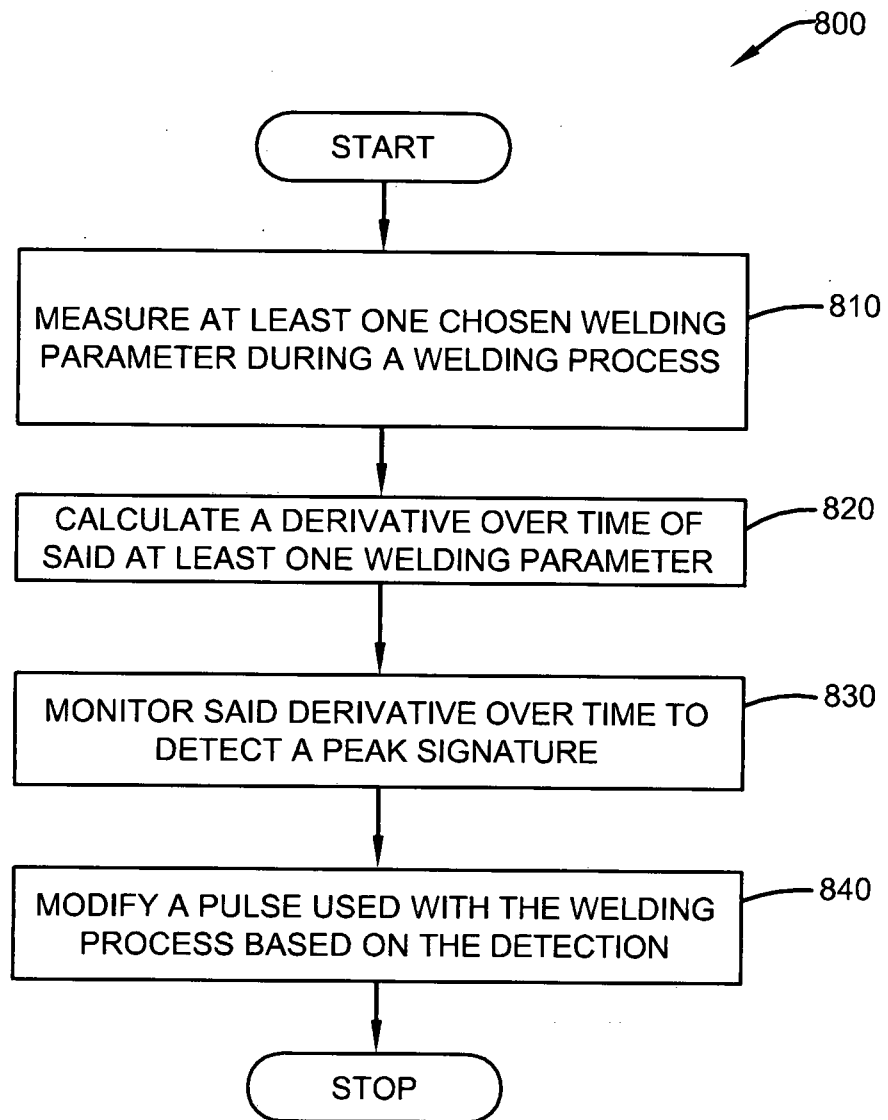


FIG. 8