Application Note 3

An Overview of Internal and External Weld Monitoring Systems

This application note is written as a broad discussion overview to explain and highlight some of the advantages and disadvantages of typical weld monitoring products, systems and equipment.

The note is designed to help the reader understand these products and to provide an aid when determining the suitability and best use of weld monitoring equipment.

The application note focuses on DC resistance spot welding applications but in broad context, is also a useful guide for micro arc spot welding applications.

Typical Questions for Users and Choosers

What weld monitoring features do I need ?

Do I need an external weld monitor ?

How good is my internal weld monitor ?

Not sure if I need or want an external weld monitor ?

What benefits should a weld monitor bring ?

How accurate is the weld monitor ?

What are the downsides in using a weld monitor ?

How can I be sure that a weld monitor will work for me ?

Introduction

Whether you currently own a weld monitor or are considering purchasing one, it is useful to fully consider the purpose and performance expectations of a weld monitor in your application.

The effective setup and application of a good Weld Monitor should dramatically increase your confidence in the quality and repeatability of your welding process. This in turn can decrease system downtimes and product scrap while simultaneously improving the operational scope of the welding equipment and manufacturing trace ability of products.

To appreciate the potential benefits of a weld monitor, one must also have a good appreciation of the welding process, which is to say, a good appreciation of the potential process variables that go to make up the welding process.

This note assumes that the reader is familiar with such variables and that any decision or questions in respect to a weld monitor will be taken with these variables borne in mind.

In simple terms, there is little point monitoring a welding process in which the process variables constitute an unstable or unknown collective process.

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More information about welding process variables is available in :-
Application Note 4 - DC Resistance Spot Welding Process Variables.

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Internal Weld Monitors - An overview

Almost all DC resistance spot welding power supplies these days are offered with options for internal weld monitoring. This scope includes capacitive discharge C.D. Micro spot welders as well as AC, DC Linear, hybrid and inverter based welding supplies.

More often than not, the internal weld monitor will form part of the user interface experience with options to setup and view certain process limit values. Such interfaces tend to be graphical in nature and are made as intuitive as possible to use. In order to offer and implement such monitors, manufacturers will have invested in graphical displays, interface controls and software development in order to realise the monitor within the welding power supply and hence there is an end user price to pay.

In practical terms and from a manufacturers perspective, an internal monitor can be an attractive and potentially useful feature bolt-on addition to the electronics that performs the main part of the welding power supply.

As such the overall additional cost to the end user may be less than the cost of a purely external dedicated weld monitor product and hence the proposition can be attractive. Furthermore, a good power supply will naturally have some built in monitoring in order to protect itself from misuse, so extending this functionality is a natural product progression.

For the discerning user or chooser, one must consider the real world capability of the internal monitor in order to manage it's performance expectations.

Internal Weld Monitors - Accuracy Performance considerations

An obvious consideration when evaluating an internal weld monitor would be it's accuracy - **Right ?**

ANSWER : In order to properly answer this, one has to appreciate what is meant by measurement accuracy in the context of the welding process and equipment.

e.g. 1 A typical HFDC inverter may operate at 2KHz or perhaps 20KHz with an inherent current ripple level of say 10 amps. Therefore having an internal monitor claiming an accuracy of 1 amp resolution means very little since the output of the power supply varies much more than the measuring capability.

Where high frequency ripple is an inherent part of the power supply operation, manufacturers are obliged to add signal filtering in order to better measure the underlying signals. Depending upon the quality of such filters, signal information and response rates can be dramatically reduced which in turn diminish the true process monitoring visibility / capability.

e.g. 2 Similarly and in terms of timing, if you take a capacitive discharge C.D. Welder that might deliver a 4000A pulse of welding current in 2mS, then a measuring system sampling at say 50µS will only collect 40 measurement samples over that period and will essentially be unable to measure signal perturbations above 10KHz e.g. electrode sparking and/or faster dynamic weldment resistance changes.

Signal sampling rates and measurement resolutions combine to determine the overall potential measurement accuracy in a digitised system. This can often be insufficient to detect small changes in the welding process and moreover, can lead to erroneous assumptions and nuisance triggering when attempting to setup a tightly controlled and monitored welding process.

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Internal Weld Monitors - Performance considerations

As a basic starting point when considering the accuracy performance of an internal or an external weld monitor, it is perhaps better to start by considering and setting up real world scenarios that you would want your weld monitor to detect, rather than actually trying to quantify what the various electrical specifications of a monitor really mean in the your real world application.

Such erroneous conditions might be the detection of misplaced components, worn electrodes, incorrect welding force, operator error etc….

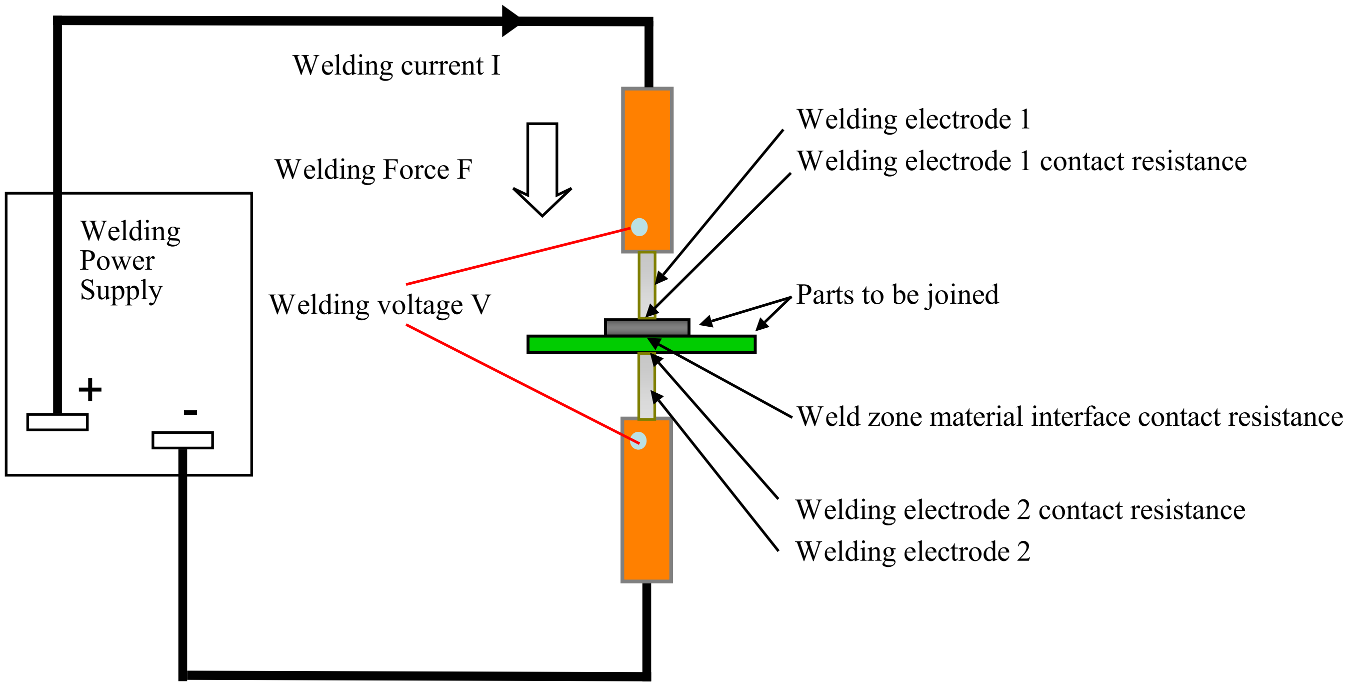
This application note assumes that when considering and/or evaluating a weld monitor, you have already established conditions that constitute a good weld. Such conditions should have been established through careful welding trials in which various process parameters have been modified until a reliable set of conditions have been found.

Working from an initial basis of a welding setup that has been derived from a welding trial, it is then possible to design welding trials that deliberately introduce conditions that you would like to detect as being outside of the "normal operating process".

It is these conditions that you will want to monitor for and detect and ultimately, it really doesn't matters what the published monitor accuracy figures are, since it matters much more that the monitor is accurate enough and repeatable enough to detect the difference between a good weld and a poor weld.

It is also important to realise that due to the nature of their inclusion, many internal weld monitors simply do not have the measurement performance to detect small process changes at the weld and as such, may not actually provide a means for detecting real process problems.

Fig 1 - Electrical conditions for resistance spot welding



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Internal Weld Monitors - Performance Limitations

Fig 1 shows some basic parameters that can be measured in a typical DC resistance spot weld application. It should be clear that monitoring circuitry can be added within the welding power supply to measure voltage and current OR it could be provided by an external box of electronics.

It should also be clear that the performance of an internal weld monitor will very much depend upon the sophistication of both the power supply output type and dynamics as well as the sophistication of the measurement and filtering circuitry, all of which are extremely difficult to actually quantify for any given weld condition.

By focusing on the ability of the monitor to actually detect an erroneous condition, one can start to gauge the value add effectiveness of a weld monitor.

From a pure quality control perspective, a common problem and question that arises with internal weld monitors lies in whether or not they truly have the ability to act and monitor independently.

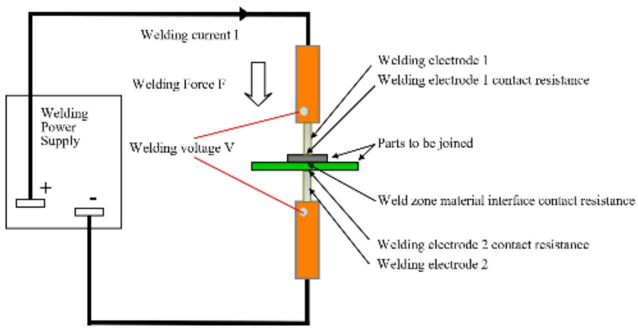
More often than not, such monitors share electronics with the welding power supply, so should a fault occur within the power supply, then the same fault can likely affect the internal monitor and hence faults can go undetected. This is why external weld monitors are commonly added to welding equipment with built in internal weld monitors in order to safe guard the quality process.

N.B. In more sophisticated equipment, internal weld monitors can sometimes be configured to dynamically change the operating mode of the power supply, perhaps when a certain limit is reached. Such features can occasionally be useful for particularly challenging welds and are normally limited to use in high precision Linear based power supplies where electrical noise levels are low and dynamic response rates are high. The actual performance will depend very much upon the dynamics of the signals being measured and controlled and as such, these relatively rare and more in-depth applications are outside the scope of this generalised application note.

Weld Monitors - What to measure ?

From Fig 1 we can see that the circuit current and voltage can be relatively easy to measure. Welding force can be set and measured separately and if needs be, additional monitoring of physical weld collapse could be added with additional sensors.

Looking purely at the electrical signals, it should be clear that practical voltage measurements should be taken as close as possible to the weldment, usually at the electrode holders.



Since there will be voltage losses in the welding cables and physical connection joints throughout, measuring voltage at or within the power supply **will not** give a reliable indication of what is happening at the weld. Ultimately, the electrical heating effect from the welder at the joint will be determined by the electrical power developed at the weldment over time i.e. The weld energy.

This is defined as Energy = Volts x Current x Time

The weldment melting effects will be determined by the density or concentration of this energy over a certain area, determined by the electrode contact areas and material dimensions and makeup.

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Weld Monitors - What to measure ?

It therefore follows that an accurate and reliable measurement of the electrical weld energy will yield a signal that is highly indicative of the welding process, particularly when such a measurement includes voltage sensing points close to the weldment in combination with an accurate weld current signal.

To ensure true independence and quality control, it should also be clear that an external monitor will provide a quality advantage over an internal weld monitor by virtue of it's separation and independence from the power supply electronics .

Working on this basis, we can start to consider the effects on the weld energy measurement in various scenarios with various types of equipment.

Weld Monitors - Measuring the weld energy at the electrodes

Fig 2 : Constant Current Mode

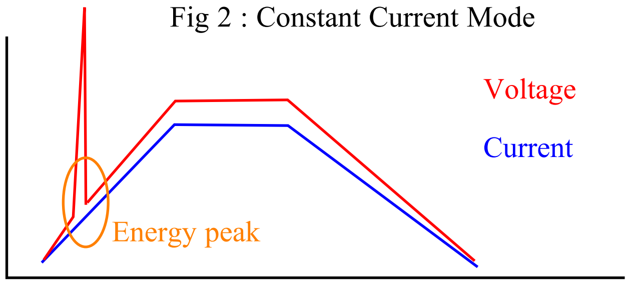
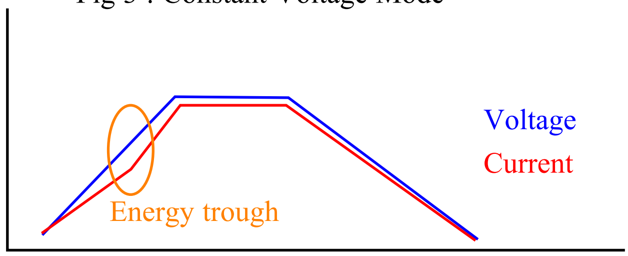


Fig 3 : Constant Voltage Mode



The above graph Fig 2 shows a constant current trapezoidal waveform in blue. Also shown is a typical voltage signal, which in this case has a spark perturbation. Since current is programmable, the voltage is free to vary in accordance with the weld resistance. From ohms law, V = I x R. Since I is constant, R is variable and hence V is variable.

Multiplying the current and voltage waveforms to derive power, we can see that on the up-slope, the spike of voltage will combine with the current to generate a spike in power which ultimately increases the instantaneous energy at the weld, which in this case might be a sign of a bad weld.

In a constant voltage mode Fig 3, ohms law dictates that the current will inversely follow the weldment resistance, having a tendency to diminish the welding current if the resistance goes up. Again, a measurement of the energy will indicate this change.

Some power supplies offer a constant power mode, which by definition, should deliver a constant energy into the weld. In such cases, it is useful to monitor the total welding current applied over the duration of the weld in order to be sure that the weldment resistance has remained within desired process limits.

This comes from the ohms equation V = I x R and Power = V x I

Thus, P = I x I x R. With P constant, both the current and resistance can change, hence monitoring applied to the current will provide a good indication of process variability.

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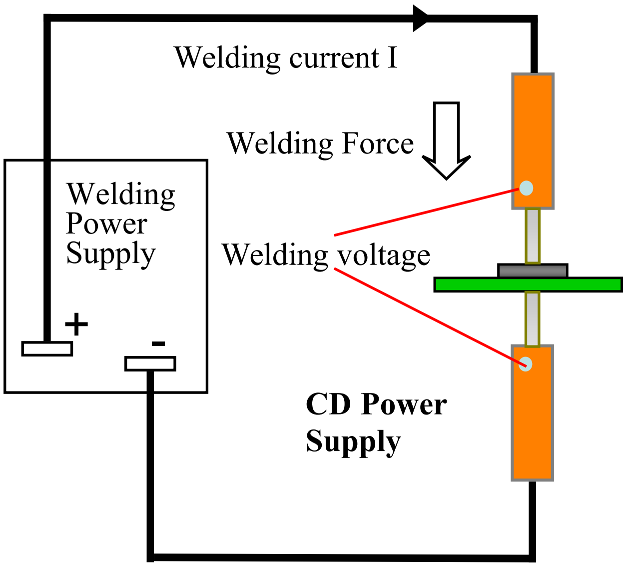
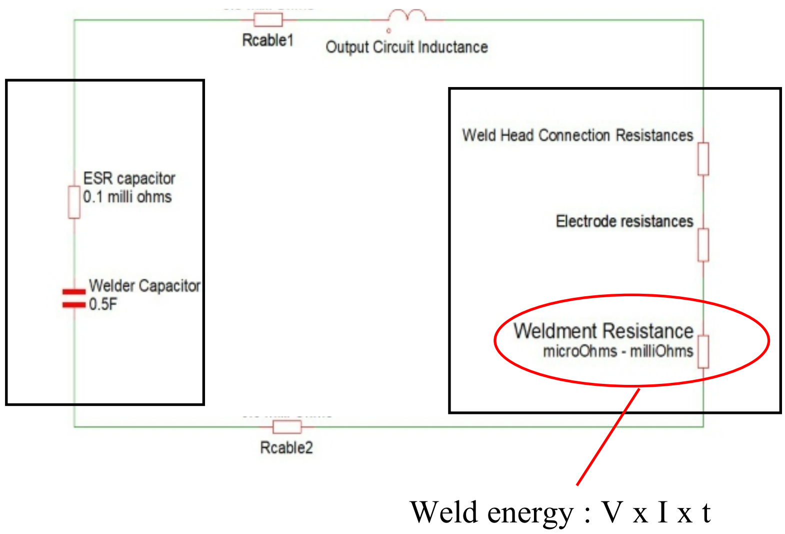
Weld Monitors - Measuring the weld energy with capacitive discharge welders

Capacitive discharge welding power supplies are uncontrolled and as such, both the voltage and current are free to vary along with the weldment resistance. The actual energy reaching the weldment is usually very different from the actual energy released by the welder.

This fundamental fact is due to the real and reactive losses both in the power supply itself and the welding circuit as a result of connection resistance's and cable inductive reactance.

Therefore measuring anything other than energy directly at the weldment is likely to be erroneous in terms of providing true process visibility. **For more information, see Application notes 1 & 2.**





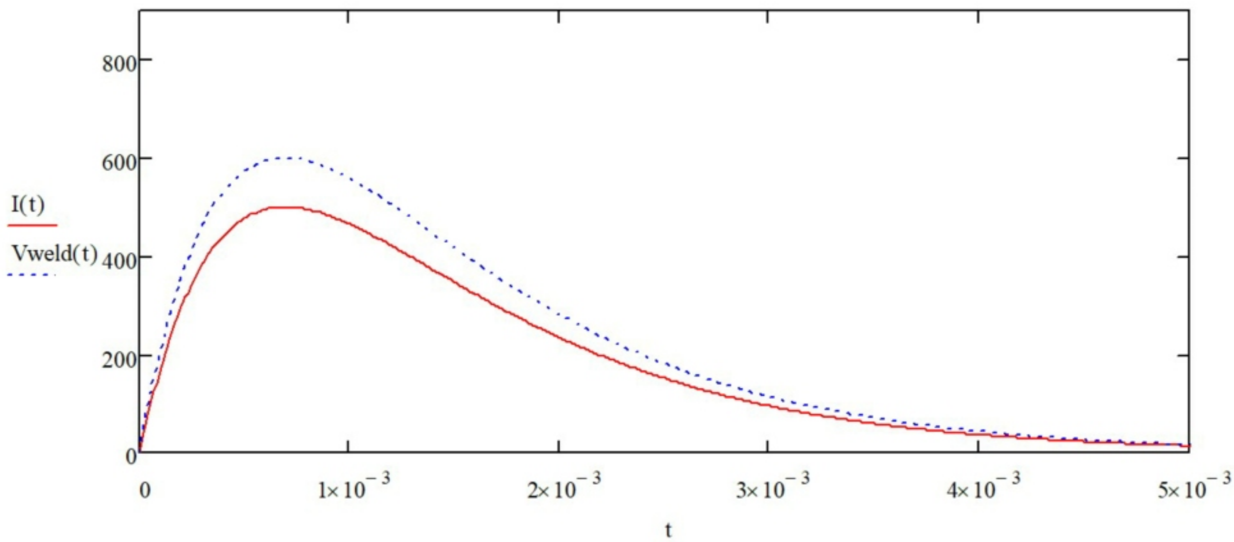


Fig 4 : Capacitor discharge welding current curve

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Weld Monitors - Using weld energy measurements to detect process problems

This note has described how weld energy can be used as a good indication of the welding process stability. We have thus far also covered some of the technical details of how weld monitors work and why the absolute performance figures often mean very little in terms of real world ability to detect problems.

In most cases, the determination of a good weld versus a bad weld is made subjectively and/or by using pull or peel tests to check the strength of the weld.

Ironically, most digital based weld monitors attempt to derive measurement values in terms of absolute S.I. Units, whereas in actual fact, the measured values mean very little to the user other than to provide a reference value from weld to weld. This fallacy often leads to expensive and unnecessary effort in attempting to “calibrate” the weld monitor.

As stated before, if the weld monitor delivers precise & stable results, the actual values measured do not really matter since the objective is simply to determine values outside of the normal operating range.

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This next section covers fault scenarios we would like to detect and how these might be detected through measuring weld energy changes at the weld. To illustrate this, consider an opposed cross wire welding scenario, for example welding two conventional component leads together.

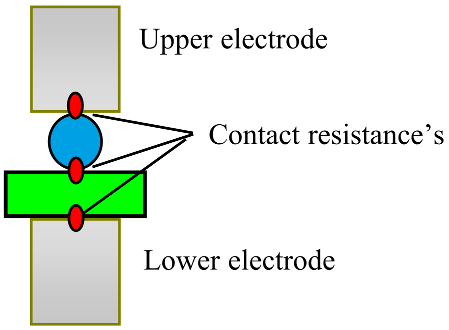

Fig 5 : Opposed cross wire weld

In this example we can see the points at which heat energy will be developed at the contact resistance points as current starts to pass.

Since the total energy will be proportional to dynamic resistance, changing the physical setup will change the resistance and hence change the energy.

Welding Force Changes : The initial resistance at the contact points will to some extent be determined by the squeezing force applied to the components. With a low force, the contact resistance will be higher and hence so will the energy. A higher force will reduce the contact resistance and lower the weld energy.

Missing components : The circuit resistance will change significantly if either of the components are missing when the weld is initiated. This in turn will result in a different energy dissipation and hence provide a means of detection.

Worn Electrodes : As electrodes wear or become contaminated, their contact resistance with the components will start to vary. This in turn will effect the dynamic weldment resistance which in turn changes the overall energy dissipated in the weld and hence provides a means for detection.

Operator Error : Typical operator error will include misplacement or misalignment of components prior to welding. Such errors present a different contact area prior to welding, which give rise to a different weld energy density. This in turn changes the dynamic weld resistance and hence the overall weld energy can be changed and detected.

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Weld Monitors - Advantages and disadvantages

This note has stressed the importance of setting up reliable, trial based welding conditions prior to attempting to monitor the process. A common disadvantage in monitoring is that users start to monitor a welding setup without having established a reliable welding condition. This then leads to nuisance tripping from the weld monitor for reasons that will not be fully understood. In such cases, the welding process is not optimised and neither is the monitoring process.

Weld monitors usually provide a means by which data can be collected via a data acquisition system. Such systems provide an excellent way to examine broad manufacturing trends over long time periods while also providing a weld by weld record of what has taken place for quality purposes.

Statistical Process Analysis / Control (SPC) can provide a useful means by which a welding process may be gradually improved through incremental changes. Such analysis is generally used to embellish work carried out at the initial welding trial and usually results in small changes being applied on a trial and error basis over larger production runs. Such work is generally used to optimise electrode dressing routines and for optimising the weld forces applied.

Attempting data collection and process analysis through weld monitoring without a proper welding trial is highly likely to lead to erroneous conclusions and actions which will diminish the potential value add offered by a monitor.

Weld Monitors - KISS : Keep It Simple, Stupid

In almost all cases, potential weld monitor users will be looking for a monitor that will simply discern the difference between a good weld and a potentially bad weld. We have seen that as long as the weld monitor can be setup to measure the correct weld energy parameters reliably, consistently and at the right points, then there is little need to become concerned and / or confused with the need to take absolute S.I. measurements and perform calibration routines.

The importance of an initial proper welding trial to determine the best weld process conditions has been stressed throughout and once achieved and documented, should then be used as the bench mark base point for monitoring.

Furthermore, when evaluating the potential usefulness of a weld monitor, it makes a lot of sense to deliberately contrive fault based welding conditions by which to judge the effectiveness of the weld monitor for any given application.

Data collection facilities within a weld monitor can be a useful supplement toward honing long term process optimisation but in general, the most important aspect is to get the welding process optimised in the first instance through proper welding trials.