LORCH

Description of AVC/ seam tracking for TIG welding

B. Jaeschke, Auenwald, Germany, 13.05.2015

The use of the TIG arc as a sensor for gathering distance information is the general state of the art technology. In the simplest case we just measure the arc voltage and position regulation to keep the torch height above the melt pool is attempted by compensation of the deviations in arc voltage with regard to the reference value using mechanical height adjustment. This gives us the abbreviation AVC = Automatic Voltage Control.
In actual fact, this process is only suitable to a limited extent because changes in the welding current also change the arc voltage and thus influence the height regulation in an undesired manner.
The signal produced by Lorch for seam tracking in TIG welding can largely compensate for the undesirable current influence. This technical documentation is intended to provide the background knowledge.

Technical Facts

AVC = Automated Voltage Control, the term designating the sensor system for arc position and length by measuring the arc voltage

Internal base for algorithmisation: Nahtverfolgung_WIG_DC2.mcd

Algorithmisation:

- TP1 hardware pre-filter
- Sensing Ua with 80kS/s 13bit cycle-synchronised
- Current-dependent voltage correction (Ohmic), adjustable (Start 10mOhm). num16
- Software filter TP1, 25Hz (shift 9), residual error 9µV (512, num32)
- Sensing with 1kS/s (main loop)
- Software filter TP1, adjustable (shift 3 to 16), residual error <1.2mV
- Start at I>0 with shift 3, step every 100ms to set value (rapid transient start)
- Scaling Sub(5V), Mult(0.5), measuring range 5V to 25V
- sample/transmit CAN 10ms at I>0 to Msg. 0196 (ANA04 Int06)
- at pulses <25Hz, transmit CAN bit with I1=1 and I2=0, >25Hz = 0.

Function of "Compensation" (current-dependent voltage compensation)

The arc voltage is dependent on a range of influencing factors. The dependence of the arc voltage on the arc length is desirable (the term AVC is based on it). The dependence of the arc voltage on the arc current has a negative effect, particularly in the case of current variations (pulses, ramps).

The "Compensation" function is intended to compensate for the current dependency in the ideal case. To do this, the measured current is multiplied by an adaption factor and subtracted from the measured voltage. The ideal adaption factor is a resistance value, seen from a physical point of view, and depends on various different boundary conditions, including the resistance and temperature of the welding cables and the electrode, the size of the weld pool, the base material and additive material and the inert gas.

Overview of current-dependent voltage compensation (parameter "Compensation Step")

Step	Ohmic [mOhm]	Correction [V/100A]	Step	Ohmic [mOhm]	Correction [V/100A]
0	- 20	+2	5	30	-3
1	-10	+1	6	40	-4
2	0	+/- 0	7	50	-5
3	10 (factory setting)	-1	8	60	-6
4	20	-2	9	70	-7

For easy optimisation of the "Compensation" function, the adaption factor can be modified simply by using the "Compensation Stage" parameter. The "Compensation Stage" selected determines which (Ohmic) adaption factor is to be used in the compensation algorithm.
The factory setting is Compensation Stage 3.

The algorithm for current compensation has the mathematical form:

Compensated value = initial voltage - Ohmic adaption factor * initial current.

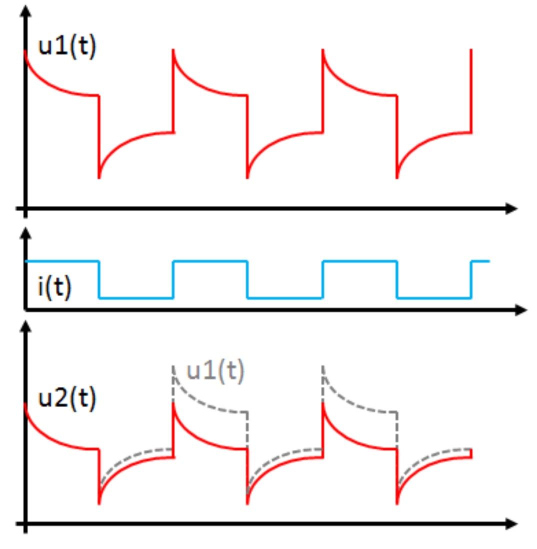


Illustration of the compensation effect:

- the strongly pulsing voltage signal u1(t)
- with the pulsing current i(t)
- becomes a less pulsing signal u2(t)
- if the current signal i(t), multiplied by an adaption factor is subtracted from the voltage signal u1(t), with the result u2(t).

"Filter" function

We see that the voltage fluctuations cannot be compensated for entirely using the "Compensation" function, because the electrode temperature and the size of the melt pool only change with a delay in the event of current fluctuations and also have an influence on the arc voltage.

For this reason, the compensated signal is additionally filtered. The signal u2(t) is smoothed in this way to the result u3(t). The strength of the smoothing effect is determined by the "Filter Stage" parameter. The greater the Filter Stage, the greater the smoothing. The factory setting for the filter is Stage 7.

Please note: The voltage signal of arc length changes is also smoothed by the filter.

Overview filter stages (parameter "Filter Stage")

Step	shift	3dB threshold frequency	Step	shift	3dB threshold frequency
0	3	20 Hz	7 (factory setting)	10	0.16 Hz
1	4	10 Hz	8	11	0.08 Hz
2	5	5 Hz	9	12	0.04 Hz
3	6	2.5 Hz	10	13	0.02 Hz
4	7	1.25 Hz	11	14	0.01 Hz
5	8	0.6 Hz	12	15	5e-3 Hz
6	9	0.3 Hz	13	16	2.5e-3 Hz

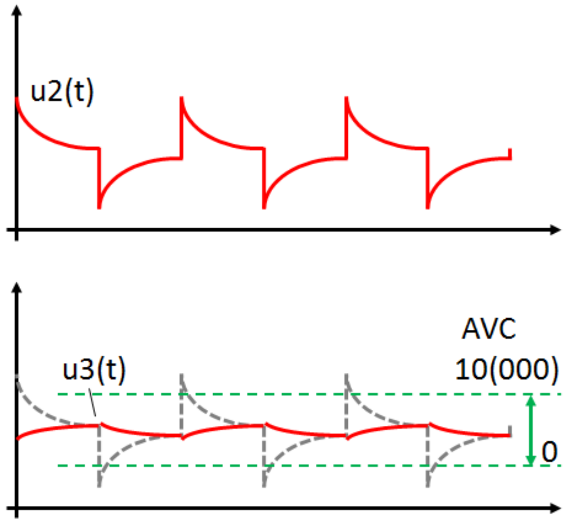


Illustration of the filtering effect:
- severely fluctuating voltage signal u2(t)
- is smoothed by the filter function
- becomes a smoothed signal u(3)

Scaling:

The smoothed signal u(3) is scaled to the AVC seam tracking signal and emitted. The scaling takes place by subtracting an offset and multiplication by a scaling factor.
The scaling cannot be changed by the user.

Significance of the signal values provided by the welding power source

Even if the abbreviation "AVC" is close to the fact that the signal values of the arc voltage provided by the welding power source corresponds to the arc voltage: this is not entirely the case.

The control of the welding power source determines the fed-back signal, summarised in the following way:

- If there is no weld current flowing (even at idling voltage), the signal value 0 is sent back.
- If the welding current flows, the voltage is measured at the outlet of the welding power source (→ u1(t)).
- This voltage value is corrected by the flowing current value by a specific factor, (→ u2(t)). The value can be parametrised with the "Compensation Stage" parameter.
- The value determined in this way is smoothed in a filter, (→ u3(t)). The strength of the smoothing effect can be parametrised with the "Filter Stage" parameter.
- The value determined in this way is scaled for better exploitation of the signal range by subtracting an offset and multiplication of a reinforcement.

Since the current-dependent voltage compensation influences the scaling, it is not possible to quote accurate scaling.

Setting in the job system

There are different optima of all parameter settings for different welding conditions. It may be that one parameter setting functions well for many different weld conditions. This depends on the requirements regarding speed and accuracy of the positioning control of the torch. Under certain conditions an individual optimisation to the special weld conditions may be necessary.

For adapting the preparation of the AVG signal we have the "Filter Stage" and the "Compensation Stage" parameters which can be optimised for each job individually.

Direct setting via the bus system

Direct access via the bus system permits separate setting of the "Filter Stage" and "Compensation Stage" parameters. Use of the "Flex-Parameter" of the LorchNet Connector.

Tapping the AVC signal:

- Int 06, analogue channel 4, (0 to 10V)
- LorchNet Connector, seam tracking voltage

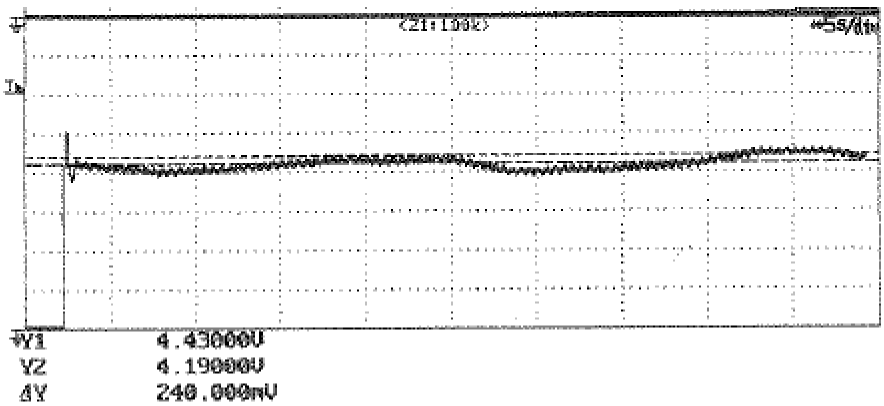
Optimisation during welding

The "Filter Stage" and "Compensation Stage" parameters appear in the operation behind the other process parameters (buttons < >), if an automation interface is connected, otherwise not. The parameters can be adjusted and optimised during welding.

Application

The factory setting is a good start. It is very useful if the signal provided by the machine can be represented in time sequence in the framework of the AVC adjustment. The following figure shows an uptake of the analogue voltage of Int06, where 0V..10V corresponds to a number range from num. 0 to num. 10,000.

The uptake was created in a TIG-DC-2Hz Pulse Process on a pipe clamped in an out-of-round manner, so that there would be changes in the arc lengths. The factory setting filtered the 2Hz Pulses to an adequate level, the height regulation worked. Around 4,200 was used as the reference value.



Trial welding for setting the start delay, the reference value, the Blind Spot, the amplification of the maximum correction speed for the external AVC regulation is imperative.
An initial trial with a long arc length can help for testing the basic parameters for the external AVC regulation, without damaging the TIG electrode by an undesirable short-circuit.
The most suitable setting of the parameters of the external AVC regulation is decisive for success.

External AVC regulation (height adjustment)

A tried and tested method of AVC regulation has the following parameters and properties:

External parameters	Description, properties
Gain	Height adjustment with a difference in the AVC signal from the reference value, unit = 1 mm/difference value (1mm/difference value can be standardised in a controller e.g. to 100%)
Reference value	Reference value for the AVC signal, that corresponds to the desired height
Bias	Speed of height adjustment, unit = 1 mm/s (2mm/s can be standardised in a controller e.g. to 100%)
Blind Spot	Difference value which first has to be exceeded before the height adjustment can be initiated by the gain. The value of the Blind Spot "calms" the height adjustment to prevent frequent small adjustment processes. Unit = 1mm/difference value. The Blind Spot is not subtracted from the gain, i.e. after exceeding the Blind Spot, the gain is completely converted as the height adjustment.

Notes concerning the problem images and remedies

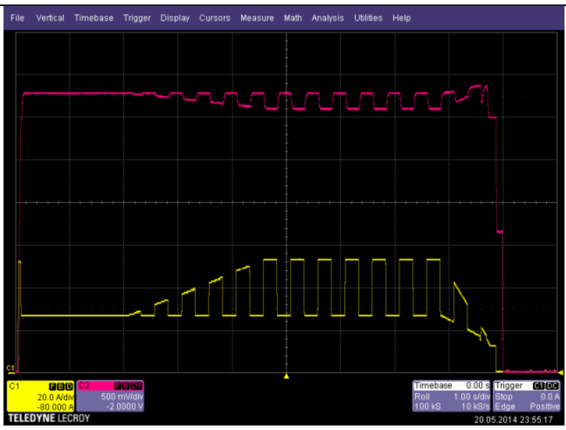
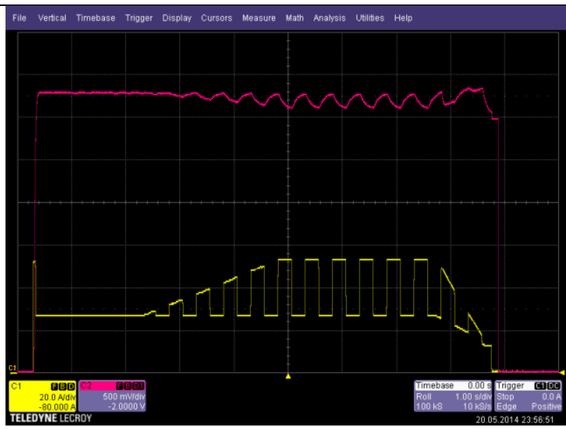
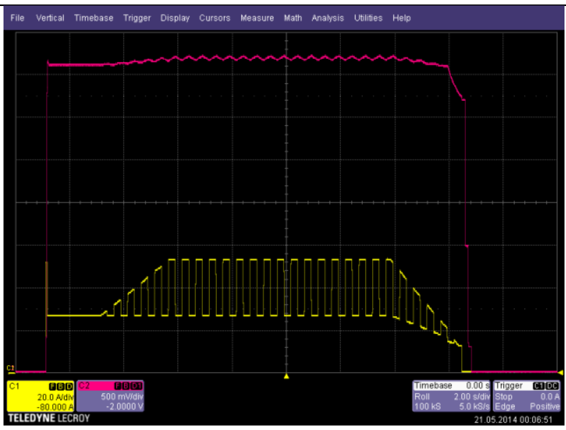
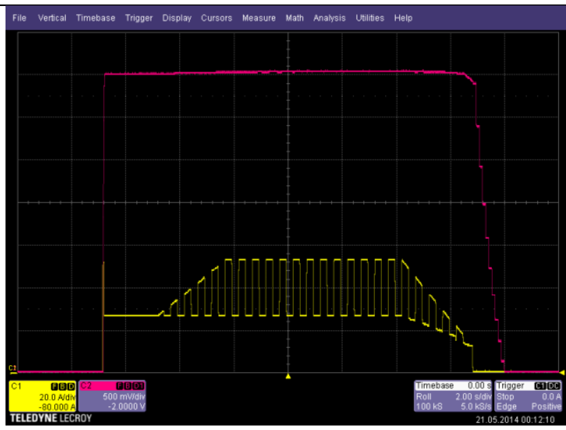
Problem images	Notes
At the start and/or at the end, the position regulation moves upwards in an undesirable manner	• If no current is flowing, the signal 0 is delivered. The position regulation starts too early and/or remains too long at the end. • We recommend starting the position regulation only after complete formation of the melt pool • We recommend ending the position regulation before the melt pool changes at the end of welding (e.g. with overlap welding or current drop)
Arc gets even longer or even shorter until the short-circuit	• The direction of regulation amplification may be incorrect. Negating. • The reference value is incorrect or unsuitable • The amplification (gain) of correction speed (bias) is too great • The "Compensation Stage" K, "Filter Stage" F are completely wrong. Try the factory settings. K=3, F=7

The arc length is not regulated at all	• The amplification (gain) or maximum correction speed (bias) is too small • Blind Spot is too big • The "Compensation Stage" K, "Filter Stage" F are completely wrong. Try the factory settings. K=3, F=7
Arc length regulation fluctuates (no pulses)	• The amplification (gain) or maximum correction speed (bias) is too large • Blind Spot is too small • The "Filter Stage" F parameter is not optimum. Step-wise adjustment of the parameter F and in each direction and test weld, which direction improves the situation. Searching for the optimum.
Arc length regulation (without pulses) works, but too slow	• The amplification (gain) or correction speed (bias) is too small • Blind Spot is too big • The "Filter Stage" F parameter is not optimum. Step-wise adjustment of the parameter F and in each direction and test weld, which direction improves the situation. Searching for the optimum.
Arc length regulation (without pulses) works, but when pulsing in the highest current phase of the arc is extended undesirably, and this creates severe fluctuations - If better, but optimum difficult to find, observe the other note points	• The "Compensation Stage" K is too small. Step-wise adjustment of the parameter K upwards, searching for the optimum. • The "Filter Stage" F parameter is not optimum. Step-wise adjustment of the parameter F upwards, searching for the optimum. • Blind Spot is too small • The amplification (gain) of correction speed (bias) is too great
Arc length regulation (without pulses) works, but when pulsing in the highest current phase of the arc is shortened undesirably, and this creates severe fluctuations - If better, but optimum difficult to find, observe the other note points	• The "Compensation Stage" K parameter is too great. Step-wise adjustment of the parameter K downwards, searching for the optimum. • The "Filter Stage" F parameter is not optimum. Step-wise adjustment of the parameter F upwards, searching for the optimum. • Blind Spot is too small • The amplification (gain) of correction speed (bias) is too great
Various different arc lengths at various different currents or in the event of current ramps	• If possible, the reference value must also be changed at various different currents or with current ramps. Effectively an individual optimisation. • If that is not possible, the current flow can be compensated via the "Compensation Stage" parameter. If the arc builds up a voltage that is dependent on the current in a non-linear manner, in combination with the electrode, gas, material, melt pool size, etc., this compensation cannot, however, be complete. • It may be beneficial to increase the Blind Spot.

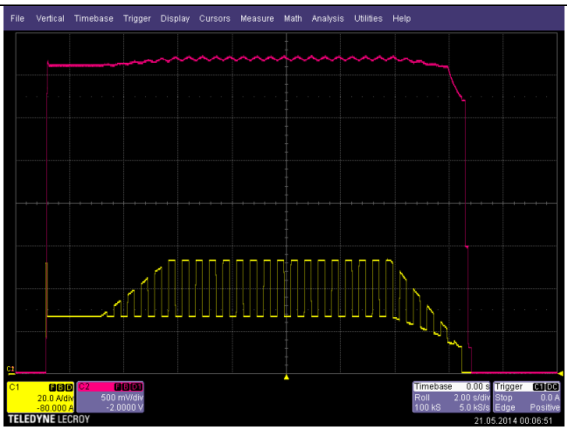
The height changes if the compensation parameter is adjusted, or if you need a different reference value for the height regulation	• This is unavoidable by the compensation function and is system-dependent. Changing the "Compensation Stage" K, changes the AVC signal even more, the higher the weld current.

Examples:

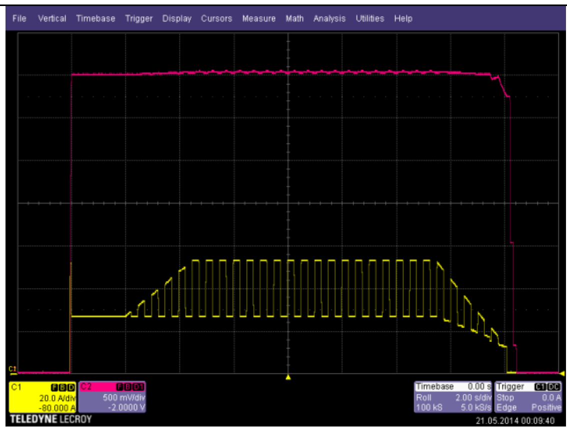
Top (red): Uana4 (seam tacking signal from Int06, corresponds to 0..10000 num
Bottom (yellow): Ia (20A/div), start current approx. 2s, pulses 2 Hz.

 **Filter stage 0 (shift 3, 20Hz), comp. 32mOhm**	 **Filter stage 3 (shift 6, 2.5Hz), comp. 32mOhm**
 **Filter stage 5 (shift 8), 0.6Hz, comp. 0mOhm**	 **Filter stage 7 (shift 10), 0.16Hz, comp. 10mOhm**

We detect the increasing smoothing of the signal derived from the arc voltage

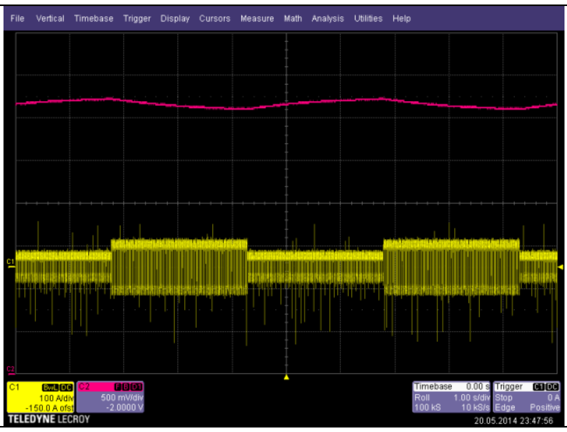


Filter stage 5 (shift 8), 0.6Hz, comp. 0



Filter stage 5 (shift 8), 0.6Hz, comp. 10mOhm

We detect the effect of the current-dependent voltage compensation (Ohmic). The compensation stage must be chosen with care. An incorrectly set compensation can make the signal completely unusable and this cannot be rectified entirely by a strong filter stage. Factory setting is Stage 3 (10mOhm).



AC mode 30Hz, with additional pulse approx. 0.2Hz, timescale 1s/div, Filter Stage 7 (shift 10), comp. 10mOhm

Setting examples

Steel, t = 5 mm, pipe diameter 60 mm, weld speed 25 cm/min, arc length 3mm

Current source parameters:

- Comp. Stage 3 (factory setting), filter stage 7 (factory setting)
- Set current value TIG DC = 95 A, pulse = 115 A.

Parameters of the external AVC regulation (height adjustment):

- Bias 1.8 mm/s, gain 0.2 mm/difference value, Blind Spot 0.3 mm/difference value, reference value 27.

Height changes, caused by a pipe running off centre, of 5 mm can be corrected reliably.

Aluminium, t = 2 mm, pipe diameter 60 mm, weld speed 20 cm/min, arc length 6mm

Current source parameters:

- Comp. Stage 3 (factory setting), filter stage 4

- Set current value TIG AC sine = 65 A.

Parameters of the external AVC regulation (height adjustment):
- Bias 1.6 mm/s, gain 0.35 mm/difference value, Blind Spot 0.5 mm/difference value, reference value 23.

Height changes, caused by a pipe running off centre, of 5 mm can be corrected reliably.
Height adjustment on aluminium is more difficult than on steel. For this reason, you need to work using a greater arc length.