AVS-48SI PICOBRIDGE
Comparing AVS-48SI with AVS-47B

Our popular model, the **AVS-47B**, is rather old and increasing obsolescence of key components is casting a shadow on its future production. Upgrading to our new Model **AVS-48SI** means giving up stand-alone operation, i.e. local display and keyboard, and replacing the old GPIB interface standard by an even older RS232. However, thanks to low-cost USB-232 converters, the asynchronous serial protocol is still very much alive. On the other hand, the AVS-48SI offers more functions and possibilities, temperature controller, improved accuracy and digital resolution, and means for easy on-site calibration without external standards. This document does not deal with differences between computer interfaces nor differences between the LabView virtual instrument programs that come with both instruments. The focus is on comparing the hardware features of the two instruments.

AVS-48SI Picobrige

The AVS-48SI is a **"black box"** instrument without a display or keyboard of its own. All its functions are controlled by a remote computer via an asynchronous serial interface. The bridge is divided in three parts: 1) a preamplifier that should be located near to the cryostat, 2) a 19" main unit for rack mounting inside the shielded room and 3) a small galvanically isolated microprocessor unit (CPU) which should be located outside the shielded space. The CPU is connected to the controlling computer. This arrangement combines excellent RF silence with short leads to sensors.

The standard AVS-48SI offers 7 sensor channels, 8 resistance ranges from 3Ω to 30MΩ and 8 nominal excitations from 3μV to 10mV. Automatic compensation of input capacitance guarantees useful accuracy even on the 3MΩ and 30MΩ ranges. Any sensor can be either floating or its current return lead can be grounded to the cryostat. Any sensor can be switched programmatically from 4-wire to 2-wire connection e.g. for determining current lead resistances. This can reveal also some short circuits.

Resistance is output at **5 1/3 -digit resolution** (e.g. 299.999kΩ).

The AVS-48SI has three automatic procedures for calibrating the instrument **in its normal operating place and temperature**. No external standards are required.

A low-cost **temperature controller** is included in the AVS-48SI.

A LabView Virtual Instrument program "avs48si.vi" with direct temperature display etc. is included in the price.

The serial interface can be used from **any computer, operating system and programming language that support serial communications is its simplest form**. The computer-CPU connection can be replaced by an optional optical fibre link for ultimate RF silence and freedom from ground currents.

The AVS-48SI is perhaps the most accurate cryogenic resistance bridge commercially available for research and low-temperature resistance thermometry. Multiple input channels make it suitable for scanning applications and with the "avs48si.vi" many fine features are easy to use without need to write a line of code.

AVS-47B

The AVS-47B is a **stand-alone** instrument with display and front panel switches. The instrument is divided in two parts: 1) a preamplifier that should be located as near to the cryostat as possible and 2) a 19" main unit for rack mounting inside the shielded room. Almost all functions can also be controlled by a remote PC-type Windows computer via our own galvanically isolated synchronous, serial "Picobus" protocol. The possible external computer should be located outside the shielded space. By grounding the shielding jacket of the Picobus cable guarantees an excellent RF silence combined with short leads to sensors.

The AVS-47B offers 8 sensor channels, 7 resistance ranges from 2Ω to 2MΩ and 7 nominal excitations from 3μV to 3mV. Automatic compensation of input capacitance guarantees useful accuracy even on the 2MΩ range even if the sensors leads are lightly filtered. Normally all sensors are in 4-wire configuration and they are isolated from the cryostat gound. They can be wired differently, however.

Resistance is output at **4 1/2 -digit resolution** (e.g.199.99kΩ).

The AVS-47B has two calibration modes: a quick calibration from the front panel and complete **calibration at factory**, which needs external instruments and standards. The quick mode is used by setting the offset and scale for the 200Ω range and one (high) excitation. Changes between ranges and excitations cannot be nulled. They are "second-order" effects, however.

There is **no temperature controller** available for the 47B. The old model TS-530A has been discontinued.

A set of LabView VIs is available for the 47B and they can be used for creating applications. There is no complete instrument program, like the "avs48si.vi". These VIs are useful **only for a Windows-PC running LabView**.

We can manufacture only a very limited number of the Model AVS47-IB GPIB interfaces before this interface has to be discontinued.

Production of the AVS-47B bridge continues until it becomes impossible or economically unfeasible.

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CHANNELS AND INPUT CONNECTION

7 channels, numbered from 1 to 7. Channel 0 is devoted to measuring one of the seven internal calibration resistors (see Calibration).

Wiring to the DC37 input connector is identical to wiring of AVS-47B sensors 0..6. An input cable that has been used with the 47B can be direcly plugged into 48SI provided, that only 7 first channels are occupied.

Any sensor's current return lead can be grounded to the cryostat or the sensor can be left floating (default). This must be told to the firmware. Floating sensor is better, if ground currents are a problem, whereas grounded sensor can have better thermal contact and needs less wiring.

Any sensor can be set **programmatically** into **4-wire** (default) or **2-wire** connection. Difference between readings tells the total current lead resistance. By keeping record of such differences, one can detect poor connections and some short circuits. Change between 4- and 2-wire connections can be done without affecting the experiment.

RANGE

Eight ranges 0-3Ω, 0-30Ω .... 0-30MΩ. A negative display usually means that voltage leads were inversed.

EXCITATION

Eight excitations 3µV, 10µV ... 10mV. Excitation current is the nominal excitation voltage divided by one third of the selected range. For example, if 20kΩ is measured on 30kΩ range and 10µV excitation, the current is 10µV÷(30kΩ/3) = 1E-10A= 0.1nA.

Excitation is symmetrical square wave at **12.5, 13.64 (default) or 15.0Hz**. Frequency is crystal-controlled. If the measurement suffers from interference at the mains frequency or a frequency very near to it (vibration due to induction motors, pumps etc.), use 12.5Hz in a 60Hz country and 15.0Hz in a 50Hz country for increasing the beating frequency. This makes it easier to suppress the interference by averaging the readings. 13.64Hz excitation frequency provides about 1Hz beating if interference is either 50 or 60Hz. An external frequency source can also be used for implementing other frequencies..

It is guaranteed by design that heating by any possible DC component in the excitation remains non-detectable.

A/D CONVERSION

The AVS-48SI uses the LTC2400 A/D converter from Linear Technology. Although it is a 24-bit ADC, other noise sources limit the useful resolution to **5 1/3 digits**, which in

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8 channels, numbered from 0 to 7. Channel 0 is similar to other channels. DC37 input connector (female: preamplifier, male: sensor cable).

Any sensor's current return lead can be grounded or the sensor can be left floating inside the cryostat (default). Floating sensors are better against ground currents whereas grounded sensors need less wiring and can have a better thermal contact. A grounded sensor requires removal of a short-circuit piece inside the preamplifier. Programmatic change is not possible.

Sensors are normally **soldered** for 4-wire connection. 2-wire connection is possible by soldering corresponding voltage and current terminals together. Programmatic change is not possible.

Seven ranges 0-2Ω, 0-20Ω .... 0.2MΩ. A negative display usually means that voltage leads were inversed.

Seven excitations 3µV, 10µV ... 3mV. Excitation current is the nominal excitation voltage divided by one half of the selected range. For example, if 10kΩ is measured on 20kΩ range and 10µV excitation, the current is 10µV÷(20kΩ/2) = 1E-10A= 0.1nA.

Excitation is symmetrical square wave at **≈13.64Hz**. Frequency is generated by a simple free-running RC oscillator. This frequency works both in 50 and 60Hz countries.

It is guaranteed by design that heating by any possible DC component in the excitation remains non-detectable.

The AVS-47B uses the old type ICL7135 A/D converter which was designed mainly for 7segment displays. It is a free-running ADC that makes one conversion and updates the front panel display in every 0.4 seconds. Digital

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this case means digital output from **-300000 to +300000** counts corresponding to a measuring range.

The converter is not free-running but converts only after a command. One A/D conversion takes about 0.2 seconds, and maximum sample rate of 5/second is achieved when several conversions are averaged. After issuing the "ADC1" command, result of one conversion is available by query "ADC?" or "RES?". Repeated "ADC;ADC?" command-query pairs take longer than if the 48SI makes averaging itself. Completion of the conversion can be detected by polling the interface port (recommended) or the result can just be read after a sufficient delay.

After having measured an average of n readings ("ADCn"), there is also some **statistical information** available: minimum, maximum, standard deviation and the "quality ratio" of peak-to-peak/STD. A Q-ratio much higher than 5 indicates that the averaged readings contain something else than random noise or drift, typically interference spikes.

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output can be read using the included LabView programs. Because of Windows, 2/second is the maximum reading rate for repeated conversions.

The 7135 yields a **4 1/2 digit** output, in this case from **-1.9999 to +1.9999** corresponding to a measuring range.

After a starting command, the LV software waits until a fresh conversion result is available. This takes a non-predictable time, which is 400ms at most.

The AVS-47B outputs only single readings. Any further processing of repeated readings must be done in the LabView software.

Reading the 7135 **without using LabView** for Windows on a PC is complicated and the process is therefore not documented.

CAPACITANCE COMPENSATION

Active compensation tries to maintain the square shape of the voltage drop across the sensor by quickly charging the input capacitance. The input time constant can be in excess of 1ms even on the highest **30MΩ range**. This makes it possible to have light RF filters in the I+, V+ and V- leads. The I- lead shall not be filtered.

Active compensation tries to maintain the square shape of the voltage drop across the sensor by quickly charging the input capacitance. The maximum input time constant of 1ms is allowed even on the highest **2MΩ range.** This makes it possible to have light RF filters in the I+, V+ and V- leads. The I- lead shall not be filtered.

CALIBRATION

The automatic Main Calibration process measures zero offsets and scale factors using all 64 combinations of range and excitation and calculates required corrections. Seven ultra-stable wire wound resistors are used for measuring the scale factors

Instead of just correcting the digital output, which is the most common way, the process adjusts the offset and scale of the analog output for each RAN/EXC combination so, that both the output and the digital reading is equal to the value of the calibrator resistor. These values are stored in the non-volatile memory of the CPU. Very long averages are used at low excitations. Because of the number of combinations and long averages, full calibration takes about 3.5 hours. No external instruments or tools are required. The AVS-48SI can be calibrated in its normal operating place and temperature.

Because of the long time needed, there are also two shorter calibration modes: 1) Calibrate only one RAN/EXC combination to full accuracy and 2) Calibrate all combinations using shorter settling times and averages. Alternative 2 takes about 0.5 hours but is less accurate.

The AVS-47B has two front panel trimmers for quick adjustment of zero offset and scale factor on 200Ω range using the selected excitation. This should be done only on a high excitation range. Adjustment when excitation is low would require long averages because of increased noise.

This quick adjustment cannot null differences between various excitations and between ranges. However, such changes are much smaller ("second-order") effects than drifting of the overall electronic gain due to temperature changes or aging, which can be nulled using the trimmers.

Complete calibration requires external resistance standards or resistors of precisely known values. It is best done at the factory but is luckily seldom needed.

The most frequently encountered situation which requires complete calibration is when the preamplifier is changed. Therefore the AVS-47B main unit and its original preamplier should always be used together. Changing either of them without re-calibration may lead to an error of ±0.2% in the worst case.

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The calibrator resistors can be measured like any actual sensor. Channel 0 is devoted to calibrators and the value 0Ω, 1Ω, ...1MΩ is selected by the "REFIDn" command. Comparing the result with the resistor's saved value ("REFVALUE? query) tells, whether running the calibration process would be useful.

Calibrators are located in the preamplifier unit. If the preamplifier is replaced, the new preamp's calibrator values must be saved into the CPU and then the calibration process is run. The original values are found inside the preamp, we have records of them and they can also be easily measured in the field using a high-end 4-wire ohmmeter.

Suppose that the analog output is connected to user's own temperature controller or it is measured for some other purpose. Because of inevitable differences in calibrations, the AVS-48SI and the user's DVM will give different readings. It is possible and easy to change the calibration of the A/D converter so that both readings become equal. Then the full calibration process is run. Both the bridge and the external DVM give same readings, although their calibrations were originally different.

Calibration of the AVS-48SI has been given so much attention because this bridge has 5 1/2 digit output (=10µV) as compared with the 4 1/2 digit output (=100µV) of the AVS-47B.

TEMPERATURE CONTROL

The AVSA-48SI is equipped with an analog temperature controller option. This stepless PID controller has been designed for controlling low and ultralow temperatures. It features

14 proportional gains
12 integrator gains
11 derivator gains
18 heater power ranges.

The values of all parameters are spaced proportionally, which corresponds to the nature of control systems. The PID parameters are in 1:2:5... sequence whereas the ***power ratio*** between adjacent heater ranges is 2.5. Power ranges for a **100Ω heater are from 1µW to 1.8W** and for a **50Ω heater from 0.5µW to 3W**.

The controller has many useful features like no-drift latching of power so that other sensors can be visited, and changing of heater range without effect on the instantaneous power. The controller can also be driven by an external voltage or by an external digital input. Then it is a voltage-controlled or software-controlled current source taking its input e.g. from the user's own control algorithm.

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No temperature controller available

The old Model TS-530A has been discontinued.

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INPUTS AND OUTPUTS (REAR PANEL)	
Analog Out. Voltage output **0V..+3V** corresponding to (R_{SENSOR} /RANGE) * 3V BNC with grounded jacket. Analog filtering has been applied for reducing residues of the excitation frequency. This output can be set programmatically to show deviation between sensor resistance and setpoint voltage. This deviation has gone through the analog filter. **Polarity can be selected.**	**Analog Out**. Voltage output **0V..+2V** corresponding to (R_{SENSOR}/RANGE) * 2V BNC with grounded jacket. Analog filtering has been applied for reducing residues of the excitation frequency.
Control Error Out. Voltage output **-3V...+3V** corresponding to (R_{SENSOR}/RANGE)*3V - $V_{SETPOINT}$ BNC with grounded jacket Control Error has **not been filtered** in order to avoid extra time delay in the control loop. **Polarity can be selected.** This output is available also if temperature controller is not installed or if temperature control is not active.	**Difference.** Voltage output **-2V...+2V** corresponding to (R_{SENSOR}/RANGE)*2V - $V_{SETPOINT}$ BNC with grounded jacket. Deviation **has been filtered** analogically. **Polarity cannot be selected**
AC Monitor Out. Voltage output showing amplified signal across the sensor. Used for diagnostics with an oscilloscope, e.g. for checking that the sensor does not suffer from mains frequency interference.	**AC Out.** Voltage output showing amplified signal across the sensor. Used for diagnostics with an oscilloscope, e.g. for checking that the sensor does not suffer from mains frequency interference.
No relay output	**Relay Output.** Reed relay switch is available for applications that need a switch that either opens or closes when sensor resistance passes a 12-bit reference voltage (alternative setting of the front panel 10-turn potentiometer). Switching capacity 0.5A. 3-way DIN connector.
12V DC Input. Alternative low-voltage DC power input. **One 12V battery** is required. Mainly for testing existence of mains-borne interference. 4-way DIN connector.	**Battery Input.** This is an alternative low-voltage DC power input. **Two 12V batteries** are required. Mainly for testing existence of mains-borne interference. 4-way DIN connector.
18V AC Input. Alternative low-voltage AC power input. An external mains-to-18V 1 Ampere transformer is required. Use of such a safe low voltage allows user's own power filtering. A transformer cuts possible ground currents flowing via the safety earth lead. 3-way DIN connector.	**No low-voltage AC input**

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Mains Input. The AVS-48SI has a universal power supply for 90-250V 50-60Hz.

Picobus Serial Input. Primary synchronous, serial data I/O for connecting the analog front end **to the external CPU unit**. Data is transferred using a proprietary low-speed "Picobus" protocol for minimising RF leakage in the neighbourhood of the cryostat.

9 pin female DE9S socket.

Picobus provides galvanic isolation of **signals and braid** between the bridge and the CPU. It is recommended, however, to connect the cable's shielding braid to the conducting wall of the shielded cryostat room at the entering point, if possible. This prevents possible antenna effects. 50/60Hz ground currents are prevented by galvanic isolation of the braid.

No optical connectors on rear panel

(Optical isolation similar to Picolink is available also for the AVS-48SI (order codes AVS 48SI-N-F and AVS-48SI-T-F). These versions have an extra box for optical receiving/transmitting. The CPU box of the -F version has optical receivers/transmitters, which replace the connector for the Picobus wire cable. The main units of the -W (wire link) and -F (fibre link) versions are identical. This arrangement makes it easier to upgrade from -W to -F, if optical link is found necessary.)

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Mains Input. The AVS-47B has a universal power supply for 90-250V 50-60Hz.

Primary Interface. Primary synchronous, serial data I/O for connecting the AVS-47B **to the possible external computer**. Data is transferred using a proprietary low-speed "Picobus" protocol for minimising RF leakage in the neighbourhood of the cryostat.

25 pin female DB25S socket.

Picobus **signals** are galvanically isolated with the exception of the cable's shielding braid. It should be connected to the conducting wall of the shielded room at the entering point, if possible. This prevents ground currents and possible antenna effects.

PICOLINK

Connectors for four plastic optical fibres, when the AVS-47B is equipped with the **optical "Picolink" fibre link option**. This option has been available only for use together with the AVS47-IB computer interface, which is coming to the end of its lifetime as a product. Picolink can be retrofit into old interfaces at the factory.

THE FOLLOWING INPUTS AND OUTPUTS EXIST ONLY IN THE AVS-48SI

CONTROL SET POINT

Voltage from the set point DAC. Settling resolution is about 50µV. The performance of the 16-bit DAC has been improved by feedback from the more accurate A/D converter. Set point voltage for a resistance is set by command "SETPOINT [0...30,000,000 | ?]. The voltage is calculated on the basis of the currently selected resistance range.

If a set point is not required for temperature control with the 48SI's own controller, then this output is available for other purposes. The voltage is set and queried by command SDACV[0.005..2.99 | ?].

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USER DAC

This output is similar to the Control Error Output, except that it is always available for the user's own purposes. Voltage is set and queried by command UDACV[0.005..2.99 | ?].

EXT CLOCK IN

Input for an external clock that can determine the excitation frequency. The 0/+5V square wave signal must come from a low impedance, typically 50Ω. Then it replaces the 48SI's own clock. The excitation frequency (PSD frequency) depends on the currently selected internal fixed frequency (the available values are 12.5 / 13.64 / 15.0Hz). Calculate the result for the 13.64Hz default as:

$F_{PSD} = (F_{EXT} / 600\text{Hz}) * 13.64\text{Hz}$

An arbitrary frequency may help in cases, when none of the available fixed frequencies provides sufficient attenuation of beating or when increasing the beating frequency allows more effective filtering.

If EXT CLOCK IN is not loaded, it outputs 600Hz square from a 10kΩ impedance.

EXT HEATER DRIVE IN

The heater output of the PID controller can be driven by an external analog voltage 0...+3V, where 3V means full nominal output of the selected heater range. This mode is selected by changing the position of a short-circuit piece inside the main unit. Then the PID section is completely bypassed. All heater ranges are available .

This feature enables temperature control where the 48SI's own PID output is replaced by a drive signal from a computer+DAC or from some other device.

Connecting either the Control Error Out or User DAC to the Ext Heater Drive In turns the heater output to a software-controlled current source of 18 ranges.

HEATER OUT

The heater of the temperature controller should float inside the cryostat, because the heater output is a negative current that flows from the output to the bridge ground. This poses some difficulties in avoiding ground loops and in shielding the heater wires against high frequencies. The 48SI offers two solutions.

1) One single coaxial cable is connected to the middle "Heater Out" BNC connector whose jacket is grounded.

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The corresponding connector on the cryostat must float with respect to ground so, that the heater return path has only one grounding point, the bridge. If a BNC connector is used, it must be of isolated type. If a vacuum-tight isolated BNC is not available, then use alternative 2:

2) Two coaxial cables. The two BNC connectors on the cryostat must have grounded jackets, whereas the corresponding connectors on the 48SI rear panel are isolated. The heater is connected between center leads. The braids are now grounded to the cryostat for best RF shielding, whereas current from the floating heater returns to the bridge ground.

This is the preferred heater configuration.

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