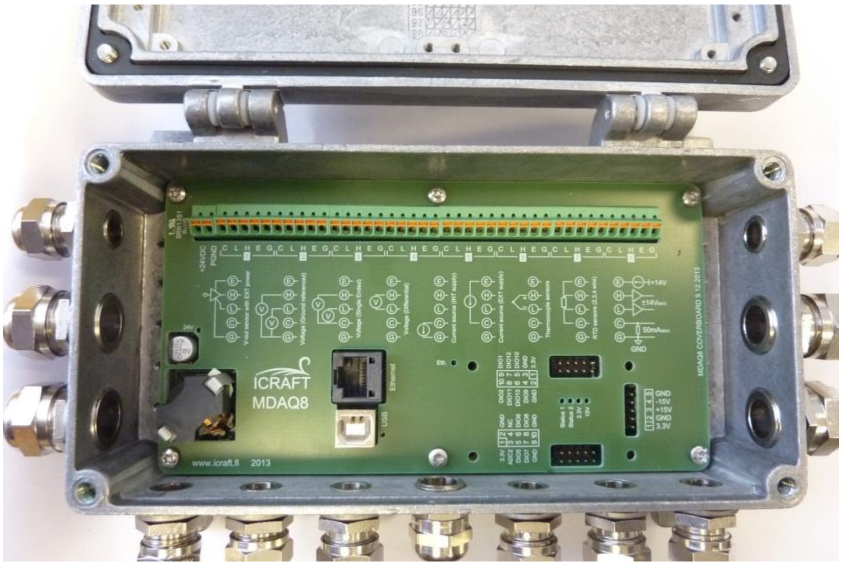
PRELIMINARY VERSION

MDAQ8

Multifunction DAQ



Features:

- *8 differential/16 single ended analog inputs (24-bit, 800 Samples/s)*
- *Sensor types: Temperature (RTD, TC), voltage, current, 4-20mA loop*
- *USB and Ethernet (Modbus over TCP/IP), connect MDAQ8 locally or over the Internet*
- *IPlotter software allows to configure the MDAQ8 and see current measurements as trends*
- *Fits to Vaisala QLI50 box (Wärtsilä SMU/DCU)*

Option:

- *CANopen interface available for CAN bus applications*

PRELIMINARY VERSION

MDAQ8

- *8 multipurpose analog input channels with DC-voltage and current outputs*
- *Common ground for all measurement channel*
- *Simultaneous sampling inside one channel*
- *Software selectable sampling frequency*
    - *1Hz, 6Hz, 50Hz 60Hz, 100Hz, 120Hz or 800Hz*
- *24-bit ADC resolution*
- *Three internal temperature sensors for thermocouple zero point calibration*
- *Isolated USB and Ethernet 10/100 interfaces*
- *Isolated power supply*
- *Supported sensor types: thermocouple, RTD, …*
- *Expansion interface*
- *Typical applications:*

Measurement Channel Characteristics

Multipurpose input channels 8
ADC
Number of ADC 3
Resolution 24-bits
Type of ADC............................... Delta-Sigma
Sampling mode.......................... Multiplexed
Data rate (f_s) per channel .... 1Hz, 6Hz, 50Hz 60Hz, 100Hz, 120Hz or 800Hz

Voltage Measurement

Input ranges.................................... ±14 VDC, ±2.5 VDC, ±250mVDC

Common mode
(±250mV).................................. ±250 mV
(±2.5V)...................................... ±2.5 V
(±14V)....................................... ±14 V

Input noise (6Hz sampling frequency)
(±250mV).................................. 80 nV_{RMS}
(±2.5V)...................................... 0.3 μV_{RMS}
(±14V)....................................... 3 μV_{RMS}

Overvoltage protection
Continuous .... 100 Vdc
ESD HBM .... ±15kV
ESD MM.................................... TBD
Input impedance (H to G / L to G) DC
High Z mode 1GΩ
10MΩ mode 10MΩ

Current Measurements

Input impedance 50Ω
Maximum current 50mA
Input bias ....<3nA (typical) 25°C

Excitation terminal

DC-out current / channel ....1mA/30mA max. 14V

Isolated communication

Universal serial bus, USB
Current from bus ....max. 100mA
Ethernet 10/100..............................Modbus

Expansion Port Characteristics

Digital IO 11
Input voltage threshold (typical)
(read as 1) ....>2.32V
(read as 0) ....<1V
Analog IO
ADC inputs 2
Supply voltage.................................+3.3V, ±15V

Power requirements

External supply voltage
Voltage.......................................+24Vdc - +30Vdc
Current.......................................350mA Max

Operating conditions

Ambient temperature ....-40 … +85°C

Not to be used without enclosure.

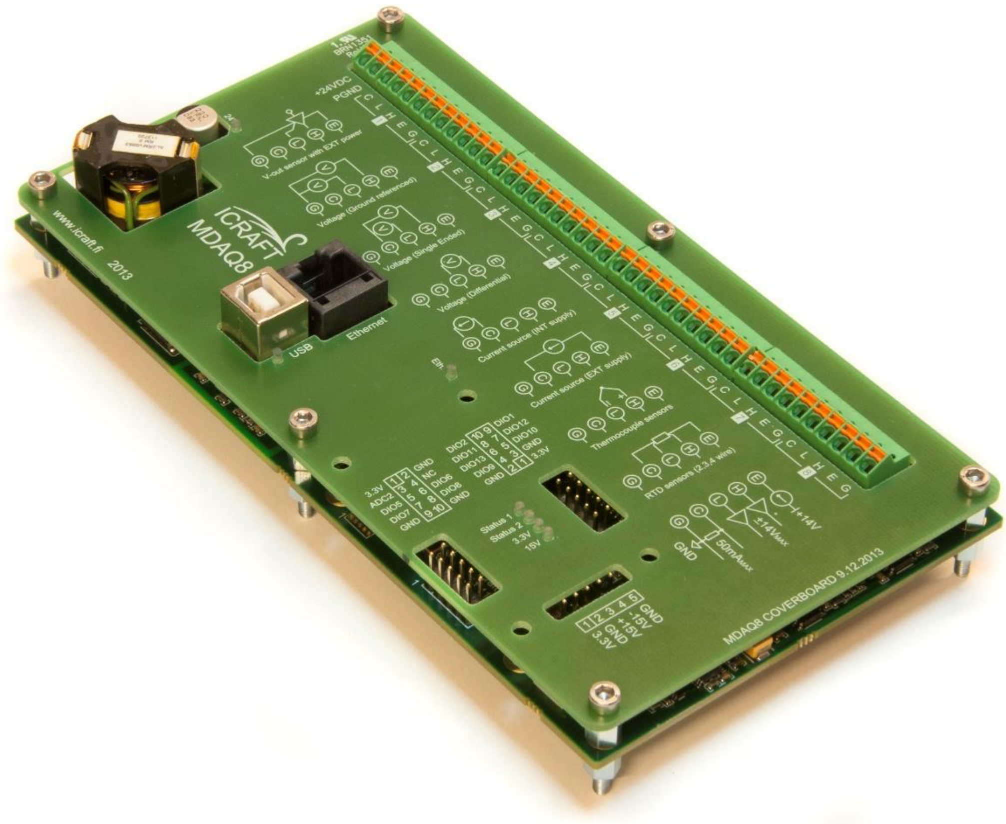


Figure 1 MDAQ8 printed circuit boards (PCB)

Introduction

MDAQ8, presented in Figure 1, is an eight channel multifunctional data acquisition system, which is fully isolated from power supply network as well as from communication interfaces. MDAQ8 (dimensions 173mm x 92.5mm) is designed to fit Vaisala's QLI50 housing making it an easy replacement part for existing measurement systems.

A simplified block diagram of the MDAQ8 measurement system is presented in the Figure 2. As presented in the Figure 2 MDAQ8 provides eight differential or sixteen single-ended simultaneous voltage measurement inputs as well as 8 current measurement inputs and 8 excitation current outputs. All measurement channels share a common ground potential, making it possible to utilize all channels with only one ground potential balancing wire between the MDAQ8 and the target system under measurement. System includes seven predefined sampling frequencies ranging from 1Hz to 800Hz. All measurement channels in the MDAQ8 share three differential analogue-to-digital converters, due to which the sampling frequency per channel is a division of total sampling frequency and amount of simultaneously utilized channels. However inside one measurement channel it is possible to perform three separate conversions simultaneously and synchronously. For example two single-ended voltages and a current can be measured at the same time. All measurement channels are calibrated during the manufacturing process to provide as accurate measurement results as possible. MDAQ8 includes three temperature sensors located close to connector strip for thermocouple zero point compensation.

MDAQ8 is designed to provide accurate measurement results with low noise. In order to utilize the full potential of the data acquisition system special attention has to be paid on implementation of measurement setup wiring. As a rule of thumb user should prevent any ground balancing current flowing in the measurement wires and prevent magnetic or electric field coupling to measurement wiring. For more information on grounding issues refer to chapter

MDAQ8 is able to communicate with data terminal computer through Ethernet and Universal Serial Bus (USB) interfaces. Both communication interfaces are galvanically isolated to prevent ground loops. MDAQ8 can be operated by utilizing an Icraft IPlotter software, MODBUS or by user's own interface software capable to implement required communication protocol. Extension interface can be used for other interfacing options.

In short MDAQ8 is an accurate voltage measuring device with an excitation current output. MDAQ8 can also measure current by transforming it into a voltage with a 50Ω resistors. Data acquisition system includes several predefined measurement setups and measurement result handling algorithms, which make it easy to implement measurements for example with thermocouples and resistive temperature devices, such as PT100.

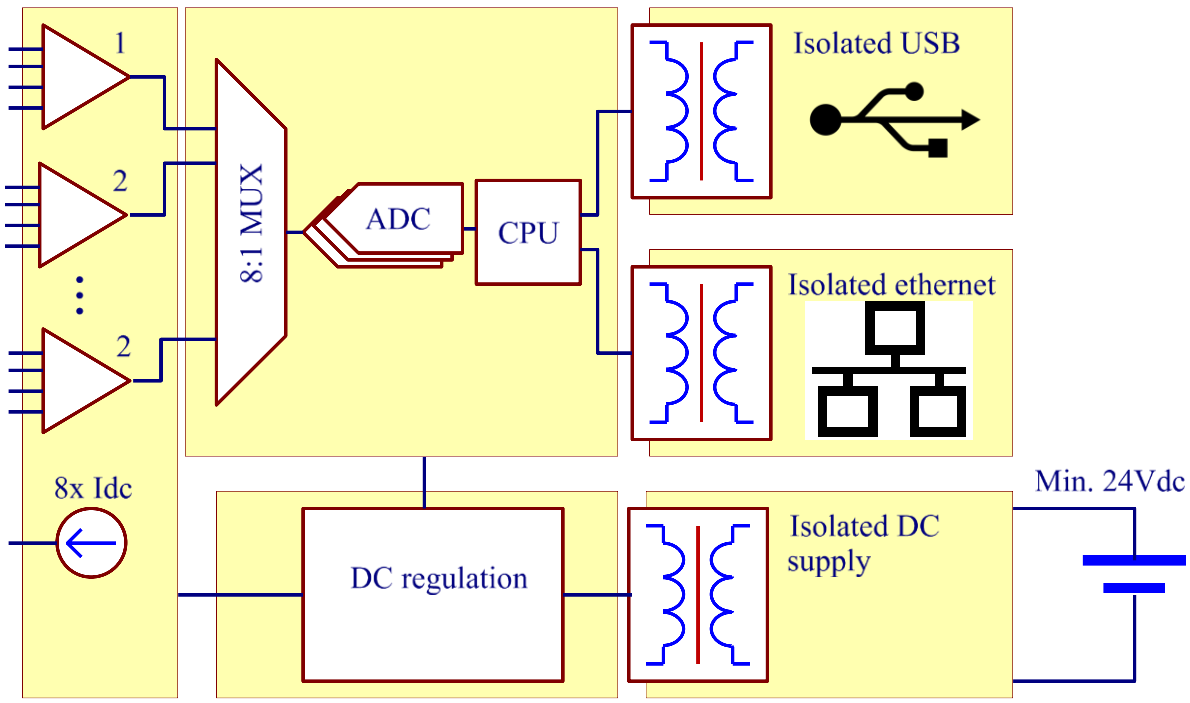


Figure 2 simplified block diagram of the MDAQ8 data acquisition system

Measurement channel characteristics

MDAQ8 has three separate differential analogue to digital converters as presented in the Figure 3. These ADC are common for all measurement channels and the channel to be measured is selected with 8/1 multiplexers. Due to this setup the actual sampling frequency on each measurement channel depends on the amount of simultaneously utilized channels. For example if the sampling frequency of the MDAQ8 is set to 800Hz and four channels are measuring simultaneously then the sampling frequency on each channel equals to 200Hz. A clear benefit on this three ADC approach is a possibility to perform three measurements in one channel simultaneously. For example one ADC can be measuring voltage in the input terminal H while another ADC is measuring voltage in the terminal L and the third ADC is measuring current flowing into the terminal C.

In sensitive measurements an interference from power supply network frequency is a significant source of error. MDAQ8 includes filtering for 50Hz common mode interference. This is operational on 6Hz and 50Hz sampling frequencies. On the 6Hz sampling frequency MDAQ utilizes the ADC inbuilt notch filter and on 50Hz sampling frequency an oversampling and average calculation technique.

MDAQ8 data acquisition system includes eight measurement channels which all consist of five terminals presented in the Figure 3 and in the Table 1.

Ground (G)

Terminal G provides a common ground point for all terminals in the measurement channel. Because the MDAQ8 measurement channels are isolated from the power supply network, this terminal is not in the same potential than the ground power supply networks neutral wire or protective earth wire. Furthermore, all eight measurement channels in the MDAQ8 share the same ground potential because channels are not isolated from each other. This has to be taken into account when sensors are physically separated on different places. (See chapter Measurement connections to minimize ground current and coupled common mode errors).

Excitation (E)

Terminal E in each measurement channel provides an excitation current output. This terminal has two operating modes namely 1mA and 14V. In 1mA mode the terminal in question provides a constant 1mA output current up to 14V output voltage. In 14V mode this terminal provides approximately 14V voltage. Output current is limited to 30mA per channel.

Voltage input (H, L)

Input voltage terminals H (High) and L (Low) have a similar topology. Input impedance of these terminals can be selected to be high impedance (High Z corresponding to approximately 1GΩ) or 10 MΩ between voltage terminal in question and ground. Each voltage terminal includes a gain stage, which has three hardware defined gains, 0.1, 1 and 10. These gain setting also define three measurement ranges ±14V, ±2.5V and ±250mV respectively.

Current / Common (C)

Terminal C provides an input for current measurements. Input impedance between this terminal and ground terminal is 50Ω. The maximum current that can be measured by the MDAQ8 is 50mA. Higher currents will saturate the current measurement circuitry and produce incorrect results. The maximum input current into terminal C is 200mA, higher currents cause a PTC resettable fuse to break the circuit. The PTC resettable fuse returns to its low resistance mode when the current through the fuse is removed and the fuse is allowed to cool down.

Table 1 Measurement channel terminals

Input	Description	Parameters
E	Voltage / constant current output	1mA/30mA max. 14V
H	Voltage input	Selectable High Z or 10MΩ input impedance
L	Voltage input	High Z or 10MΩ input impedance
C	Current input	50ohm input 50mA maximum measureable current. 200mA maximum input current
G	Measurement ground	

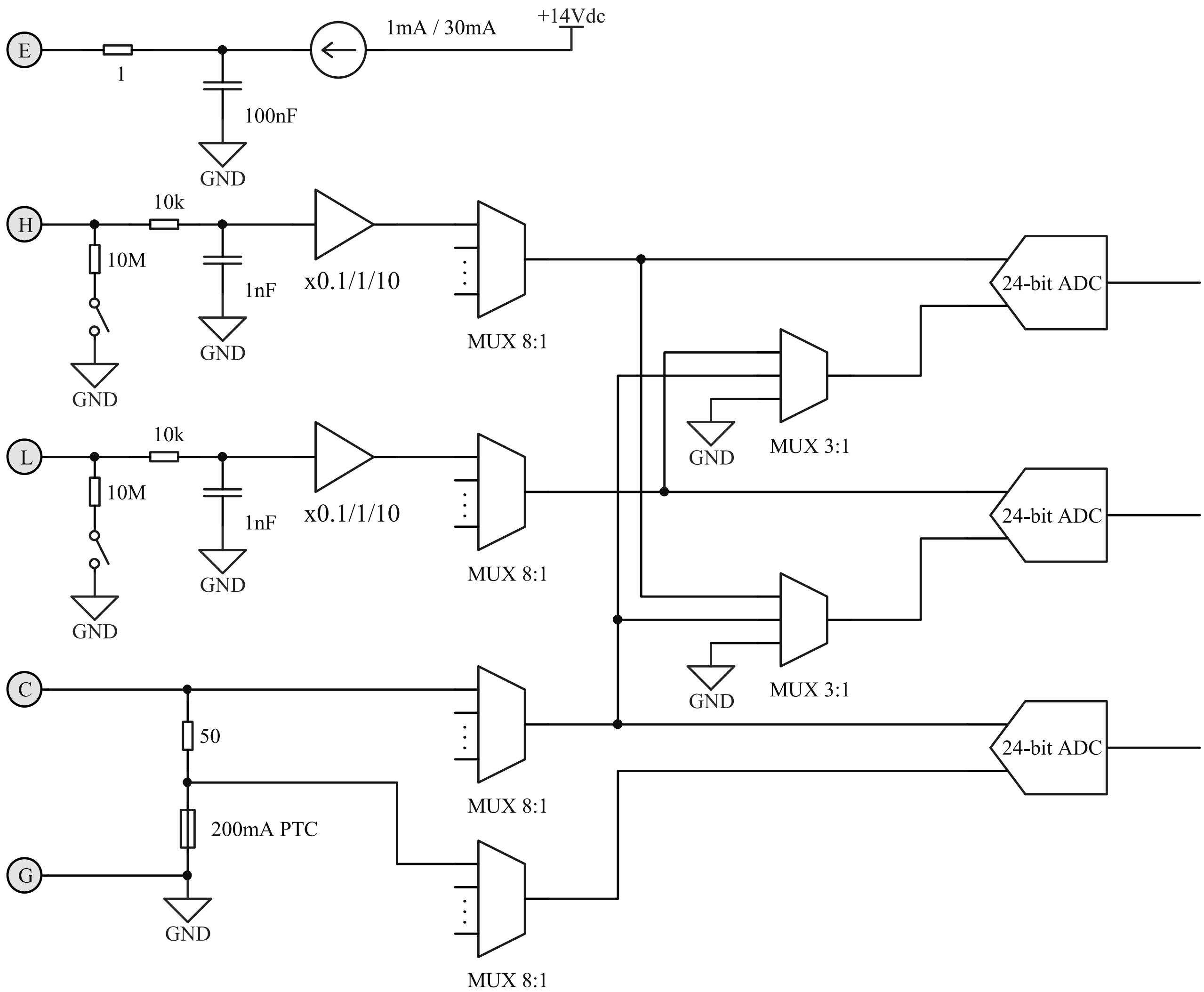


Figure 3 Block diagram of the MDAQ input stages.

Measurement connections to minimize ground current and coupled common mode errors

MDAQ8 is a high quality data acquisition system, in which special attention is paid on measurement accuracy and low noise. In order to exploit the full potential of the measurement system, the measurement connections has to be designed carefully.

Differential or single-ended measurement

Single-ended measurement is made against ground or other potential common to source and the measurement instrument. Differential measurement measures source differential regardless of the common mode or ground potential differences between the source and the measurement instrument.

In most cases differential measurement is more accurate. Symmetric input stage is designed to cancel out unwanted common mode noise. High input impedance prevents any currents from flowing in the signal wires thus preventing wire impedance from affecting the measurement. In differential measurement measured signal is connected between terminals H and L. Differential mode measurements generally require three wires. Two for signals and one for signal ground G.

Single-ended measurement requires two signal wires, but especially ground balancing currents may result significant errors to the measurement.

With MDAQ8 data acquisition system it is possible to measure one or two single-ended voltages sources simultaneously with one measurement device measurement channel as presented on the right side in the Figure 5

Grounding of measurement circuitry

One of the most critical aspects in the measurement circuit topology is grounding, especially if there is a difference in the ground potential between the location of the MDAQ8 and the location of the sensors. As a simple rule of the thumb the user should prevent ground currents from flowing in measurement signal wires.

A few different measurement situations can be recognized in all voltage measurements to be performed with the MDAQ8. In the following paragraphs these situations are explained with voltage source measurement setup.

Floating voltage source

If the voltage source is floating, i.e. there is no coupling to ground, then both single-ended and differential measurements can be used. Floating source does not cause ground current errors even if single-ended measurement is used.

Even if the source is floating, it has some capacitive, inductive and resistive coupling to its surroundings. Even though measurement channels in the MDAQ8 are isolated from the power supply network ground, it is very likely that the ground of the MDAQ8 device (GND) is coupled to a potential which is different from the GND1. Voltage difference between GND and GND1 is marked with Vdiff, in Figure 5 and in Figure 5 which present capacitive coupling.

Differential measurement will decrease unwanted coupled noise. In differential floating measurement it is important to set the voltage terminals of the MDAQ8 into 10MΩ mode. These resistors are required for the biasing of the input amplifiers.

In the case differential measurement is used, even a very small coupled current will create large common mode voltage which may saturate the input amplifier. This happens because input amplifiers have very high input impedance. Saturation or excessive common mode signal can be prevented by connecting the source to instrument ground potential as presented in Figure 6. In some cases ground contact to the the surroundings of the source will do the same. This is presented as dotted line in Figure 4.

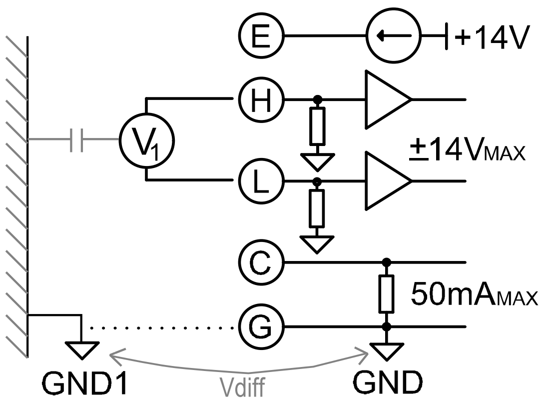


Figure 4 Differential measurement setup for a voltage source 10MΩ Input resistors connected

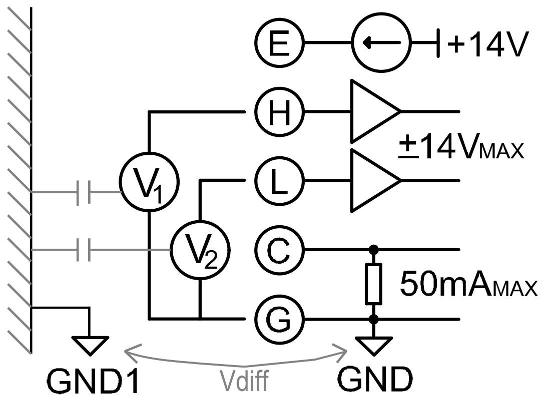


Figure 5 Simultaneous measurement of two single-ended floating voltage sources.

Ground connection can be omitted where the coupled signal is small.

Source coupled to ground potential

When the source is galvanically connected to the ground potential, the attention has to be paid on ground potential balancing currents I_B.

Figure 7 presents a single-ended measurement and Figure 8 a differential measurement. Ground current I_B will cause errors in single-ended measurement. Single-ended measurement with grounded source should not be used where good accuracy is needed.

Ground current errors are avoided with differential arrangement. It is necessary to connect ground potentials together to prevent input stage saturation. This is presented in Figure 8. The use of input resistors is no longer necessary, since input bias current can flow through the ground connections.

Because all the measurement channels of the MDAQ8 share a common ground, grounding of only one channel to measured target is required.

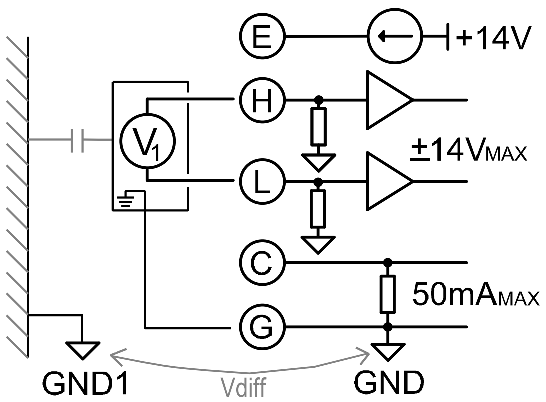


Figure 6 An improved grounding method for a floating source coupled to a ground potential different from the potential of the instrument.

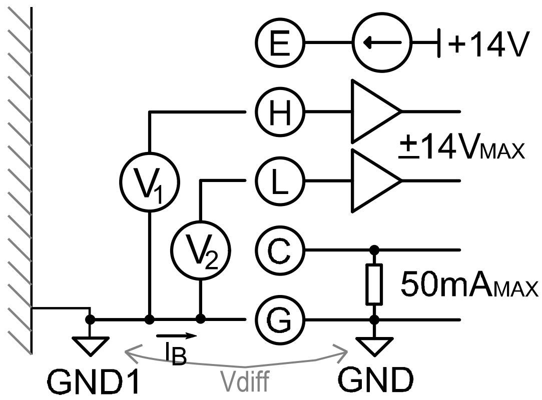


Figure 7 Effect of input bias current I_B in a single-ended measurement

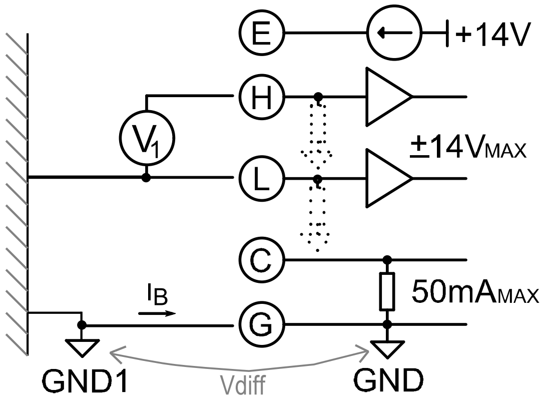


Figure 8 Effect of input bias current I_B in a differential measurements.

Exemplary measurement setups

MDAQ8 data acquisition system includes several predefined measurement setups and result handling algorithms, which ease the utilization of the system as well as measurement initialization. This section presents predefined measurement setups and discusses their utilization.

Current source with internal supply

MDAQ8 is able to measure current produced by a sensor or by another device. If the sensor or a device to be measured is powered by its own power supply then the current source is connected between MDAQ8's terminals C and G as presented in the Figure 9. In this measurement the measurement channel of the MDAQ8 is configured to be in a current mode with the excitation current output disabled. The maximum current MDAQ8 is able to measure is 50mA. Current flowing into the terminal C is converted into a voltage in a 50Ω measurement resistor, which causes at maximum a 2.5V voltage drop in the signal. Therefore the current source to be measured has to be able to drive its output at least to this voltage. This measurement mode is well suited for example for connecting sensors with standardized current output to the MDAQ8.

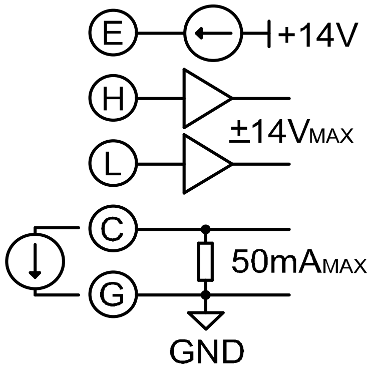


Figure 9 Current source measurement

Current source with external supply

If the current source to be measured does not have a power supply of its own, then the sensors or a device in question can be powered from MDAQ8's excitation output E. In this measurement setup the sensor or device is connected between MDAQ8's terminals E and C as presented in the Figure 10. The measurement channel to be utilized for the measurement has to be set into current mode and the excitation output into 14V mode. In the 14V mode the excitation output's maximum current is limited to 30mA, which limits the maximum current external device can draw from the MDAQ8.

Resistive temperature detector (RTD) 2, 3 and 4 wire setup

MDAQ8 input can be configured to measure resistive temperature detectors (RTD) with 2-, 3- or 4-wire measurement setup as presented in Figure 11, Figure 12 and Figure 13 respectively. Temperature sensor is driven with constant 1mA current source. Sensor voltage, voltage drop in wires and the bias current are measured. Correct sensor type should be selected from the drop down list in the IPlotter program.

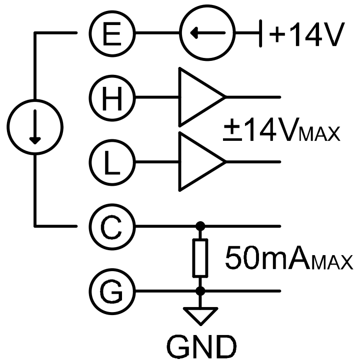


Figure 10 Current source measurement powered from MDAQ8 excitation output

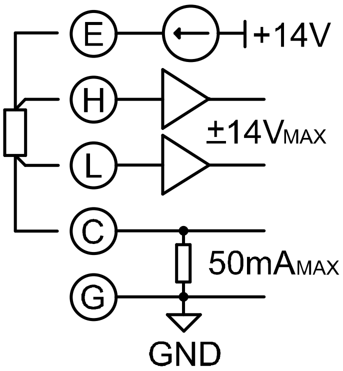


Figure 11 A 4-wire RTD measurement setup

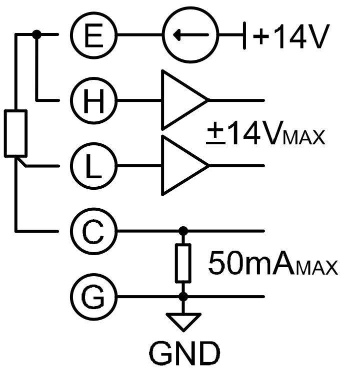


Figure 12 A 3-wire RTD measurement setup

The 4-wire configuration assumes sensor with Kelvin connection at the sensor end. Bias current flows in another pair of wires and the voltage measurement of the RTD is made with another pair of wires. This way the wire resistance is eliminated from the result and long leads can be used with good accuracy.

In 3-wire measurement voltage drop in the sensor wire between L and C as well as the voltage between H and L are measured. It is assumed that the wire resistance both side of the sensor is the same. When so, accurate voltage across RTD is found by subtracting wire voltage drop L-C from the voltage measured between H and L.

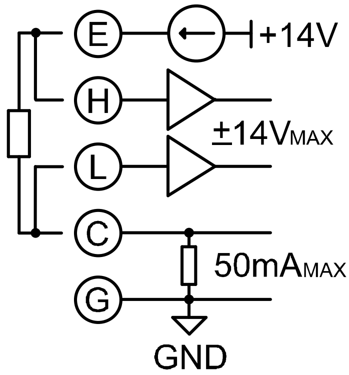


Figure 13 A 2-wire RTD measurement setup.

Terminals E and H terminals should be connected together at the MDAQ8 terminal when 3-wire measurement is used. 2-wire measurement does not measure wire impedance at all. Therefore short measurement wires should be used and/or measurement mode used only in applications where accuracy requirements are less stringent.

When RTD measurement is selected, output signal of the MDAQ8 is degrees of Celsius. For other type of RTDs the measurement channel has to be configured into differential voltage measurement mode with 1mA constant excitation output from terminal E and conversion from the measured voltage to temperature has to be implemented by the user.

Thermocouple sensors

MDAQ8 data acquisition system is able to measure one or two thermocouples simultaneously in one measurement channel. Differential measurement setup for one thermocouple sensor is presented on the left in Figure 14 and single ended measurement setup for two thermocouples in Figure 15. Differential measurement requires input resistors enabled for a path for input bias currents. When measured against ground potential, High-Z mode can be used.

Voltage signal from the thermocouples is very small. Typically around 40µV/°C (K-type). Wire resistance is also much higher than in copper wires. Therefore it is especially important to prevent ground currents to flow in the thermocouple sensor wire. Ground referenced or single-ended mode should be used only for floating sensors.

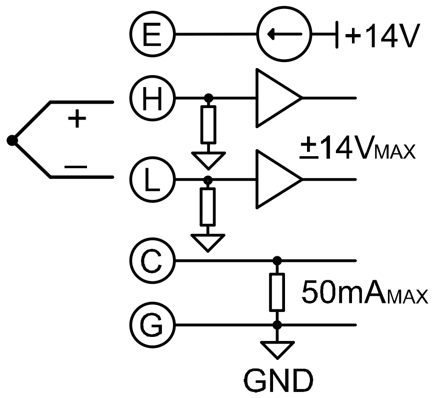


Figure 14 Differential thermocouple measurement setup.

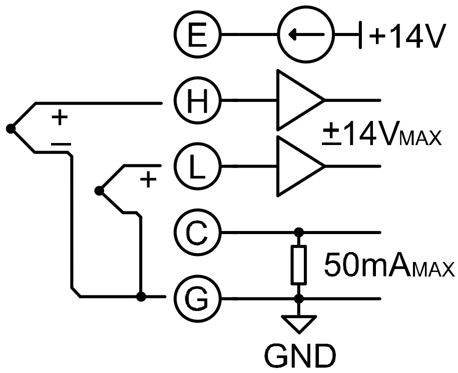


Figure 15 Two thermocouple sensors measured simultaneously on single measurement channel.

Thermocouple measurement requires always knowledge of the temperature in the so called cold junction of the measurement setup. In the MDAQ8 system this cold junction is between the thermocouples wires and the metallization of the connectors in the terminals into which the thermocouple is connected. Temperature of the cold junction is measured with the temperature sensors located on the MDAQ8 circuit board and utilized in temperature calculation. There are three cold junction compensation sensors along the terminal strip. Multiple sensors are used to compensate temperature differences in the MDAQ8 PCB. Cold junction compensation sensors have absolute accuracy of 0.4°C within the board operating temperature range with 16-bit resolution.

Temperature calculation is performed in the MDAQ8 processors and the system includes predefined parameters for several different types of thermocouples. Predefined thermocouples are presented in Table 2.

Thermocouple measurement is initialized by setting the MDAQ8's measurement channel into thermocouple measurement mode and by selecting an appropriate thermocouple setting according to utilized thermocouple.

Table 2 Properties of thermocouples inbuilt into the MDAQ8

Thermocouple type	**Measurement range °C**		**Standard color**		**Materials**
	Continuous	**Short term**	**IEC - Europe**	**ANSI - US**	
E	0 – +800	-180 - +900	positive: purple negative: white	positive: purple negative: red	positive: Chromel[1] negative: Constantan[2]
J	0 - +750	-180 - +800	positive: black negative: white	positive: white negative: red	positive: Iron negative: Constantan[2]
K	0 - +1100	-180 – +1300	positive: green negative: white	positive: yellow negative: red	positive: Chromel[1] negative: Aluminum
N	0 - +1100	-270 – +1300	positive: pink negative: white	positive: orange negative: red	positive: Nicrosil[3] negative: Nisil[4]

Thermocouple type	Measurement range °C Continuous	Short term	Standard color IEC - Europe	ANSI - US	Materials
T	-185 - +300	-250 – 400	positive: brown negative: white	positive: blue negative: red	positive: Copper negative: Constantan[2]
B	+200 - +1700	0 - +1820	positive: grey negative: white	positive: grey negative: red	positive: 30% Platinum, Rhodium negative: 6% Platinum, Rhodium
R	0 - +1600	-50 - + 1700	positive: orange negative: white	positive: black negative: red	positive: 13% Platinum, Rhodium negative: Platinum
S	0 - +1600	-50 - +1750	positive: orange negative: white	positive: black negative: red	positive: 10% Platinum, Rhodium negative: Platinum

[1]Chromel = alloy of nickel and chromium
[2]Constantan = alloy of nickel and copper
[3]Nicrosil = alloy of chromium silicon and magnesium
[4]Nisil = alloy of nickel and silicon

Powering sensors from MDAQ8

Sensors can be powered from the MDAQ8 excitation output E as long as its current consumption does not exceed 30mA and single +14Vdc voltage is sufficient. The measurement setup utilized in this mode is presented in the Figure 16. In this measurement differential measurement mode of the MDAQ8 has to be used in order to remove the voltage error caused by the supply current and resistance of the grounding wire. In other words, the reference potential of the output voltage has to be connected with a wire of its own to the L terminal of the MDAQ8. In this setup, supply current flows from the terminal E to the sensor and then from the sensor to terminal G. Output is connected between H and L.

In order to initiate this measurement setup MDAQ8's measurement channel is set to differential H-L voltage measure mode. Measurement range is selected according to the sensor parameters. Excitation output is set 14V mode, which sources up to 30mA of current to the sensor.

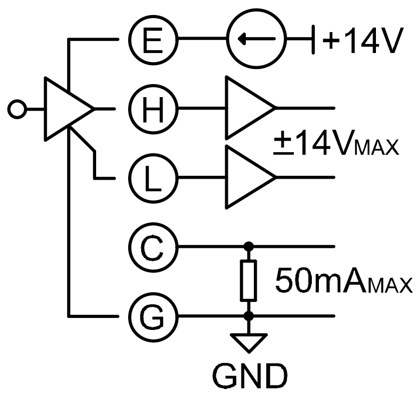


Figure 16 Measurement setup for voltage output sensor power from excitation output

IPlotter

MDAQ8 data acquisition system can be operated either with IPlotter software or with user's own data processing software or with a combination of both. IPlotter is a PC program developed by Icraft Oy. It has been utilized with several different measurement devices and includes also methods for configuring the measurement channels as well as displaying storing and processing measurement results obtained from the MDAQ8. An example of IPlotter's main window is presented in Figure 17 and the configuration window showing the configuration of the measurement channel eight is presented in Figure 18.

IPlotter provides an easy to approach graphical interface for the MDAQ8 system. Configuration of measurement channels can be done through device configuration window, presented in Figure 18, by just selecting appropriate settings with a mouse. As explained earlier in this document, MDAQ8 has several inbuilt measurement setups, such as different type of thermocouples or resistive temperature detectors. These configurations are also easily accessible through configuration window.

IPlotter software allows user to perform arithmetic and other signal handling operations for measured signals. At the moment these operations include: amplification, configurable FIR-filtering, thermocouple and PT100 voltage to temperature conversion, multiplication, division, addition, subtraction, down sampling, RMS calculation and mean (running average) filtering. These operations are configured with an xml (Extensible Markup Language) script. This approach makes it relatively easy to implement different kind of arithmetic and filtering operations for measurement results. Furthermore, after a short practice and with a text editor supporting xml scripts (such as programmers notepad) writing of these so called filters is faster than creating of them with a graphical interface. An example of an xml filter calculating a running average of 100 values from MDAQ8's measurement channel 8 is presented in Figure 19.

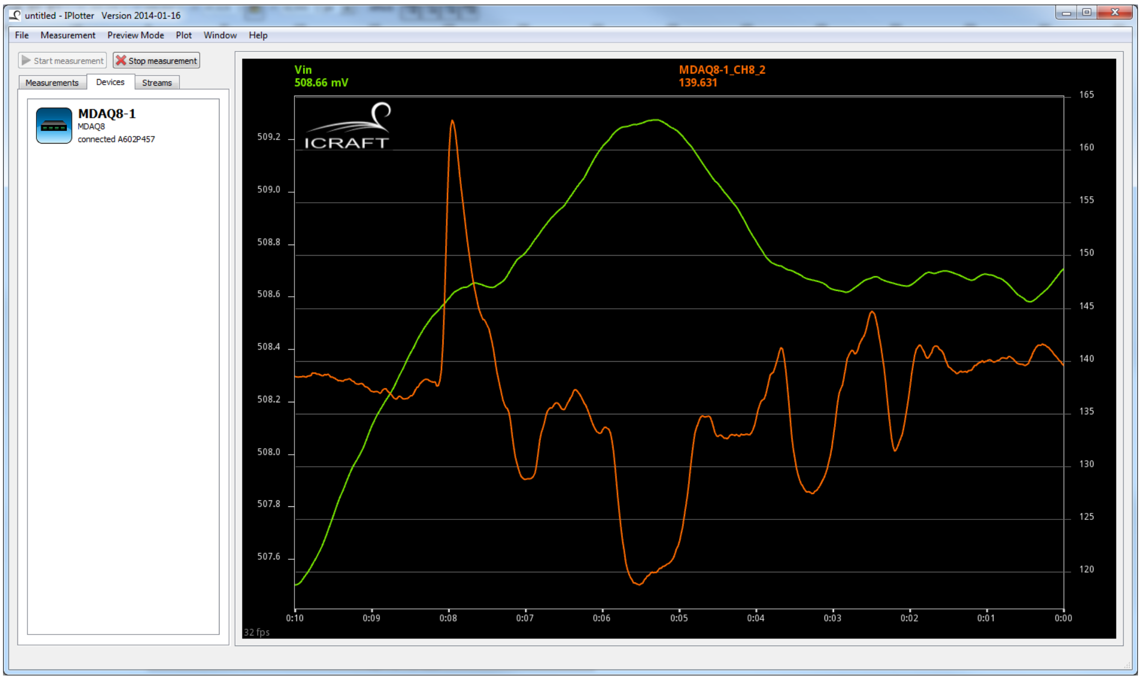


Figure 17Main window of the IPlotter computer program when connected to the MDAQ8 system.

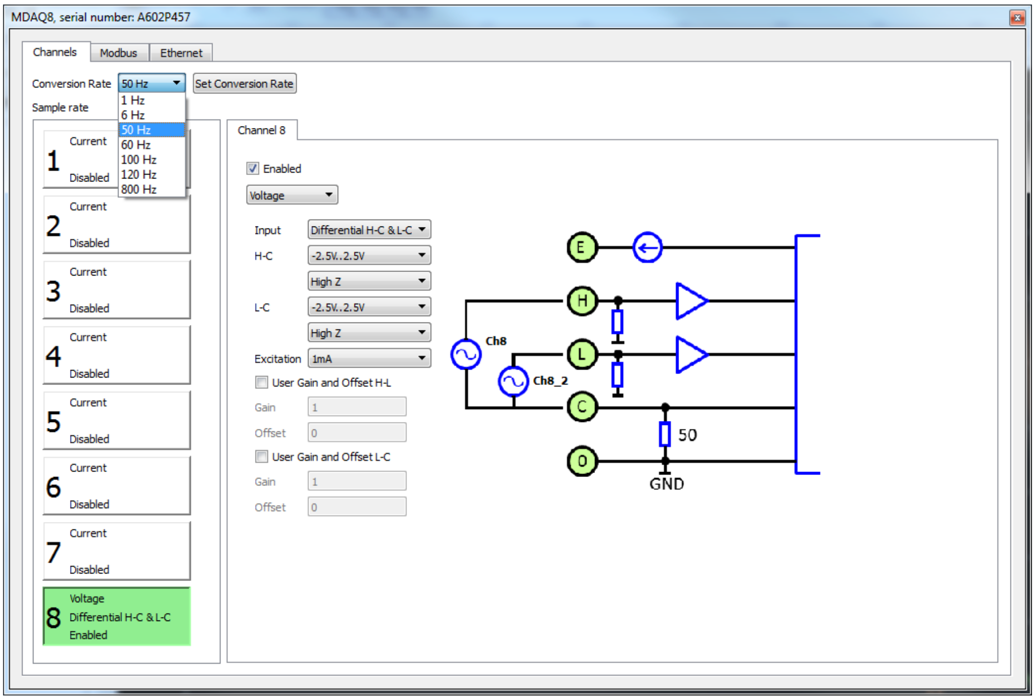


Figure 18 MDAQ8 configuration window in the IPlotter software

```xml
<?xml version="1.0" encoding="UTF-8"?>
<streams>
<stream name="Vin" preferredyaxis="1">
    <unit>mV</unit>
    <filter>
      <type>buffer</type>
      <input>MDAQ8-1.MDAQ8-1_CH8</input>
      <gain>1</gain>
    </filter>
    <filter>
        <type>mean</type>
        <length>100</length>
        <input>prev</input>
    </filter>
    <PlottedByDefault>false</PlottedByDefault>
</stream>
</streams>
```

Figure 19 XML script for calculating a runing average of 100 samples.

Contact information

http://www.icraft.fi/index.html

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33100 Tampere