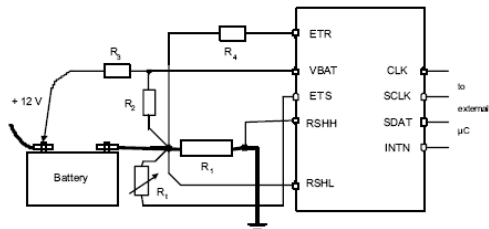


For application examples visit

<http://www.isabellenhuetten.de/index3.htm>

11. typical applications

11.1 Automotive Battery management



For an effective battery management the external μC must perform intensive calculation using a realistic model of the battery. The basis for these calculations is the knowledge of the battery current, voltage and temperature. For current detection a $100\ \mu\Omega$ precision resistor (R_1) is connected in the cable between the battery minus terminal and the central ground (chassis) connection. The increase of the overall resistance of the cable should be less than $120\ \mu\Omega$. To eliminate noise pick up the connections between the sense terminals and the ASIC inputs must be as short as possible and very narrow strip lines or twisted cables. The optimum solution is to mount ASIC and resistor in one package.

For such very low resistance values it is very important to use an precision resistance material (i.e. Manganin or Zeranin), since small thermal EMFs, which may be produced in the connections between different materials, can result in a totally wrong measurement and a high offset. If the well-known Constantan (CuNi 44) is used a temperature difference for only $2,5\ ^\circ\text{C}$ will produce an offset-voltage of $100\ \mu\text{V}$ pretending a current of $1\ \text{A}$!! (see also 10.2)

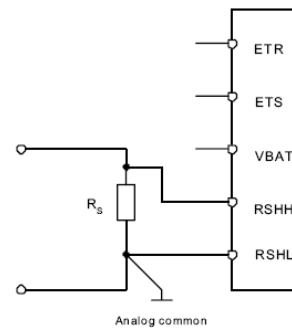
In the shown arrangement the ASIC can measure the starter current of the battery, the charging and discharging current during normal operation as well as the idle current in the stand-by mode of the car.

The battery voltage is measured over the voltage divider R_3/R_2 . The low impedance of R_2 does not supply any additional resistance noise.

The battery temperature in this example is measured with a Pt100 resistor (RTD-sensor). The sensing current is supplied by the ASIC itself. The metal film resistor R_4 is used as a reference resistor to eliminate the tolerance, drift and the TC-value of the internal current source. If both voltages ETS and ETR are measured with the same current and gain settings very shortly after one another than the ratio ETS/ETR is free of any drift, TC and gain error and proportional to R_4/R_0 , which exactly defines the temperature acc. to IEC 751.

For the determination of the dynamic internal resistance of the battery during the starting cycle a special fast double mode can be used i.e. the data of battery voltage and current are measured simultaneously.

11.2 precision bipolar A/mA/ μA -meter



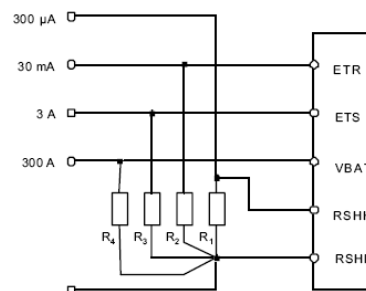
This schematic shows a simple circuit for a precision bipolar A-meter with extremely low voltage drop ($30\ \text{mV}$ max) over the sense resistor. It is very important that the analog common line of the ASIC is directly connected on the low side sense connection of the four terminal sense resistor. R_s should be a high quality metal film for $R > 1\ \text{Ohm}$ or a metal foil resistor for lower values (ISA-PLAN) with high stability and low TC-value. The absolute value can be calibrated together with the gain of the input amplifier and the correction value stored in the internal Zener-Zap memory.

To avoid noise pick up the sense connector cables should be as short as possible and twisted.

sense resistor value	current range	resolution*
$100\ \mu\Omega$	$\pm 300\ \text{A}$	$10\ \text{mA}$
$1\ \text{m}\Omega$	$\pm 30\ \text{A}$	$1\ \text{mA}$
$10\ \text{m}\Omega$	$\pm 3\ \text{A}$	$0.1\ \text{mA}$
$100\ \text{m}\Omega$	$\pm 300\ \text{mA}$	$10\ \mu\text{A}$
$100\ \Omega$	$\pm 300\ \mu\text{A}$	$10\ \text{nA}$

*measured at 100 Hz sampling rate and gain 24

11.3 precision A-meter with different inputs

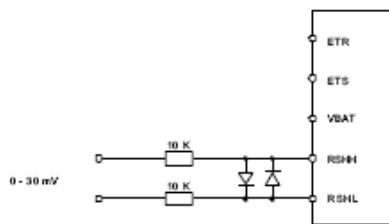


The circuit in 11.2 can be modified as shown into a system with four ground referring bipolar input ranges by just using all voltage inputs and separate sensing resistors with independent inputs and one common output.

The shown ranges are realised with:

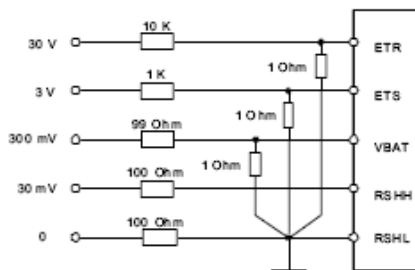
current range	sensing resistor
300 A	100 $\mu\Omega$
3 A	10 m Ω
30 mA	1 Ω
300 μ A	100 Ω

11.4 precision bipolar V/mV-meter



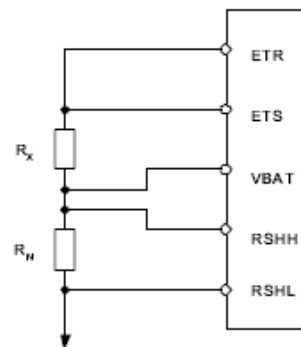
The ASIC can also act as a simple high precision mV-meter without any further external circuitry. For voltage measurements it may be wise in many applications to add an input protection as shown using two resistors and two anti-parallel diodes. The additional resistance noise of the 10 kOhm-resistor is still less than 1 μ V. For the shown measuring range of \pm 30 mV the diodes are absolutely closed and do not interfere with the measurement. Possible ranges are 7.5, 15 and 30 mV, the maximum resolution is 0.25 μ V. Limiting the bandwidth with external averaging to 1 Hz the RMS of the output noise voltage of the ASIC is less than 0.1 μ V.

11.5 multiple range bipolar V/mV –meter



Using all input ranges the ASIC can be expanded easily to a four channel V/mV-meter by adding suitable resistance voltage dividers to the inputs as shown in the schematic. Also here it will be wise to use a pair of diodes on each input for further protection.

11.6 high precision 4 1/2 digits true Ohm/mOhm-meter



$$I_{ETR} = 240 \mu A \quad I_{ETR} = 0 \mu A$$

$$U_x = ETS - VBAT \quad (\text{differential})$$

$$U_N = RSSH - RSSL \quad (\text{differential})$$

$$R_x = \frac{U_{x1} - U_{x0}}{U_{N1} - U_{N0}} \circ R_N \quad (\text{true Ohm, free of EMF})$$

The IHM-A-1500 can also be used as a stand alone high precision Ohm-meter. The device under test (R_x) and a precision reference are connected in series as shown in the schematic. The chip outputs a suitable current which produces a voltage drop over R_x and R_N . These voltages are measured in the differential mode at ETS-VBAT (U_x) resp. RSHH-RSHL ($=U_N$).

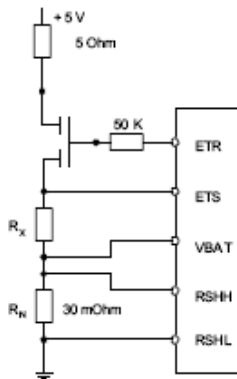
To eliminate any thermal EMFs which may be generated in the resistor or the circuit a second measurement is made with zero current. This delivers the true Ohm resistance value acc. to

$$R_x = \frac{U_{x1} - U_{x0}}{U_{N1} - U_{N0}} \circ R_N$$

with high accuracy which is limited only by the quality of R_N . Using a reference resistor of 120 Ω the measuring range is 0-300 Ω with a resolution of 10 m Ω . The measuring range increases to 30 kOhm with a $R_N = 10$ K Ω .

If the dual-mode is used to measure U_x and U_N simultaneously, it is possible to eliminate line included spurious voltages completely.

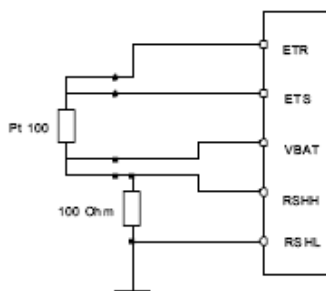
11.7 high precision true mOhm / μ Ohm-meter



To build a $m\Omega/\mu\Omega$ -meter a higher current has to be used. The schematic shows how the ASIC can drive an external power transistor to switch a current of the order of 1-10 A through R_x and R_N . Since the current is not constant in this simple arrangement due to varying lead resistances the dual channel measurement has to be used which measures both voltages very shortly after each other (i.e. 1 msec). The second measurement set with zero current eliminates also in this circuit the thermal EMFs allowing the determination of the true Ohm value exactly as in 11.6.

With the shown value of 30 $m\Omega$ for R_N the resistance measuring ranges are 7.5, 15, 30 and 120 $m\Omega$ and the resolution is better than 1 $\mu\Omega$!

11.8 precision 4-wire temperature measurement with RTDs



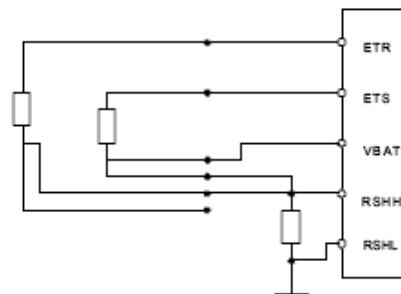
This simple circuit is stand alone a high precision four terminal temperature measurement system which eliminates nearly all possible errors and delivers a temperature which is accurate to within a few hundreds of a degree. The absolute accuracy is limited only by the RTD itself and the stability and TC-value of the reference resistor.

For the given resistance values the ASIC is programmed to deliver a current of 200 μ A on terminal ETR. Similar to the application 11.6 the voltage drop over the RTD and the 100 Ω reference resistor are measured followed by the same measurement without current. In this way all thermal EMFs and offsets are fully eliminated. Since both voltages are measured

in a four terminal configuration the cable length does not influence the measurement at all.

The system can be calibrated at 0°C (melting ice) by just measuring the temperature and adapting the value of the reference resistor in the software until the reading is 0.000 °C. This is allowed since the RTD calibration is based on the resistance ratio R_t/R_0 with R_0 being the value of the RTD at 0°C. The reference resistor is basically used to eliminate all errors of the current source and the absolute value of R_0 . Only its stability and low TC value are important. If the TC value is above 10 ppm/K and the ambient temperature of the circuit (reference resistor and ASIC) is varying in a wide range, it may be necessary for the highest accuracy to measure the TC value and store a correction value within the ASIC. In this case the tiny influence of the temperature on the reference resistance value can be eliminated in the external μ C with the result of the internal temperature measurement.

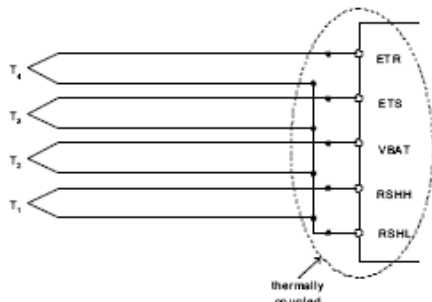
11.9 dual precision 3-wire temperature with RTDs



In this circuit two RTDs can be measured in parallel using the so called 3-wire technique. Both connection cables should be the same type and have the same length.

The influence of the cable resistance on the RTD resistance value cannot be neglected for high precision measurement and long cables. If for instance a cable resistance of 1 Ω is switched in series with a Pt100 this resistance is not subjected to the temperature to be measured thus acting basically as a constant error. A two terminal system would measure the total value and calculate a temperature which is higher by 2.5 K. The circuit in 11.8 eliminates this influence by a real 4 terminal measurement which senses the voltage at the resistor itself. In the three wire arrangement shown here the additional voltage drop on the cable is detected separately and subtracted in the μ C before the calculation of the temperature is done.

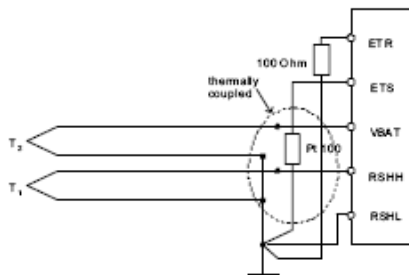
11.10 4-channel thermocouple temperature measurement



The ASIC is ideally suited for the application in temperature measuring systems with thermocouples as temperature sensors. The schematic shows how thermocouples can be directly connected to the four input channels. The internal temperature measurement can be used for the cold junction compensation. But care should be taken that the ASIC has the same temperature as the connection points between thermocouples and PC board. A sensor wire break test is readily available via the internal current sources.

In case there are more temperatures to be measured the ASIC can be paralleled easily by multiplexing the SCLK line. This solution for high precision thermocouple multiplexers has a number of advantages over existing solutions i.e. space consumption, flexibility and most important the overall costs.

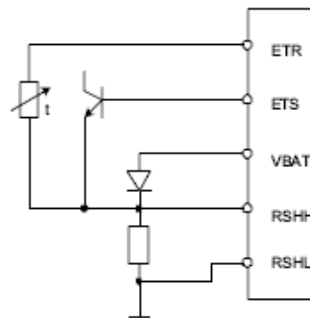
11.11 2-channel thermocouple temperature measurement with remote cold junction compensation



In applications where the thermal coupling of the ASIC and the input connector is not possible or for extremely high accuracy it may be necessary to detect the cold junction temperature with a separate temperature sensor (i.e. Pt 100). In this case two channels can be used for the thermocouple temperature measurement as already described in 11.10. Also here the expansion to more channels can be done easily with just adding another ASIC. If the connector block is of good heat conductivity it can include a number of connectors, which means that one RTD may be enough for all connectors. In this case every other ASIC supplies 4 additional measurement channels. A good thermal coupling between ASIC and connections can be achieved by a good design of the PC-board, a good thermal insulation to the outside world

(housing) or a special thermal coupling i.e. metal substrate or thermal conductivity grease or enamel.

11.12 multiple sensor temperature measurement



Due to the possibility to output a independent programmable current on each input the device is very flexible in the type of temperature sensors to be used. Instead of a Pt100 (see 11.8, 11.9) a PTC and NTC resistor or a semiconductor resistive device can be used. The sensor measures in fact the resistance ratio R_t/R_0 from which the μC can calculate the temperature according to the known temperature dependency $T(R)$. Due to the fact that the input voltage ranges up to 0.8 V also inexpensive diodes or transistors can be used as temperature sensors.

In this case the double current procedure may be used as follows:

Current-voltage dependence of a diode

$$I = I_0 \cdot e^{-\frac{eU}{kT}}$$

or for two current values I_1 and I_2

$$\ln \frac{I_2}{I_0} - \ln \frac{I_1}{I_0} = \ln \frac{I_2}{I_1} = -\frac{e}{kT} \cdot (U_2 - U_1)$$

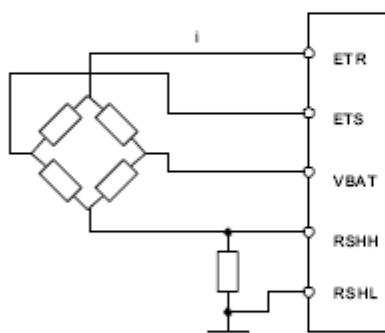
the current ratio is being detected as the voltage drop (V_R) over a suitable sensing resistor and the diode voltage is detected directly at the V_{BAT} output in this case.

From this the (absolute) temperature in Kelvin is derived as:

$$T = -\frac{e}{k} \cdot \frac{U_1 - U_0}{\ln \frac{V_{R1}}{V_{R0}}}$$

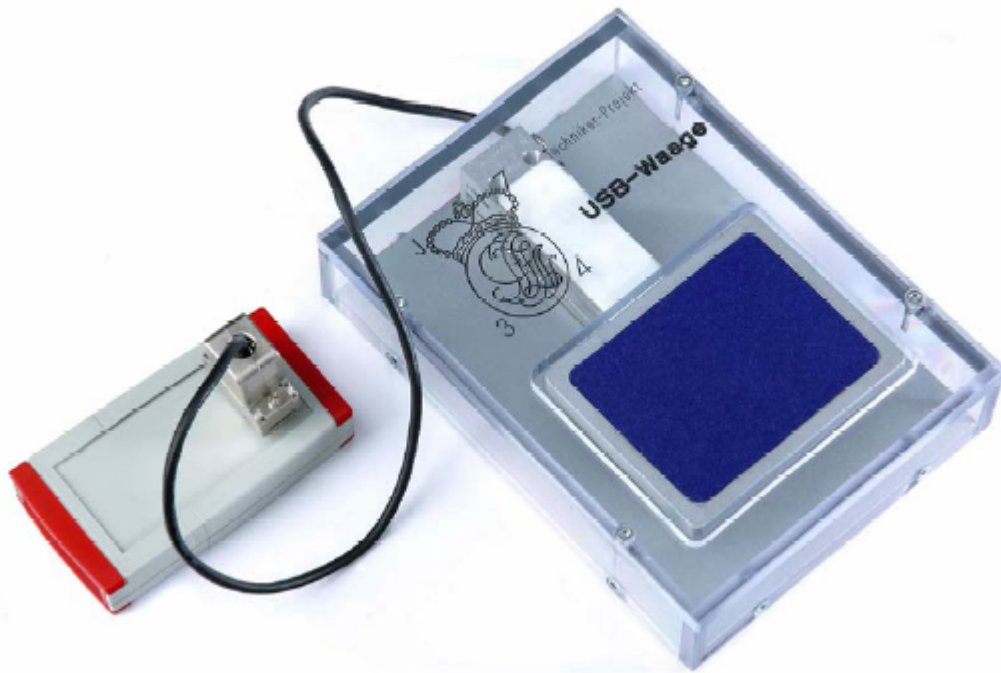
with a simple calibration at one temperature point (i.e. 0°C) this procedure can easily guarantee an accuracy of 1°C.

11.13 bridge measurement (pressure, strain gages)



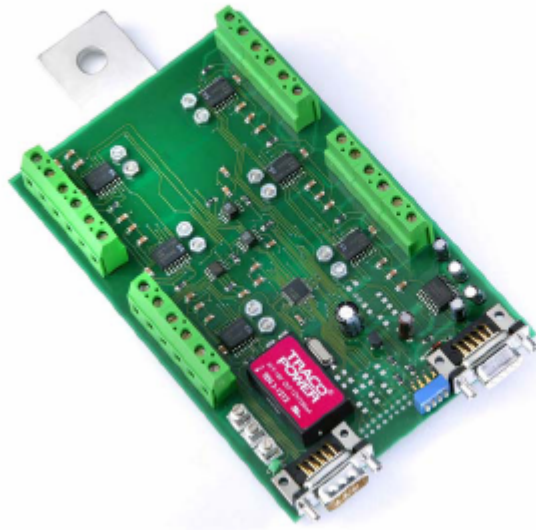
The bridge is activated by the internal current source over the terminal ETR. The differential voltage is measured between ETS and VBAT. If necessary the bridge current can be measured as shown between RSSH and RSHL. Since the bridge current can be varied in a wide range many different type of bridges up to 100 kOhms can be used. Even in this application the possibility of measuring with and without current under μC control a high precision measurement without any influence of thermal EMFs can be performed.

USB weight scale



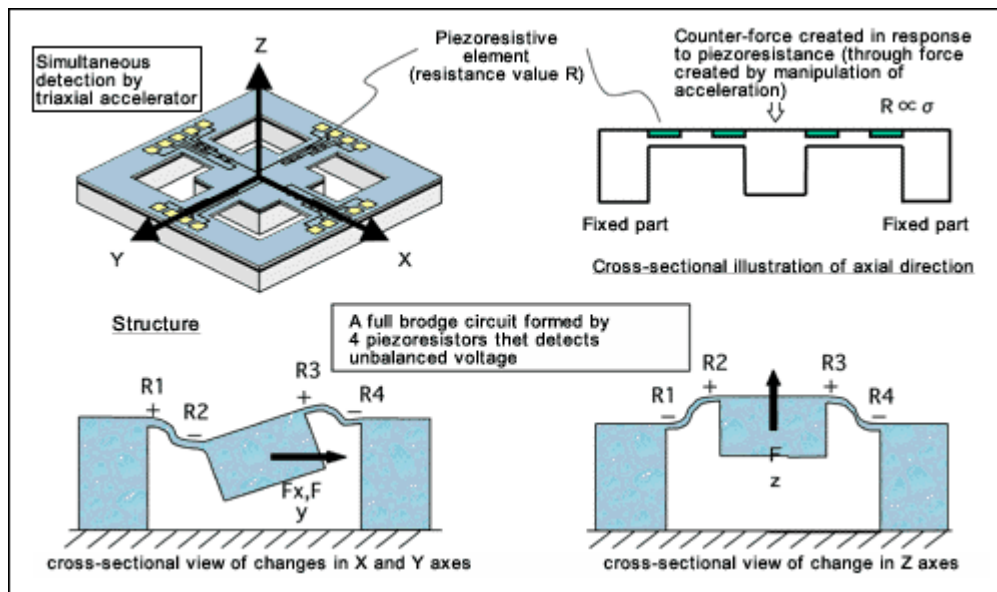
PCB-power supply with Ah-meter for drum electroplating

24 channel high side measurement



Ultra-high precision RTD- temperature measurement system with USB interface





3 axis accelerometer from Hitachi as an example for a MEMS sensor with piezo resistive bridge