Reference Design
High Voltage Intelligent Battery Shunt

LINKS TO ADDITIONAL RESOURCES

- HV-IBSS-USB reference design

DESCRIPTION

Vishay's HV-IBSS-USB reference design is designed to make evaluation of the WSBE8518 low TCR shunt easy. It uses a single USB-C connector to provide power to the circuit and to emulate a serial interface so the user can conveniently read voltage, current, and temperature readings.

Due to the low TCR of the WSBE8518 (max. ± 10 ppm/K for 100 μΩ), alongside the choice of low thermal drift components in the analog frontend, this reference design is able to achieve an overall TCR of approx. 44 ppm/K max., without thermal compensation, over the whole automotive temperature range. The device is factory-calibrated (values stored in onboard EEprom) to allow for current measurements with 0.2 % accuracy and thermal drift for currents in the range of ± 500 A [(1)].

In serial production and with statistical testing, it seems possible to get the total thermal drift down even further, since opposing thermal drifts in different components were observed during development.

During the development of this reference design it became clear that the main challenge has become finding low thermal drift analog parts, rather than compensating the resistive element.

Note

(1) Main contributor to accuracy originates from the calibration process, precision is higher and mainly limited by TCR

FEATURES

- Versatile
  - USB-C connections for power and data
  - With terminal emulation suited for a wide variety of operating systems
  - Easy to connect to busbar and lugs via M6 screws
- Precise / accurate
  - Factory two-point current calibration: < 0.2 %
  - Max. 10 ppm/K drift due to shunt
  - Approx. max. 34 ppm/K drift due to AFE and ADC

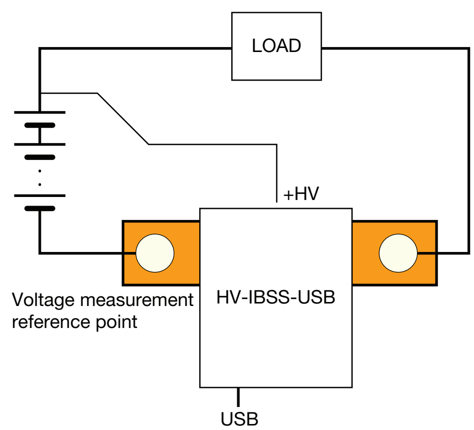
KEY COMPONENTS

- WSBE8518 100 μΩ
- CDMA2512 50 MΩ, 400:1

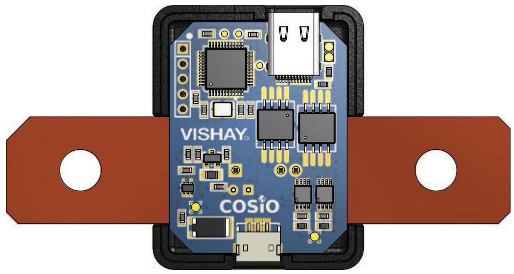
APPLICATIONS

- Industry and automation
- Home automation
- Industrial and server computing
- Networking, telecom, and base station power supplies
- Battery management systems
- EV test environment
- Solar installations

TYPICAL APPLICATION CIRCUIT



PIN CONFIGURATION



PIN DESCRIPTION		
PIN NUMBER	**SYMBOL**	**DESCRIPTION**
1	+	Marked with larger chamfer, connect to negative load terminal
2	-	Connect to negative battery terminal, current entering this terminal will be considered positive
3, 4, 5	HV+	Connect to positive battery terminal, only used for voltage measurement, referenced to battery terminal (Pin 2)
6 to 29	USB	USB interface used to supply power and transfer data, use external USB isolator for safety and if you exceed the safe range of the charge pump or isolators used

RECOMMENDED OPERATING RANGE			
PARAMETER	**MIN.**	**MAX.**	**UNIT**
HV + to +	10	850	V

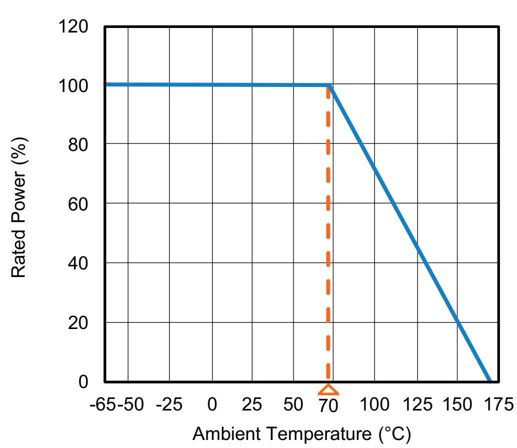
ABSOLUTE MAXIMUM RATINGS (T_A = 25 °C, unless otherwise noted)		
ELECTRICAL PARAMETER	**LIMITS**	**UNIT**
HV+ to +	± 1000	V
HV+, + and - to any USB pin [(1)]	-850 to +850	V
Measured current limits	± 500	A
Ambient temperature [(2)]	-40 to +75	°C
Storage temperature	-65 to +85	°C
Power dissipation max. power dissipation in shunt	36	W

Notes

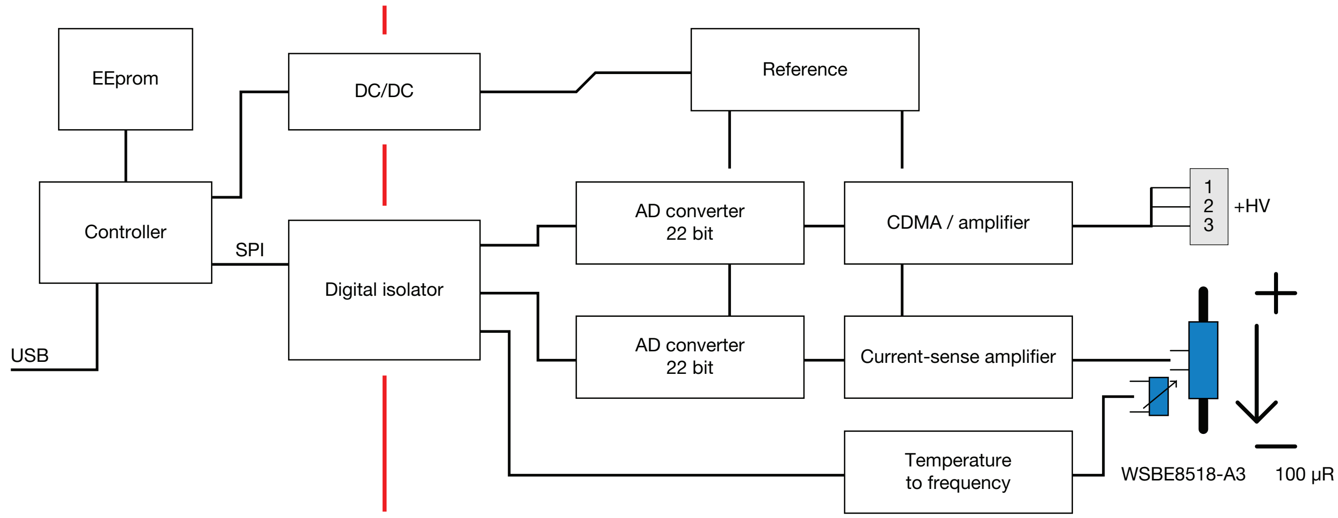
(1) Use of external USB isolator highly recommended, all high voltage safety precautions should be respected

(2) Derating of the shunt applies

DERATING



FUNCTIONAL BLOCK DIAGRAM



OPERATIONAL DESCRIPTION

Device Overview

The fundamental structure of this circuit comprises two domains: the high voltage domain (HV) and the low voltage domain (LV), which are isolated from each other.

In the low voltage domain, a microcontroller is attached to both the USB and SPI bus. The USB is used to both supply power as well as for data transfer. A charge pump is used to transfer power to the analog frontend and ADCs, which reside within the HV domain.

To make the most of the shunt's potential, the ADC and its frontend are chosen to maximize resolution (22-bit sigma-delta) while minimizing thermal drift, e.g. through automatic offset and gain calibration. Each function is described in more detail below.

Current Measurement

Due to the very low TCR value of the shunt, the bigger part of the drift is contributed to the analog circuity rather than to the shunt itself.

To match the drift of the shunt, special care has to be taken in component selection.

This reference design is based on a third-order delta-sigma modulator with automatic gain and offset error calibrations to minimize these errors over lifetime and temperature, as well as to offer the highest resolution possible.

For operation, the ADC is supplied by an external reference. A thermal drift in this reference (25 ppm/°C maximum) will directly translate to a drift of the measured values. The third component that influences the measurement is an operational amplifier that amplifies the small voltage drop over the shunt to the input range of the ADC.

Each amplifier has multiple error sources. While the gain error and offset voltage are removed by the two-point current calibration, the offset drift and gain error drift still affect the final measurement.

In this case the operational amplifier's gain drift is 7 ppm/K (maximum) and the offset drift is 80 nV/K (maximum). In relation to the measurement range of 50 mV, this is 1.6 ppm(FS)/K. Under the worst-case assumption that all drifts have the same sign, the max. drift can be approximated as 25 ppm/K + 7 ppm/K + 1.6 ppm/K, totalling to 33.6 ppm/K for the analog circuitry compared to 10 ppm/K for the shunt.

Just by comparing the drift of the voltage reference to the drift of Vishay's low TCR shunts, it becomes obvious that with this new technology the main contributor to thermal drift is not the resistive element but AFE / ADC.

The challenge for the electrical engineer is no longer to compensate for the TCR of the shunt, but to find analog components that support the low TCR of the shunt.

Voltage Measurement

Similar to the current measurement, a 22-bit sigma-delta ADC is utilized. The voltage between the HV+ port and the + port of the shunt is divided using a CDMA. This voltage is buffered and fed directly to the ADC. Since the CDMAs, divider ratio is chosen to match the ADC input range, no amplification is necessary. This eliminates the gain drift from the equation so that the main contributors to thermal drift in the voltage measurement are the tracking TCR of the voltage divider, the temperature-dependent offset voltage of the opamp / buffer, and the gain / offset error of the ADC.

Temperature Measurement

To visualize the temperature of the shunt, an NTC and multivibrator are used as a temperature to frequency converter. The PWM signal generated by the analog circuitry is transmitted over the isolation barrier and sensed by the MCU.

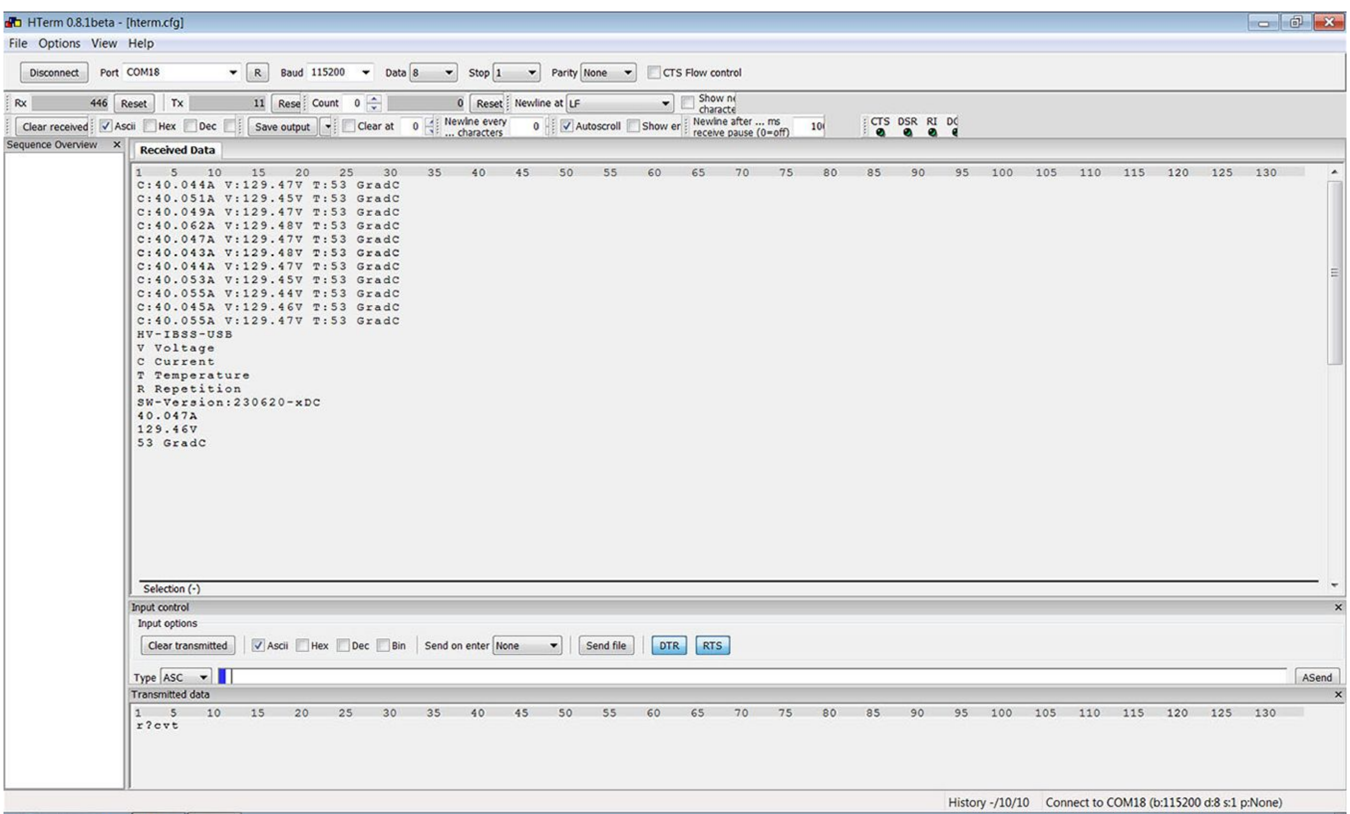
Serial Interface

The user can connect the USB cable to any computer they like. After connection to the computer, a USB to serial adapter should be automatically detected (listed as STMicroelectronics Virtual COM port). In case the driver is not automatically detected, try to manually install / use drivers provided by STM.

Once initialized by the system the user can access the virtual COM port with their terminal of choice, e.g. HTERM. Due to the nature of the virtual COM port, there is no specific baud rate setting required.

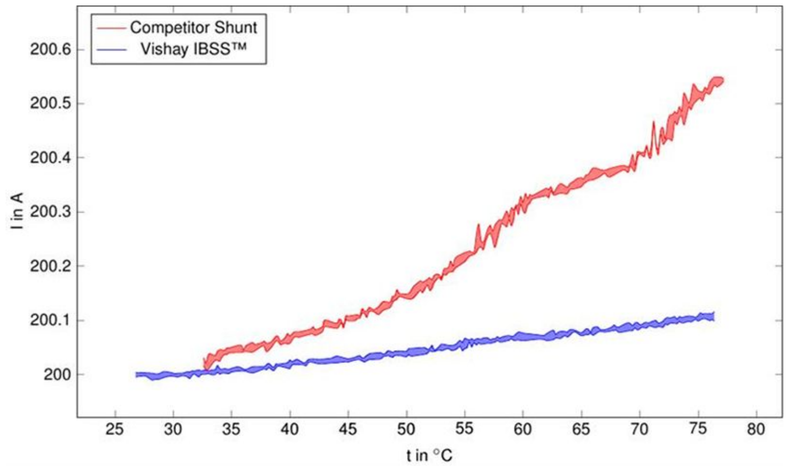
After initial connection to the COM port, the user will see a blank screen and can interact with the device using the following commands:

SERIAL INTERFACE			
CHARACTER	**FUNCTION**	**ACTION**	**RETURN VALUE**
C	Current	Display most recent current reading	e.g. 200.123 A
V	Voltage	Display most recent voltage reading	e.g. 500.12 V
T	Temperature	Display most recent temperature reading	e.g. 38 °C
R	Repeat	Display current / voltage and temp once per second until a new command is issued	
?	Help	Every unassigned character will display a help	

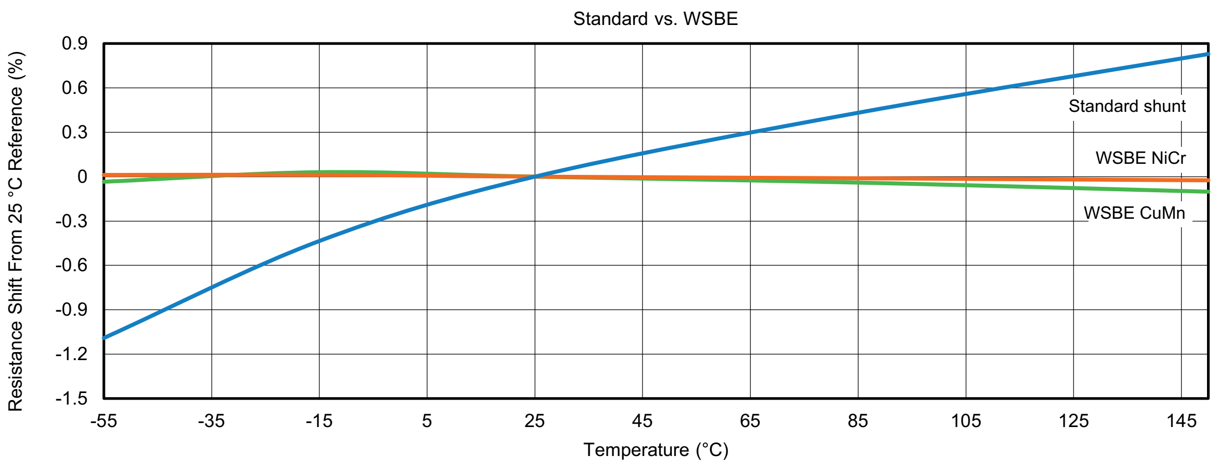


ELECTRICAL CHARACTERISTICS SYSTEM

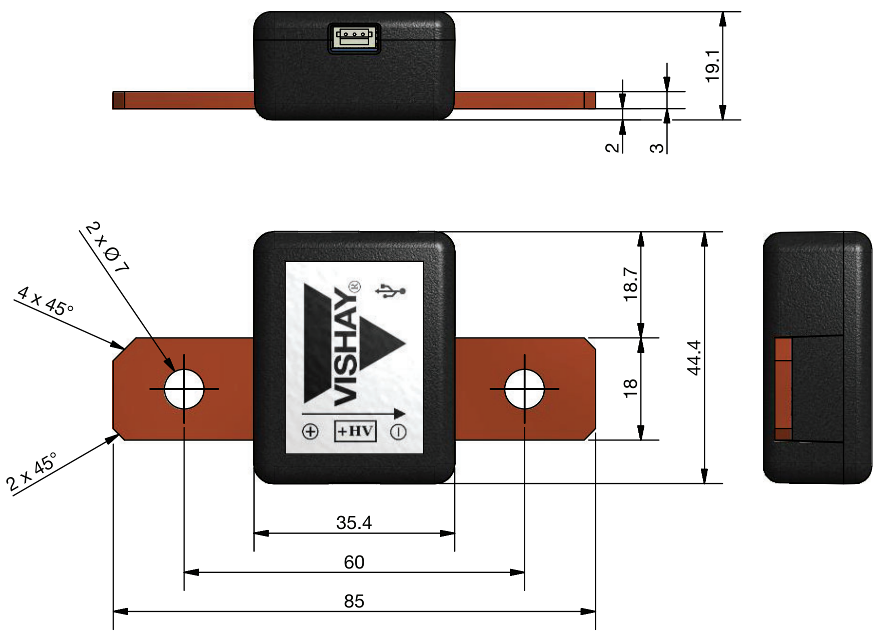
(V_{IN} USB = 5 V, I_{shunt} = 200 A, T_A = 27 °C, values measured on an abitrary unit unless otherwise noted)



ELECTRICAL CHARACTERISTICS SHUNT



DIMENSIONS



PACKAGE LIST OF THE REFERENCE KIT

1. HV-IBSS-USB reference design
2. USB-C to USB-A cable 0.6 m
3. HV-voltage Molex connector with open wires

ADDITIONAL RESOURCES

- Calculator: Change of Resistance Due to TCR Calculator www.vishay.com/resistors/change-resistance-due-to-rtc-calculator/
- Video: Power Metal Strip® Temperature Coefficient of Resistance www.vishay.com/videos/resistors/vishays-power-metal-strip-temperature-coefficient-of-resistance.html
- Overview: Power Metal Strip® Surface-Mount Current Sensing Resistors www.vishay.com/doc?49581

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