

1 Introduction

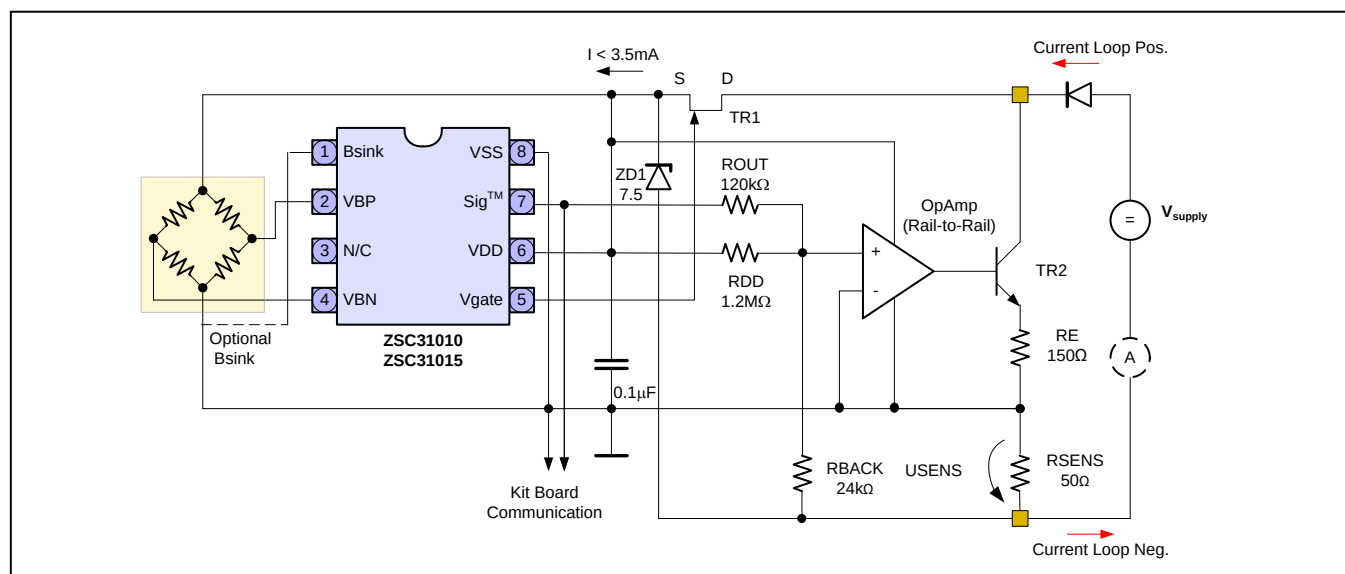
This document outlines the 4-to-20mA current loop output application for the ZSC31010/ZSC31015 SSC ICs, which are designed to interface with a resistor bridge sensor in a 3-wire sensor module. During normal operation, the Sig™/OUT pin outputs the corrected sensor reading as analog 5V ratiometric, 0 to 1V, or digital output. (During calibration/configuration, this pin acts as a bi-directional serial data channel.) The current loop output, a common robust analog output in industrial applications, was not originally supported by the ZSC31010/ZSC31015 as it is for the ZSC31050, which integrates a regulation loop that senses the actual current and regulates the output current to the calibrated target value.

Calibrating the ZSC31010/ZSC31015 for a current loop output application requires a different method of starting the Command Mode (CM) for communication. The command to enter CM must be sent within the command window, which is the first 5ms after power up for the ZSC31010 or the first 3ms for the ZSC31015. Meeting the command window requirements is especially complicated with a current loop application, particularly for the ZSC31015. The recommended method is to send the "Start CM" command before turning on the current loop voltage supply. This procedure is an exception to standard procedures: even if the absolute maximum ratings given in the data sheet are not observed, it will not harm the IC because there is no significant power consumption via the communication lines. If the master communicates via a push-pull stage, no pull-up resistor is needed; otherwise, a pull-up resistor with a value of at least 150 Ω must be connected.

2 ZSC31010/ZSC31015 with 4-to-20mA Current Loop Output

With additional external circuitry (see Figure 2.1), the calibrated voltage output signal can be transformed into a corresponding current loop output ranging from 4 to 20mA. To achieve high accuracy, an additional step is necessary to correct errors caused by the resistor tolerances of the external circuitry. The error of the analog output buffer, which is not included in the calibration path, can also be corrected.

Figure 2.1 – ZSC31010 with Current Loop Output Using ZACwire™ Communication



With the circuitry in Figure 2.1, the objective is to convert the 10% to 90% VDD output of the ZSC31010/ZSC31015 to a corresponding 4 to 20mA current loop output. To keep the output current small, RDD and ROUT must be chosen in the ratio $ROUT = RDD/10$ with RDD in the range of megohms. The resistor values are discussed in detail in section 3. For the op amp, a low power 5V rail-to-rail type must be used (e.g., OPA337). The Zener diode (7.5V) provides overvoltage protection for the VDD line. TR1 is an N-channel type JFET as recommended in the data sheets (e.g., BSS169 or DN3545). For TR2, an NPN transistor with a power consumption rated for the actual supply voltage must be selected (e.g. BCX56 or FZT651).

Important: The voltage supply and the amp meter of the current loop must be galvanically separated from the PC / Kit Board ground.

3 Current-Loop Calibration

The following special calibration procedures required for this application use the same calibration steps as for the voltage output mode but include an additional calibration step to change the target values $VOUT/VDD$ [%], (named Measure [%] in the software) in the calibration procedure to correct the errors.

Step1

Separately determine the additional error of the external circuitry and the back end with a two-point current measurement versus the DSP DAC control.

Step2

Use a formula with offset and gain errors to calculate the new target values “Measure [%].”

Step3

Use the new values in the ZSC31010/ZSC31015 calibration window and calculate the coefficients in the same way as for the voltage output mode.

The loop current is determined by the following transfer function for the current loop current $I_{CL}=f(V_{OUT})$.

$$I_{CL}=U_{SENS}/R_{SENS}=(R_{BACK}*V_{DD})/(100*R_{SENS}*R_{OUT}) * V_{OUT}/V_{DD} + R_{BACK}*V_{DD}/(R_{SENS}*R_{DD}) \quad \text{Equation 1}$$

With

$$Gain = (R_{BACK}*V_{DD})/(100*R_{SENS}*R_{OUT}) \quad \text{Equation 2.1}$$

$$Offset = R_{BACK}*V_{DD}/(R_{SENS}*R_{DD}) \quad \text{Equation 2.2}$$

The current can be calculated as

$$I_{CL}= Gain * V_{DAC}[\%] + Offset \quad \text{Equation 3}$$

The 11-bit (12-bit) output DAC of ZSC31010/ZSC31015 is controlled by the DSP and uses the normalized value.

$$V_{DAC} [dec]=ROUND(target\ value[\%]*2^{14},0) \quad \text{Equation 4.1}$$

The 4-digit hex code is calculated

$$XXYY = \text{DEC2HEX}(V_{DAC} [\text{dec}], 4) \quad \text{Equation 4}$$

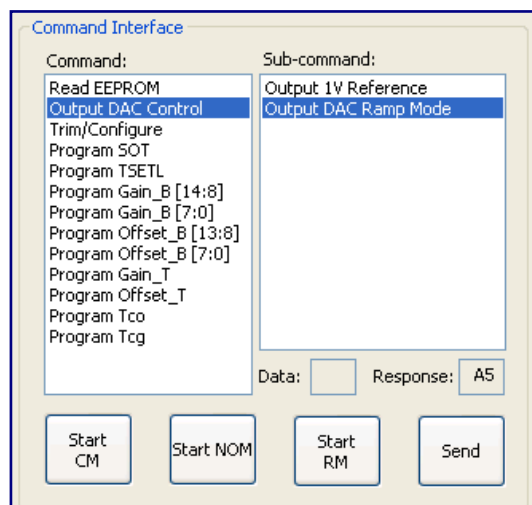
For example ($V_{DD}=5.000\text{V}$):

$$\text{For the target value of 10\%, } V_{OUT}/V_{DD} \rightarrow V_{DAC} = 1638_{\text{dec}} \rightarrow XXYY = 666_{\text{hex}}. \quad \text{Equation 5.1}$$

$$\text{For the target value of 90\%, } V_{OUT}/V_{DD} \rightarrow V_{DAC} = 14746_{\text{dec}} \rightarrow XXYY = 399A_{\text{hex}} \quad \text{Equation 5.2}$$

The DAC is controlled by writing the XXYY value in the Gain_B EEPROM bits <51:44> for the ZSC31010 or <31:17> for the ZSC31015. Offset_B must be set to 0x00. The output mode must be set to ratiometric, and the JFET regulation must be set to 5V. All other settings do not matter for this test. The necessary control command 0x205X (ZSC31010/ZSC31015) is sent by the Evaluation Kit software. Send the “Start CM” and connect the Vsupply.

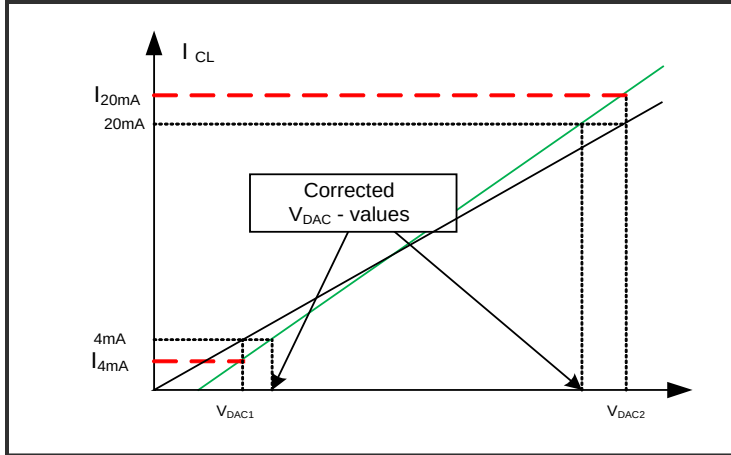
Figure 3.1 Sending the DAC Command



- Start Command Mode
- Program Gain_B [14:8] XX --> SEND
- Program Gain_B [7:0] YY --> SEND
- Program/Keep Offset_B 00 (step size 0)
- Output DAC Control --> Output DAC Ramp Mode
- Measure I_{CL}

Figure 3.2 illustrates the method for calculating these corrected target values. The blue line shows the ideal function described by equation 2. The green one is the error-line (with 2 current measurement points).

Figure 3.2 Line Correction



This transfer function for the measured currents I_{4mA} and I_{20mA} is given by

$$I_{xmA} = (Gain + \Delta Gain) * V_{out}/V_{DD} + (Offset + \Delta Offset) \quad \text{Equation 6}$$

With the selected resistor values (Figure 2.1), $R_{SENS}=50\Omega$, $R_{DD}=1.2M\Omega$, $R_{OUT}=120k\Omega$, $R_{BACK}=24k\Omega$, and the recommended IC supply voltage $V_{DD} = 5V$, $Gain = 0.2mA$, and $Offset = 2mA$.

The “error-free” target values

$$V_{out}/V_{DD} = (I_{CL\_min} - 2mA)/0.2mA = 10\% \text{ corresponds with } I_{CL\_min}=4mA \quad \text{Equation 7.1}$$

$$V_{out}/V_{DD} = (I_{CL\_max} - 2mA)/0.2mA = 90\% \text{ corresponds with } I_{CL\_max}=20mA \quad \text{Equation 7.2}$$

The offset and tolerances of the circuitry cause different values of I_{CL} when setting the DAC to these values. After the DAC has been set to the corresponding values (666_{hex} , $399A_{hex}$), the resulting currents I_{4mA} and I_{20mA} must be measured to determine the error values $\Delta Gain$ and $\Delta Offset$.

$$\Delta Gain = (I_{20mA} - I_{4mA})/(V_{DAC2} - V_{DAC1}) - Gain \quad \text{Equation 8.1}$$

$$\Delta Offset = I_{4mA} - (Gain + \Delta Gain) * V_{DAC1} - Offset \quad \text{Equation 8.2}$$

These equations can be used to re-calculate the target values:

$$V_{DAC\_4mA} = 4mA * (2mA + \Delta Offset)/(0.2mA + \Delta Gain) \quad \text{Equation 9.1}$$

$$V_{DAC\_20mA} = 20mA * (2mA + \Delta Offset)/(0.2mA + \Delta Gain) \quad \text{Equation 9.2}$$

This calculation can be done with Excel™ sheet *ZSC31010_ZSC31015 Current Loop Calibration.xls*. Software support is pending.

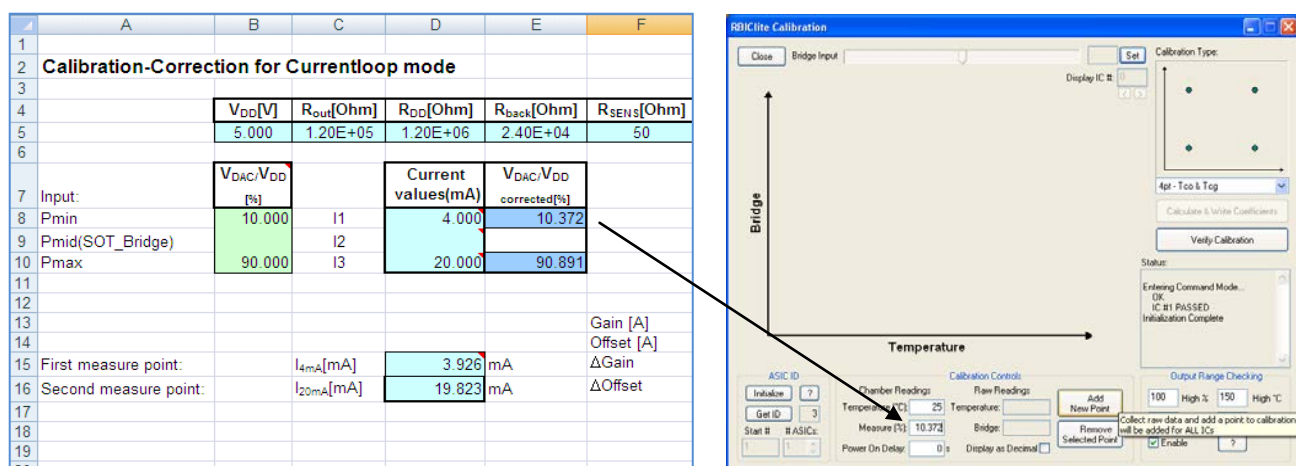
The Excel™ sheet also allows re-calculating the DAC control values in case different resistor values are selected.

4 Example

The measured currents $I_{CL4mA} = 3.926mA$ (for Gain_B=0x666 in DAC Ramp Mode) results in 10.327% instead of the original 10% and $I_{CL20mA} = 19.823mA$ (for Gain_B=0x399A in DAC Ramp Mode) results in 90.891% instead of the original 90%.

Using the common calibration window, the calculated value must now be used for calibration as shown in Figure 4.1.

Figure 4.1 Calibration with Corrected Target Values Measure[%]



5 Related Documents

Document
ZSC31010 RBiC _{Lite} ™ Data Sheet
ZSC31015 RBiC _{dLite} ™ Data Sheet

Visit www.IDT.com/ZSC31010 and www.IDT.com/ZSC31015 or contact your nearest sales office for the latest version of these documents.

6 Definitions of Acronyms

Term	Description
CM	Command Mode
DAC	Digital-to-Digital Converter
DSP	Digital Signal Processing
SSC	Sensor Signal Conditioner

7 Document Revision History

Revision.	Date	Description
1.0	January 8, 2009	First release
1.1	February 22, 2010	Revise command window period from 1.8ms to 3.0ms for the ZSC31015.
1.2	July 28, 2010	Revised product names from ZMD31010 to ZSC31010 and from ZMD31015 to ZSC31015.
1.21	March 2, 2011	Update for contact information.
	April 19, 2016	Changed to IDT branding.

Notice

1. Descriptions of circuits, software and other related information in this document are provided only to illustrate the operation of semiconductor products and application examples. You are fully responsible for the incorporation or any other use of the circuits, software, and information in the design of your product or system. Renesas Electronics disclaims any and all liability for any losses and damages incurred by you or third parties arising from the use of these circuits, software, or information.
2. Renesas Electronics hereby expressly disclaims any warranties against and liability for infringement or any other claims involving patents, copyrights, or other intellectual property rights of third parties, by or arising from the use of Renesas Electronics products or technical information described in this document, including but not limited to, the product data, drawings, charts, programs, algorithms, and application examples.
3. No license, express, implied or otherwise, is granted hereby under any patents, copyrights or other intellectual property rights of Renesas Electronics or others.
4. You shall be responsible for determining what licenses are required from any third parties, and obtaining such licenses for the lawful import, export, manufacture, sales, utilization, distribution or other disposal of any products incorporating Renesas Electronics products, if required.
5. You shall not alter, modify, copy, or reverse engineer any Renesas Electronics product, whether in whole or in part. Renesas Electronics disclaims any and all liability for any losses or damages incurred by you or third parties arising from such alteration, modification, copying or reverse engineering.
6. Renesas Electronics products are classified according to the following two quality grades: "Standard" and "High Quality". The intended applications for each Renesas Electronics product depends on the product's quality grade, as indicated below.

"Standard": Computers; office equipment; communications equipment; test and measurement equipment; audio and visual equipment; home electronic appliances; machine tools; personal electronic equipment; industrial robots; etc.

"High Quality": Transportation equipment (automobiles, trains, ships, etc.); traffic control (traffic lights); large-scale communication equipment; key financial terminal systems; safety control equipment; etc.

Unless expressly designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not intended or authorized for use in products or systems that may pose a direct threat to human life or bodily injury (artificial life support devices or systems; surgical implantations; etc.), or may cause serious property damage (space system; undersea repeaters; nuclear power control systems; aircraft control systems; key plant systems; military equipment; etc.). Renesas Electronics disclaims any and all liability for any damages or losses incurred by you or any third parties arising from the use of any Renesas Electronics product that is inconsistent with any Renesas Electronics data sheet, user's manual or other Renesas Electronics document.

7. No semiconductor product is absolutely secure. Notwithstanding any security measures or features that may be implemented in Renesas Electronics hardware or software products, Renesas Electronics shall have absolutely no liability arising out of any vulnerability or security breach, including but not limited to any unauthorized access to or use of a Renesas Electronics product or a system that uses a Renesas Electronics product. RENESAS ELECTRONICS DOES NOT WARRANT OR GUARANTEE THAT RENESAS ELECTRONICS PRODUCTS, OR ANY SYSTEMS CREATED USING RENESAS ELECTRONICS PRODUCTS WILL BE INVULNERABLE OR FREE FROM CORRUPTION, ATTACK, VIRUSES, INTERFERENCE, HACKING, DATA LOSS OR THEFT, OR OTHER SECURITY INTRUSION ("Vulnerability Issues"). RENESAS ELECTRONICS DISCLAIMS ANY AND ALL RESPONSIBILITY OR LIABILITY ARISING FROM OR RELATED TO ANY VULNERABILITY ISSUES. FURTHERMORE, TO THE EXTENT PERMITTED BY APPLICABLE LAW, RENESAS ELECTRONICS DISCLAIMS ANY AND ALL WARRANTIES, EXPRESS OR IMPLIED, WITH RESPECT TO THIS DOCUMENT AND ANY RELATED OR ACCOMPANYING SOFTWARE OR HARDWARE, INCLUDING BUT NOT LIMITED TO THE IMPLIED WARRANTIES OF MERCHANTABILITY, OR FITNESS FOR A PARTICULAR PURPOSE.
8. When using Renesas Electronics products, refer to the latest product information (data sheets, user's manuals, application notes, "General Notes for Handling and Using Semiconductor Devices" in the reliability handbook, etc.), and ensure that usage conditions are within the ranges specified by Renesas Electronics with respect to maximum ratings, operating power supply voltage range, heat dissipation characteristics, installation, etc. Renesas Electronics disclaims any and all liability for any malfunctions, failure or accident arising out of the use of Renesas Electronics products outside of such specified ranges.
9. Although Renesas Electronics endeavors to improve the quality and reliability of Renesas Electronics products, semiconductor products have specific characteristics, such as the occurrence of failure at a certain rate and malfunctions under certain use conditions. Unless designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not subject to radiation resistance design. You are responsible for implementing safety measures to guard against the possibility of bodily injury, injury or damage caused by fire, and/or danger to the public in the event of a failure or malfunction of Renesas Electronics products, such as safety design for hardware and software, including but not limited to redundancy, fire control and malfunction prevention, appropriate treatment for aging degradation or any other appropriate measures. Because the evaluation of microcomputer software alone is very difficult and impractical, you are responsible for evaluating the safety of the final products or systems manufactured by you.
10. Please contact a Renesas Electronics sales office for details as to environmental matters such as the environmental compatibility of each Renesas Electronics product. You are responsible for carefully and sufficiently investigating applicable laws and regulations that regulate the inclusion or use of controlled substances, including without limitation, the EU RoHS Directive, and using Renesas Electronics products in compliance with all these applicable laws and regulations. Renesas Electronics disclaims any and all liability for damages or losses occurring as a result of your noncompliance with applicable laws and regulations.
11. Renesas Electronics products and technologies shall not be used for or incorporated into any products or systems whose manufacture, use, or sale is prohibited under any applicable domestic or foreign laws or regulations. You shall comply with any applicable export control laws and regulations promulgated and administered by the governments of any countries asserting jurisdiction over the parties or transactions.
12. It is the responsibility of the buyer or distributor of Renesas Electronics products, or any other party who distributes, disposes of, or otherwise sells or transfers the product to a third party, to notify such third party in advance of the contents and conditions set forth in this document.
13. This document shall not be reprinted, reproduced or duplicated in any form, in whole or in part, without prior written consent of Renesas Electronics.
14. Please contact a Renesas Electronics sales office if you have any questions regarding the information contained in this document or Renesas Electronics products.

(Note1) "Renesas Electronics" as used in this document means Renesas Electronics Corporation and also includes its directly or indirectly controlled subsidiaries.

(Note2) "Renesas Electronics product(s)" means any product developed or manufactured by or for Renesas Electronics.

(Disclaimer Rev.5.0-1)

Corporate Headquarters

TOYOSU FORESIA, 3-2-24 Toyosu,
Koto-ku, Tokyo 135-0061, Japan
www.renesas.com

Trademarks

Renesas and the Renesas logo are trademarks of Renesas Electronics Corporation. All trademarks and registered trademarks are the property of their respective owners.

Contact Information

For further information on a product, technology, the most up-to-date version of a document, or your nearest sales office, please visit:
www.renesas.com/contact/