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## Flexible Temperature Measurement with the ZSSC3241 Enables Bridge as Temperature Sensor

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### Introduction

Accurate measurement using sensor elements requires precise and local measurement of the element's temperature for correction and compensation across a wide operating range. Thus, an integral part of Sensor Signal Conditioner (SSC) functionality is to provide at least one or more methods to measure temperature of the sensor element, which is typically a resistive bridge or capacitive transducer.

One simple and effective way to create a precise thermometer is to build a standard circuit called a PTAT (Proportional To Absolute Temperature) that generates a linear, consistent voltage versus temperature. This is fine as long as the SSC silicon is tightly coupled thermally to the sensor element such that the temperature of the two elements is nearly equal.

In some cases, however, the sensor element may be separated from the SSC by several centimeters or even further. In these instances, the SSC cannot be used predictably for temperature compensation and some type of external thermometer is needed that can be co-located with the bridge sensor. Silicon diodes or thermistors of the NTC or PTC type are commonly used for these cases, but these solutions require additional components and may have the same issue of co-location with the primary sensing element.

For resistive bridges, the ultimate way to measure the sensor temperature accurately with no additional cost or space is to use the temperature coefficient of the bridge itself. However, this requires some additional complexity in the biasing circuitry for the sensor bridge and more sophisticated calibration algorithms in the SSC to linearize the temperature coefficient of the bridge, which may exhibit up to third order variation.

With advanced modern SSCs like the ZSSC3241, this functionality is fully integrated and supported. The ZSSC3241 can support temperature measurement using an internal PTAT, external diodes or thermistors, and using the main sensing bridge itself as the thermometer. The various options are fully programmable and configurable using internal Non-Volatile Memory (NVM) for optimal performance based on system requirements.

### The ZSSC3241 provides for 7 different temperature measurement modes

Below is the basic block diagram for the ZSSC3241, showing the configurable sensor interface with biasing and amplification functions in the analog frontend. There is also an Internal Temperature Sensor onboard. The ADC converts the sensor and temperature readings into the digital domain, where all the linearization, correction, and temperature compensation functions are performed. The final calibrated and scaled outputs are available as either analog or various digital representations.

# Flexible Temperature Measurement with the ZSSC3241 Enables Bridge as Temperature Sensor

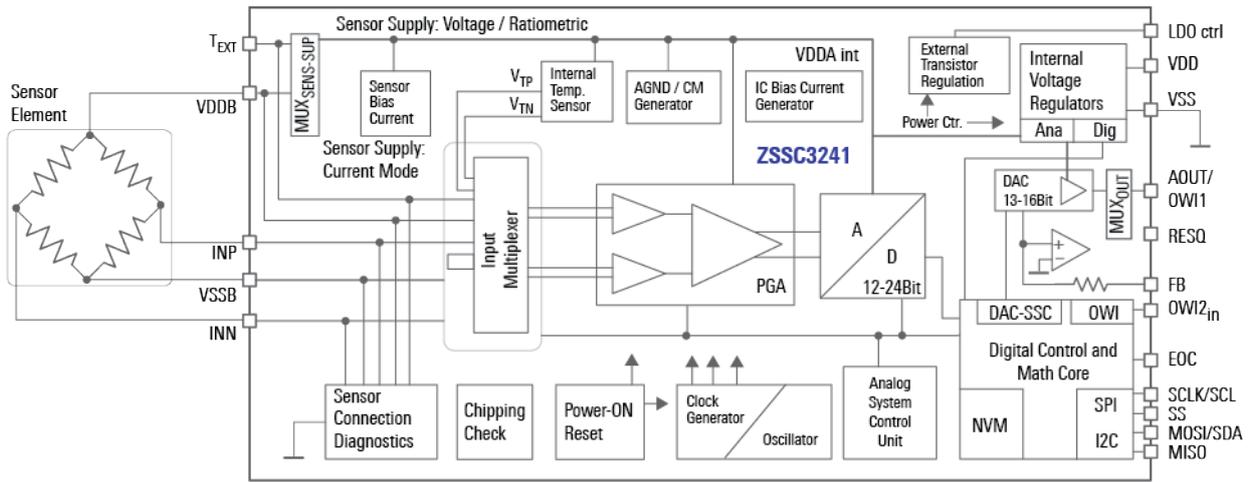


Figure 1. Block Diagram of the ZSSC3241 Sensor Signal Conditioner (SSC)

Looking more closely into the analog frontend, there are four blocks in particular that enable the ZSSC3241 to reconfigure temperature measurements: a sensor-supply multiplexer to switch between current and voltage bias modes, a sensor bias current source, internal temperature sensor, and an input multiplexer that selects between the measurands. These blocks are controlled by bits in the NVM labelled *sensor\_sup*, *Tbiasout*, and *gain\_polarity*.

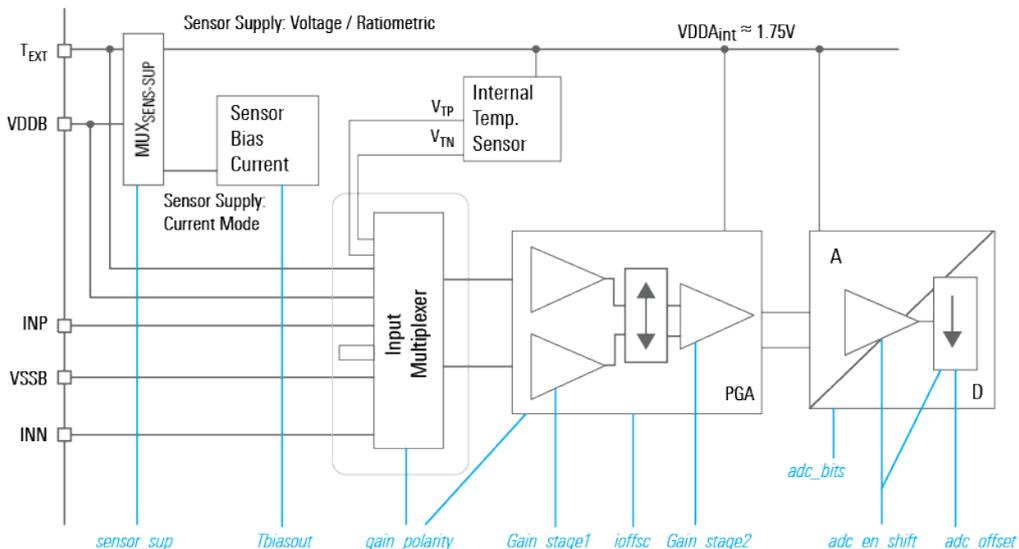


Figure 2. Configurable blocks of the Analog Front End interface to the bridge and temperature sensors

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With these blocks and the configuration options, the ZSSC3241 provides for 7 different temperature measurement modes as summarized in the table below. There are two primary biasing modes for using the sensor bridge as a thermometer: current or voltage. For each of these types a series resistor,  $R_t$ , is required to adjust the common mode voltage of the bridge into the proper range for the internal Programmable Gain Amplifier (PGA). The ZSSC3241 provides the option to have this series resistance fully integrated for many cases, but some external resistance might be required in cases where accuracy requirements are stringent.

| Reference | Temperature Sensor | Bridge bias mode | External components | Comments                          |
|-----------|--------------------|------------------|---------------------|-----------------------------------|
| T0        | Internal PTAT      | Current/Voltage  | None                | Independent bridge bias           |
| T1        | Sensor Bridge      | Current          | None                | Internal $R_t$ for CM adjustment  |
| T2        | Sensor Bridge      | Current          | Resistor(s)         | Ext. $R_t$ should have low tempco |
| T3        | Diode/Thermistor   | Voltage          | Diode/Thermistor    | No series resistors               |
| T4        | Sensor Bridge      | Voltage          | None                | Internal $R_t$ for CM adjustment  |
| T5        | Sensor Bridge      | Voltage          | Resistor(s)         | Ext. $R_t$ should have low tempco |
| T6        | Diode/Thermistor   | Voltage          | Diode/Thermistor    | Same as T3 with internal $R_t$    |

**Table 1. Summary of Temperature sensing options in the ZSSC3241**

The figures below provide more details on how the blocks are configured for each of the cases in the table. In each figure, the blue lines show the bias path for the sensor bridge and the red lines show the signal path measured to represent temperature.

### Configuration for using internal PTAT thermometer

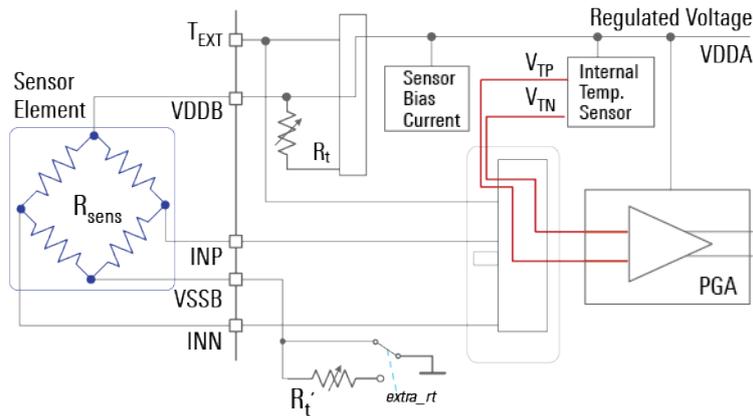


Figure 3.

Figure 3 shows the configuration for T0, using an internal PTAT thermometer. Sensor bridge biasing is completely independent and can be either ratiometric voltage or current. No external components are required.

### Configuration for using the sensor bridge as a thermometer

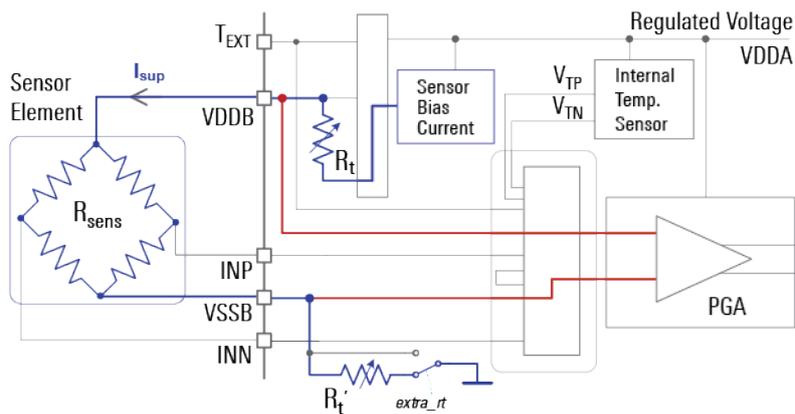


Figure 4.

Figure 4 illustrates the configuration for T1, using the sensor bridge as a thermometer. In this case the bridge is driven by current and two internal resistors,  $R_t$  and  $R_t'$ , are used to adjust the Common Mode voltage of the bridge into the appropriate range for the ZSSC3241. The values of  $R_t$  and  $R_t'$  are adjustable by settings in the NVM registers.

Configuration with external  $R_t$  for cases with high accuracy requirements

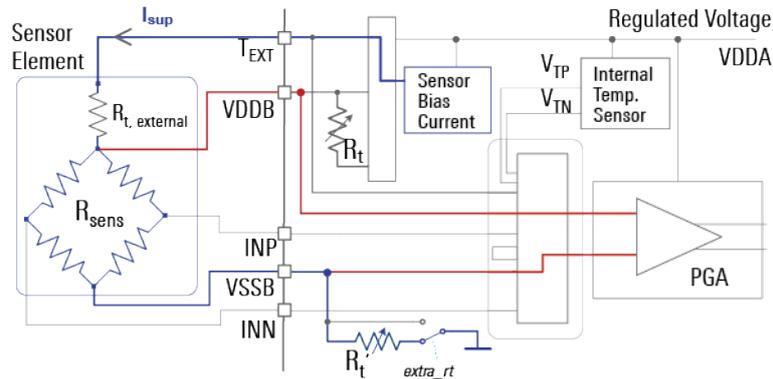


Figure 5.

Figure 5 shows configuration for T2 with external  $R_t$  for cases with high accuracy requirements.  $R_{t,external}$  should have a low temperature coefficient so that the temperature variation is dependent on the sensor bridge temperature coefficient. The internal  $R_t'$  is optional depending on whether CM adjustment is required.

Configuration with external diode or thermistor as thermometer

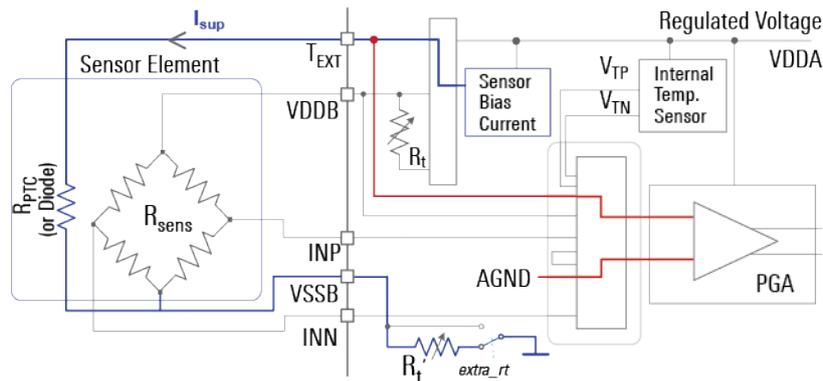


Figure 6.

Figure 6 illustrates the configuration for T3 with external diode or thermistor as thermometer. The thermistor can be of the NTC or PTC type. The temperature sensor is biased with a programmable current source and the bridge sensor is voltage driven. Internal  $R_t'$  can be used if necessary for shifting the CM voltage.

### Configuration using the sensor bridge as a thermometer with internal $R_t$ and $R_t'$

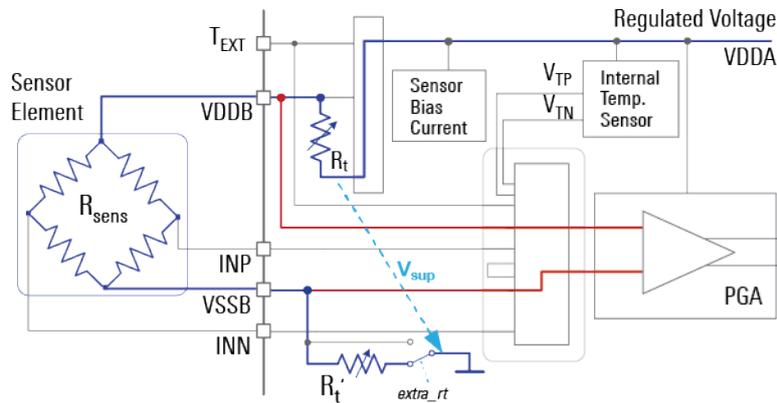


Figure 7.

Figure 7 shows the configuration for T4, using the sensor bridge as a thermometer with internal  $R_t$  and  $R_t'$ . This corresponds to T1 except the bridge is biased by voltage rather than current.

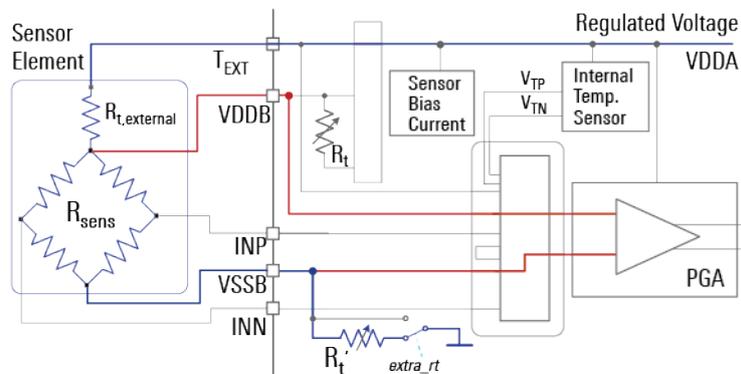


Figure 8.

Figure 8 shows the configuration for T5, using the sensor bridge as a thermometer with external resistance,  $R_t$ , external. This corresponds to T2 except the bridge is biased by voltage rather than current.

## Configuration using an external diode or thermistor for temperature sensing

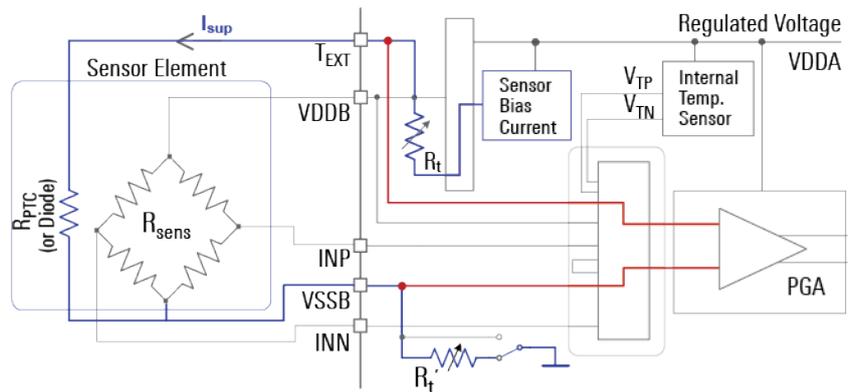


Figure 9.

Figure 9 illustrates the configuration for T6, using an external diode or thermistor for temperature sensing. This corresponds to T3 but allows for a high-side resistance,  $R_t$ , internally in case additional CM voltage adjustment is required for the external temperature sensor.

## Summary

Additional information for these configurations including the range of currents, voltages, and  $R_t/R_t'$  values along with the corresponding NVM settings is available in the datasheet for the ZSSC3241. The references T1-T6 used here correspond to the labels used in the datasheet.

With its wide range of front-end configurations, the ZSSC3241 enables designers to optimize both the main sensor interface and the type and location of sensors used for temperature compensation in order to achieve the best accuracy possible with fewer components and cost.

Renesas also provides additional resources for developing and characterizing designs with the ZSSC3241. These include a full evaluation kit with device samples, application notes, and dedicated support staff.

## Reference

- ZSSC3241 product page: [renesas.com/zssc3241](https://www.renesas.com/zssc3241)

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