Analyse Designs (Konzepts) 1

Messbereich: -200°C bis 400°C

20SPS

AVDD = 5 V

AVSS = 0V

DVDD = 3.3 V

$R_{RTD@400°C}$ = 247.09 Ω [3]

$I_{IDAC1} = I_{IDAC2}$ = 1 mA

V_{REF} = 2 V

$$V_{IN\_MAX} = \mathrm{R}_{RTD@850°C} * \mathrm{I}_{\mathrm{IDAC1}} = 247.09\ \Omega * 1\ mA = 247.09\ mV\ [1]\ (28)$$

$$PGA_{GAIN\_MAX} = \frac{V_{REF}}{V_{IN\_MAX}} = \frac{2\ V}{247.09\ mV} = 8.09\ [1]\ (29)$$

-> Nächstliegende PGA_{GAIN_MAX} = 8

-> d.h. ca. 98.89 % des Messbereichs (FSR = Full Scale Range)

$$R_{REF} = \frac{V_{REF}}{2 * I_{IDAC}} = \frac{2\ V}{2 * 1\ mA} = 1\ k\Omega$$

- ➔ Bestmöglichste Widerstand mit 1 kΩ wurde mit ± 0.01 % und ± 0.2 ppm/°C gewählt.

Es muss sichergestellt werden, dass der Eingangsspannungsbereich innerhalb des common-mode input voltage range des Verstärkers (PGA) ist. Dies ist mit folgender Formel sicherzustellen:

$$AVSS + 0{,}1\ V + \frac{V_{IN\_MAX} * Gain}{2} \leq V_{CM} \leq AVDD - 0{,}1\ V - \frac{V_{IN\_MAX} * Gain}{2}\ [2]\ (20)$$

$$0\ V + 0.1\ V + \frac{247.09\ mV * 8}{2} \leq V_{CM} \leq 5V - 0.1\ V - \frac{247.09\ mV * 8}{2}$$

$$1.08836\ V \leq V_{CM} \leq 3.91164\ V$$

- ➔ ???

The excitation current sources operate properly to a maximum IDAC compliance voltage

$$V_{IDAC1\_MAX} = R_{RTD\_MAX} * I_{IDAC1} + \left(R_{REF} * (I_{IDAC1} + I_{IDAC2})\right) = 0.25\ V + 2\ V = 2.25\ V[1]\ (27)$$

A compliance voltage of $5\ V - 2.25\ V = 2.75\ V$ is sufficient for proper IDAC operation.

VREF sets the input common-mode voltage at 2 V, satisfying the
requirements for both the input common-mode voltage and the IDAC compliance voltage of the ADS1247[1]

Measurement Resolution

$$LSB(V) = \frac{2 * V_{REF}}{Gain * 2^{24}} = \frac{2 * 2V}{8 * 2^{24}} = 29.8\ nV[2](34)$$

$$LSB(\Omega) = \frac{LSB(V)}{I_{IDAC}} = \frac{29.8\ nV}{1\ mA} = 29.8\ \mu\Omega$$

$ADC_{RES}(\Omega) = \pm \frac{Noise_{RTI\_pp}/2}{I_{IDAC}} = \pm \frac{2.05\ \mu V_{pp}/2}{1\ mA} = \pm\ 1.025\ m\Omega$ //NoiseRTI_pp aus Tabelle 3[1]

$ADC_{RES}(°C) = \frac{ADC_{RES}(\Omega)}{S(T)} = \frac{\pm\ 1.025\ m\Omega}{374\ \frac{m\Omega}{°C}} = \pm\ 0.00274\ °C$ //S(T) Empfindlichkeit @150 °C [3]

Error calculation excluding Temperature Drift [2]

<u>Errors due to R_{REF}:</u>

$R_{REF\ Tol}$(%) = 0.01 %

$$Gain\ Error_{R_{REF\ Tol}}(\%) = \frac{R_{REF\ Tol}(\%)}{R_{REF\ Tol}(\%) + 100} * 100 = \frac{0.01}{0.01 + 100} * 100 = 0.009999\ \%$$

$$Gain\ Error_{R_{REF}}(V) = \frac{Gain\ Error_{R_{REF}}(\%)}{100} * V_{IN_{MAX}} = \frac{Gain\ Error_{R_{REF}}(\%)}{100} * I_{IDAC} * R_{RTD@150°C}$$
$$= \frac{0.009999}{100} * 1\ mA * 157.33\ \Omega = 15.7314267\ \mu V$$

<u>Errors due to ADS1248:</u>

Offset $Error_{ADC}$ (V) = 15µV (datasheet after selfocal)
$Gain\ Error_{ADC}\ (V) = \frac{Gain\ Error_{ADC}\ (\%)}{100} * V_{IN_{MAX}} = \frac{0.02}{100} * 157.33\ mV = 31.466\ \mu V$ (0.02 datasheet)
$INL\ Error_{IDAC}\ (V) = \frac{INL}{1\ 000\ 000} * \frac{2 * V_{REF}}{Gain} = \frac{15}{1\ 000\ 000} * \frac{2 * 2\ V}{8\ \frac{V}{V}} = 7.5\ \mu V$ (15 datasheet)

$$Gain\ Error_{IDAC}(\%) = \frac{I_{IDAC\ Mismatch}(\%)}{I_{IDAC\ Mismatch}(\%) + 200} * 100 = \frac{0.15}{0.15 + 200} * 100 = 0.07494\ \%$$

$$Gain\ Error_{IDAC}\ (V) = \frac{Gain\ Error_{IDAC}\ (\%)}{100} * V_{IN_{MAX}} = \frac{0.07494}{100} * 157.33\ mV = 117.903102\ \mu V$$

Error calculation including Temperature Drift [2]

Die Berechnungen werden über einen Temperaturbereich von -40°C bis +85°C durchgeführt.

Die größten Abweichungen in bezug auf Temperaturdrift treten weitestgehend von der Raumtemperatur 25°C auf.

$$\Delta T_{MAX} = 25\ °C - (-40\ °C) = 65°C$$

Errors caused by R_{REF} Temperature Drift:

$R_{REF\ Drift}\left(\frac{ppm}{°C}\right) = 0.2\ \frac{ppm}{°C}$ (datenblatt Widerstand Rref)

$$R_{REF\ Drift}(ppm) = R_{REF\ Drift}\left(\frac{ppm}{°C}\right) * \Delta T_{MAX} = 0.2\ \frac{ppm}{°C} * 65\ °C = 13\ ppm$$

$$R_{REF\ Drift}\ (\%) = \frac{R_{REF\ Drift}\ (ppm)}{1\ 000\ 000} * 100 = \frac{13}{1\ 000\ 000} * 100 = 0.0013\ \%$$

$$Gain\ Error_{R_{REF\ Drift}}\ (\%) = \frac{R_{REF\ Drift}\ (\%)}{R_{REF\ Drift}(\%) + 100} * 100 = \frac{0.0013}{0.0013 + 100} * 100 = 0.00129998\%$$

$$Gain\ Error_{R_{REF\ Drift}}\ (V) = \frac{Gain\ Error_{R_{REF\ Drift}}\ (\%)}{100} * V_{IN_{MAX}} = \frac{0.001299831}{100} * 157.33\ mV$$
$$= 2.045\ \mu V$$

Errors due to ADS1248 Temperature Drift:

$Offset\ Error_{ADC\ Drift}(V) = 1\mu V$ (-40°C datasheet)

$Gain\ Error_{ADC\ Drift}(V) = \frac{Gain\ Error_{ADC\ Drift}(\%)}{100} * V_{IN@150°} = \frac{0.01}{100} * 157.33\ mV = 15.733\ \mu V$(datas.)

$$I_{IDAC\ Mismatch\ Drift}(\%) = \frac{I_{IDAC\ Mismatch\ Drift}\ (ppm)}{1\ 000\ 000} * \Delta T_{MAX} * 100 = \frac{10}{1\ 000\ 000} * 65\ °C * 100$$
$$= 0.065\ \%$$

$$Gain\ Error_{Mismatch\ Drift}\ (V) = \frac{Gain\ Error_{Mismatch\ Drift}\ (\%)}{100} * V_{IN_{MAX}} = \frac{0.03249}{100} * 157.33\ mV$$
$$= 51.12\ \mu V$$

$$Error_{TOTAL}(\mu V) = \sqrt{\begin{array}{c}\left(Gain\ Error_{R_{REF\ Tol}}\right)^2 + \left(Gain\ Error_{R_{REF\ Tol\ Drift}}\right)^2 + \\ (Offset\ Error_{ADC})^2 + \left(Offset\ Error_{ADC\ Drift}\right)^2 \\ +(Gain\ Error_{ADC})^2 + \left(Gain\ Error_{ADC\ Drift}\right)^2 + (INL\ Error_{ADC})^2 \\ +(Gain\ Error_{IDAC})^2 + \left(Gain\ Error_{IDAC\ Mismatch\ Drift}\right)^2\end{array}}$$

$$Error_{TOTAL}(\mu V) = \sqrt{\begin{array}{c}(15.7314267\ \mu V)^2 + (2.045\ \mu V)^2 + \\ (15\mu V)^2 + (1\mu V)^2 \\ +(31.466\ \mu V)^2 + (15.733\ \mu V)^2 + (7.5\ \mu V)^2 \\ +(117.903102\ \mu V)^2 + (51.12\ \mu V)^2\end{array}}$$

$$Error_{TOTAL}(\mu V) = 135.2255232\ \mu V$$

$$Error_{TOTAL}(\Omega) = \frac{135.2255232\ \mu V}{1\ mA} = 135.2255232\ m\Omega$$

$$Error_{TOTAL}(°C) = \frac{135.2255232\ m\Omega}{374\ \frac{m\Omega}{°C}} = 0.36\ °C$$

(Handbuch der tech. Temp.messung Empfindlichkeit bei 150°C)

(0.36 °C schlechtestens im Bereich 90°C bis 150°C)

Improvements: All IDAC mismatch Errors can be removed by chopping the IDAC sources (Including gain and drift). A two point gain and offset calibration can remove the Gain and Offset Errors. Only the INL Error and all Temperature Drift Errors are remaining[1].

$$Error_{TOTAL}(\mu V) = \sqrt{\begin{matrix} +\left(Gain\ Error_{R_{REF}\ Tol\ Drift}\right)^2 + +\left(Offset\ Error_{ADC\ Drift}\right)^2 \\ +\left(Gain\ Error_{ADC\ Drift}\right)^2 + (INL\ Error_{ADC})^2 \end{matrix}}$$

$$Error_{TOTAL}(\mu V) = \sqrt{\begin{matrix} (2.045\ \mu V)^2 + (1\mu V)^2 \\ +(15.733\ \mu V)^2 + (7.5\ \mu V)^2 \end{matrix}}$$

$$Error_{TOTAL}(\mu V) = 17.57723852\ \mu V$$

$$Error_{TOTAL}(\Omega) = \frac{17.57723852\ \mu V}{1\ mA} = 17.57723852\ m\Omega$$

$$adjusted\ Error_{TOTAL}(°C) = \frac{17.57723852\ m\Omega}{374\ \frac{m\Omega}{°C}} = 0.047°C$$

([3]Handbuch der tech. Temp.messung Empfindlichkeit bei 150°C=374mOhm pro °C)

(adjusted $0.047\ °C$ schlechtestens im Bereich 90°C bis 150°C)

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