ATTACHMENT (2)

CALCULATION NO. CA07018, REVISION NO. 00001, MAIN FEEDWATER PRESSURE INPUT UNCERTAINTY TO CALDON CHECKPLUS LEFM

Calvert Cliffs Nuclear Power Plant, Inc.
June 11, 2009

ATTACHMENT 1, CALCULATION COVER SHEET

A. INITIATION

Site ☒ CCNPP ☐ NMP ☐ REG

Calculation No.: CA07018 Revision No.: 0001

Vendor Calculation (Check one): ☒ Yes ☐ No

Responsible Group: E&C Design Engineering Unit

Responsible Engineer: D. A. Dvorak

B. CALCULATION

ENGINEERING DISCIPLINE: ☐ Civil ☒ Instr & Controls ☐ Nuclear ☐ Electrical ☐ Mechanical ☐ Other ______

Title: MAIN FEEDWATER PRESSURE INPUT UNCERTAINTY TO CALDON CHECKPLUS LEFM

Unit ☒ 1 ☒ 2 ☐ ISFSI

Proprietary or Safeguards Calculation ☐ YES ☒ NO

Comments:

Vendor Calc No.: CCN-IC-07001 REVISION NO.: 1

Vendor Name: HURST TECHNOLOGIES, CORP.

Safety Class (Check one): ☐ SR ☐ AUGMENTED QUALITY ☒ NSR

There are assumptions that require Verification during walkdown: Yes TRACKING ID: ES200800030-010

This calculation **SUPERSEDES**: CA07018, REV. 0000

C. REVIEW AND APPROVAL:

Responsible Engineer: HURST TECHNOLOGIES, CORP, SEE PAGE 2

Printed Name and Signature Date

Is Design Verification Required? ☐ Yes ☐ No

If yes, Design Verification Form is: ☐ Attached ☐ Filed with:

Independent Reviewer: HURST TECHNOLOGIES, CORP, SEE PAGE 2

Printed Name and Signature Date

Approval: HURST TECHNOLOGIES, CORP, SEE PAGE 2

Printed Name and Signature Date

MAIN FEEDWATER PRESSURE INPUT UNCERTAINTY TO CALDON CHECKPLUS LEFM

For Calvert Cliffs Nuclear Power Plant
Units 1 & 2

Calculation No. CCN-IC-09002 Revision 1

Prepared By Hurst Technologies, Corp.

Project: CCNAKT

Client: Constellation Nuclear
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Attachment 3 – Excerpt from Burr-Brown Product Data Sheet PDS-1304B for ADS7825 4 Channel, 16-Bit Sampling CMOS A/D Converter, October 1997 [3 pages]

Attachment 4 – Burr-Brown Uncertainty Analysis for Model ADS7825 A/D Converter for 0-5 Volt Input [4 pages]

RECORD OF REVISIONS

Rev.	Date	Pages Involved	Description	Originator
0	02/02/09	All	Initial Issue	R.A. Hunter
1	04/15/09	All	Revised to include the uncertainties of the LEFM system, to address the total uncertainty of the digital indication. Changed the approach for determination of PMEb. Consolidated Assumptions 6.1 and 6.5 into Assumption 6.1. Added Attachments 2, 3, 4.	K. R. Melson

1.0 PURPOSE

The purpose of this calculation is to determine the total loop uncertainty of Main Feedwater pressure digital indications for the Caldon CheckPlus LEFM and Plant Computer.

Uncertainties are calculated for normal operating (non-harsh) conditions only.

2.0 COMPONENT LISTING

This calculation applies to the following instruments:

Main Feedwater Pressure Transmitters

1-PT-1131A, B	1-PT-1141A, B
2-PT-1131A, B	2-PT-1141A, B

I/E Converters

1I/E1C209A, B	1I/E1C209E, F
2I/E2C209A, B	2I/E2C209E, F

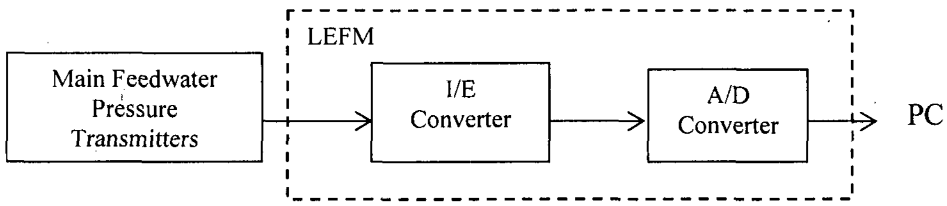
A/D Converters

1M/P1C209A1, B1	1M/P1C209A2, B2
2M/P2C209A1, B1	2M/P2C209A2, B2

LEFM Electronic Unit

1CPU1C209A1, B1	1CPU1C209A2, B2
2CPU2C209A1, B1	2CPU2C209A2, B2

3.0 FIGURE



Note: The loop configuration is determined from Reference 7.9 and Assumption 6.9.

4.0 METHOD OF ANALYSIS

This calculation is performed in accordance with ES-028, Instrument Loop Uncertainty / Setpoint Methodology. This calculation utilizes the Square Root Sum of the Squares (SRSS) methodology when all variables are random, independent and normally distributed. Bias uncertainties are combined algebraically with random uncertainties.

This calculation determines device uncertainties for the Main Feedwater pressure transmitters, I/E converters, and A/D converters and then combines these uncertainties to determine the total loop uncertainty for the digital indication of the LEFM. The error in this digital indication is the same as in the plant computer, since the signal is passed to the plant computer via a digital link.

5.0 DESIGN INPUTS

5.1 MAIN FEEDWATER PRESSURE SENSOR CONSIDERATIONS (Subscript: $_S$)

TAG NUMBER:	1(2)-PT-1131A, B	[7.2]
	1(2)-PT-1141A, B	
MANUFACTURER:	Rosemount	[7.2]
MODEL NUMBER:	3051CG5	[7.2]
SPAN:	0 to 1300 psig	[7.2]
UPPER RANGE LIMIT (URL)	2000 psig	[7.1]

5.1.1 Per References 7.1, the Reference Accuracy for Range Code 5 transmitters with a turn down ratio (ratio of URL to Span) of less than 10:1 is ± 0.065% Span. Per Reference 7.1, URL for these transmitters is 2000 psig. Per Reference 7.2, span for these transmitters is 1300 psig, yielding a turn down ratio of 1.54:1 (result of 2000 /1300). Therefore, the sensor Reference Accuracy (RA_S) is given as:

$RA_S = \pm 0.065\%$ Span

5.1.2 Per Reference 7.2, the setting tolerance for these sensors is ± 0.25% Span. Therefore, the Sensor Setting Tolerance (ST_S) is:

$ST_S = \pm 0.250\%$ Span

5.1.3 For conservatism, and to provide flexibility in the choice of test equipment, the Sensor Measurement and Test Equipment Effect (MTE_S) is set equal to the sensor setting tolerance (ST_S). Therefore,

$MTE_S = \pm 0.250\%$ Span

5.1.4 The Drift term (DR_S) is given in Reference 7.1 as ± 0.125% URL for 5 years with temperature variation limited to within ± 50°F, and up to 1000 psi line pressure. Reference 7.1 shows URL for range code 5 transmitters is 2000 psi. Per Reference 7.3, Turbine Building Maximum / Minimum design temperatures are 110°F / 60°F, respectively, ensuring that maximum temperature variation is bounded by ±50°F. Line pressure effects are only applicable to differential pressure transmitters. Therefore, the Sensor Drift (DR_S) is given as:

$$DR_S = \pm\left(\frac{0.125\% \text{ X } 2000\,\text{psi}}{1300\,\text{psi}} \text{ X } 100\%\text{Span X } \frac{50^\circ\text{F}}{50^\circ\text{F}}\right)\%\text{Span}$$

$$DR_S = \pm\ 0.192\%\ \text{Span}$$

5.1.5 Per Reference 7.1, the Sensor Temperature Effect (TE_S) is given as ± (0.0125% URL + 0.0625% Span) per 50°F for Range Code 5. Per Reference 7.1, URL for range code 5 transmitters is 2000 psi. Per Reference 7.3, Turbine Building Minimum / Maximum design temperatures are 60°F / 110°F, respectively. Using Minimum / Maximum temperatures for calibration temperature and normal operating temperature ensures that maximum temperature variation (±50°F) is considered in determination of TES. Therefore, the Sensor Temperature Effect (TE_S) is given as:

$$TE_S = \pm\ (0.0125\%\text{URL} + 0.0625\%\text{Span}) \text{ X } \frac{50^\circ\text{F}}{50^\circ\text{F}}$$

$$TE_S = \pm\left[\frac{0.0125\% \text{ X } 2000\,\text{psi}}{1300\,\text{psi}} + 0.0625\%\text{Span}\right] \text{X } \frac{50^\circ\text{F}}{50^\circ\text{F}}$$

$$TE_S = \pm\ 0.082\%\ \text{Span}$$

5.1.6 Per Reference 7.1, Sensor Power Supply Effect (PSE_S) is less than ± 0.005% Span per volt variation. Reference 7.4 states that, for DC power supplies, considering a 5 volt variation in power supply voltage is conservative. Therefore PSE_S is determined as follows:

$$PSE_S = \pm\ \frac{0.005\%\text{Span}}{\text{volt DC}} \text{ X } 5\,\text{volts DC}$$

$$PSE_S = \pm\ 0.025\%\ \text{Span}$$

Per Reference 7.4, uncertainties less than ±0.050% are considered negligible. Therefore,

$$PSE_S = \text{N/A}$$

5.1.7 Per Reference 7.1, Sensor Vibration Effect (VE_S) is negligible except at resonant frequencies. When at resonant frequencies, vibration effect is less than ± 0.1% of URL per g when tested between 15 and 2000 Hz in any axis relative to pipe-mounted process conditions. Per Assumption 6.2, vibration is bounded by 1 g at the test conditions described. Per Reference 7.1, URL for range code 5 transmitters addressed in this calculation is 2000 psi. Reference 7.2 shows calibrated span for these transmitters is 1300 psig. Therefore VE_S is determined as follows:

$$VE_S = \pm \frac{0.1\% \;\; X \; 2000\,\text{psi}}{1300\,\text{psi}}$$

$$VE_S = \pm\, 0.154\% \text{ Span}$$

5.1.8 Per Reference 7.1, Sensor RFI Effects (RFI_S) is ± 0.1% Span from 20 to 1000 MHz and for field strength up to 30 V/m. Per Assumption 6.3, transmitters addressed in this calculation are not exposed to RFI conditions beyond the limits stated in the specification. Therefore:

$$RFI_S = \pm\, 0.100\% \text{ Span}$$

5.2 I/E CONVERTER CONSIDERATIONS (Subscript: $_{P1}$)

TAG NUMBER:	1I/E1C209A, B, E, F	
	2I/E2C209A, B, E, F	
MANUFACTURER:	Analog Devices	
MODEL NUMBER:	5B32	
SPAN:	4 to 20 mAdc	[7.1]
PROCESS SPAN:	(0 to 1300 psig)	[7.2]
OUTPUT SPAN:	0-5 Vdc	[7.6]

5.2.1 Per Reference 7.6, the initial accuracy at +25°C for the I/E Converters is ± 0.05% Span ± 0.05% of I_Z. The nonlinearity is defined as ± 0.02% Span. The accuracy of the input resistance (20 Ω) is shown to be ± 0.1%. The accuracy of the input resistance is converted to percent of span at the highest input reading. This calculation conservatively computes Reference Accuracy, based on the combination of all these terms, via addition. The Converter 1 Reference Accuracy (RA_{P1}) is computed as follows.

$$ACC_{RES} = \text{Accuracy of Input Resistance}$$

$$ACC_{RES} = \pm 0.1\% \times \left(\frac{20 \text{ mAdc}}{(20 \text{ mAdc} - 4 \text{ mAdc})} \right) = \pm 0.125\% \text{ Span}$$

$$I_Z = 4 \text{ mAdc}$$

$$0.05\% \text{ of } I_Z = 0.0005 \times 4 \text{ mAdc} \times \left(\frac{100\% \text{ Span}}{(20 \text{ mAdc} - 4 \text{ mAdc})} \right) = 0.0125\% \text{ Span}$$

$$A_{INIT} = \text{Initial Accuracy}$$

$$A_{INIT} = \pm 0.05\% \text{ Span} \pm 0.05\% \text{ of } I_Z \text{ (Conservatively Add)}$$

$$A_{INIT} = \pm 0.05\% \text{ Span} + 0.0125\% \text{ Span} = \pm 0.0625\% \text{ Span}$$

$$RA_{P1} = \pm(0.0625 + 0.02 + 0.125)$$

$$RA_{P1} = \pm 0.208\% \text{ Span}$$

5.2.2 Per Reference 7.4, the setting tolerance for these converters is set equal to the Reference Accuracy, since MCDS sheets do not yet exist. Therefore, the Converter 1 Setting Tolerance (ST_{P1}) is:

$$ST_{P1} = \pm 0.208\% \text{ Span}$$

5.2.3 For conservatism, and to provide flexibility in the choice of test equipment, the Sensor Measurement and Test Equipment Effect (MTE_{P1}) is set equal to the Converter 1 Setting Tolerance (ST_{P1}). Therefore,

$$MTE_{P1} = \pm\ 0.208\%\ \text{Span}$$

5.2.4 Per Assumption 6.6, Reference 7.6 does not provide a time-dependent drift specification for the I/E converter, and no historical data is available for analysis. This device is a modern electronic module used for high accuracy situations; and drift should be near zero. Therefore, the drift term for these converters is conservatively set equal to the Reference Accuracy term. The Converter 1 Drift (DR_{P1}) is defined:

$$DR_{P1} = \pm\ 0.208\%\ \text{Span}$$

5.2.5 Per Reference 7.6, there are four (4) terms relating to temperature effect. This calculation conservatively computes temperature effect, based on the combination of all these terms, via addition. Note that the LEFM √ + cabinets are air-conditioned and maintained within an approximate 10°F band, however, for conservatism, this calculation computes the I/E converter temperature effect, based on room temperatures without air conditioning. Per Reference 7.3, Turbine Building Minimum / Maximum design temperatures are 60°F / 110°F, respectively. Using Minimum / Maximum temperatures for calibration temperature and normal operating temperature ensures that maximum temperature variation (±50°F) is considered in determination of TE_{P1}. Therefore, the Converter 1 Temperature Effect (TE_{P1}) is computed as follows:

$$TE_{IO} = \text{Input Offset vs. Temp}$$

$$TE_{IO} = \pm 0.0025\%\ \text{of Iz}/°C \times \left(\frac{4\ \text{mAdc}}{(20\ \text{mAdc} - 4\ \text{mAdc})}\right) = \pm 0.000625\%\ \text{Span}/°C$$

$$TE_{OO} = \text{Output Offset vs. Temp}$$

$$TE_{OO} = \pm 20\ \mu V/°C \times \left(\frac{100\%\ \text{Span}}{5\ \text{Vdc}}\right) \times \left(\frac{1\ \text{Vdc}}{1{,}000{,}000\ \mu\text{Vdc}}\right) = \pm 0.0004\%\ \text{Span}/°C$$

$$TE_G = \text{Gain vs. Temp}$$

$$TE_G = \pm 0.0025\%\ \text{of Reading}/°C\ \text{(Considered Applied as Input Specification)}$$

$$TE_G = \pm 0.0025\%\ \text{Span}/°C \times \left(\frac{20\ \text{mAdc}}{(20\ \text{mAdc} - 4\ \text{mAdc})}\right) = \pm 0.003125\%\ \text{Span}/°C$$

TE_{SR} = Stability vs. Temp for Input Resistor

$$TE_{SR} = \pm 0.001\%/°C \times \left(\frac{20\ mAdc}{(20\ mAdc - 4\ mAdc)}\right) = \pm 0.00125\%\ Span/°C$$

$$TE = \pm(TE_{IO} + TE_{OO} + TE_{G} + TE_{SR})$$

$$TE = \pm(0.000625 + 0.0004 + 0.003125 + 0.00125)$$

$$TE_{P1} = \pm 0.0054\%\ Span/°C \times \left(\frac{1°C}{1.8°F}\right) \times 50°F$$

$TE_{P1} = \pm 0.150\%$ Span

5.2.6 Per Reference 7.6, the Converter 1 Power Supply Effect (PSE_{P1}) is defined by power supply sensitivity of ± 2μV/Vs%, with a required power supply voltage of 5 Vdc ±5%. Conservatively using the worst case voltage variation specified for the module of ±5% (Assumption 6.7), the PSE_{P1} is determined as follows:

$$PSE_{P1} = \pm\left(\frac{2\mu Vdc}{V_S\ \%}\right) \times 5\% \times \left(\frac{1\ Vdc}{1{,}000{,}000\ \mu Vdc}\right) \times \left(\frac{100\%\ Span}{5\ Vdc}\right)$$

$PSE_{P1} = \pm\ 0.0002\%$ Span

Per Reference 7.4, uncertainties less than ±0.050% Span are considered negligible. Therefore,

PSE_{P1} = N/A

5.2.7 Per Reference 7.6, the Converter 1 RFI Effect (RFI_{P1}) is defined by RFI Susceptibility, ± 0.5% Span error @ 400 MHz, 5 Watts, at 3 feet. Per Assumption 6.8, the converters addressed in this calculation are not exposed to RFI conditions beyond the limits stated in the specification. Therefore:

$RFI_{P1} = \pm\ 0.500\%$ Span

5.3 A/D CONVERTER CONSIDERATIONS (Subscript: $_{P2}$)

TAG NUMBER:	1M/P1C209A1, A2, B1, B2	
	2M/P2C209A1, A2, B1, B2	
MANUFACTURER:	Burr Brown	
MODEL NUMBER:	ADS7825	
SPAN:	0 to 5 Vdc	[7.6]
PROCESS SPAN:	(0 to 1300 psig)	[7.2]

5.3.1 Reference 7.7 provides the uncertainty specifications for the Burr Brown A/D converters. However, Reference 7.8 is the accuracy analysis as provided by the vendor for these devices, when using an input span of 0 to 5 Vdc. The output of this analysis is the overall accuracy for the A/D converters. Per Reference 7.8, the overall uncertainty value is derived as ± 17.5 mVdc. The Overall Accuracy of the A/D Converter (ACC_{P2}) is computed as follows.

$$ACC_{P2} = \pm 17.5\ \text{mVdc} \times \left(\frac{100\%\ \text{Span}}{5\ \text{Vdc}}\right) \times \left(\frac{1\ \text{Vdc}}{1000\ \text{mVdc}}\right)$$

$$ACC_{P2} = \pm 0.350\%\ \text{Span}$$

In order to ensure that adequate temperature effects, etc., have been considered, an extra degree of conservatism is added, and ±0.400% Span will be used for the Total Device Uncertainty of the A/D Converter (TDU_{P2}). (Note that the LEFM √ + cabinets are air-conditioned and maintained within an approximate 10°F band, so additional temperature effect uncertainties should not be present outside the uncertainty analysis of Reference 7.8.)

$$TDU_{P2} = \pm\ 0.400\%\ \text{Span}$$

5.4 PROCESS MEASUREMENT EFFECT CONSIDERATIONS

Not all of the transmitters addressed in this calculation are installed (as of Revision 1 issue), making precise determination of PMEb impossible at this time. However, based on Assumption 6.1, an elevation difference of 30 feet can be used to quantify a bounding PMEb for use in this calculation. This process requires that transmitter calibration offsets be calculated and applied as stipulated on Reference 7.2. Per Assumption 6.4 this will be done prior to the initial calibration of each transmitter.

Reference 7.2 uses a conversion factor of 0.0361 psig / inH_2O to calculate offset. Multiplying the conversion factor by $(12\text{ in})^3 / \text{ft}^3$ yields the actual calibration density, 62.3808 lbm/ft^3.

The following equation is used to calculate the PMEb due to sensing line density variations:

$$\text{PMEb} = \left(\frac{h(\rho_N - \rho_C)}{144}\right)\left(\frac{100\%\ \text{Span}}{1300\,\text{psi}}\right) \qquad \text{[EQ-1]}$$

where,
h = height of sensing line in feet (30 ft. per Assumption 6.1)
1300 psi = transmitter span
ρ_N = assumed sensing line fill fluid density during normal operation
ρ_C = assumed sensing line fill fluid density to determine bounding calibration offset

NOTE: The factor 144 is used to convert from lbf/ft^2 to lbf/in^2. At standard gravity, lbf may be replaced with lbm.

Per Reference 7.3, the design minimum temperature is 60°F and the design maximum temperature is 110°F in the area where the transmitters and sensing lines are located. To ensure the most conservative result, 60°F is considered calibration temperature and 110°F is the maximum temperature during normal conditions. A conservative process pressure of 1000 psia is used for density determinations.

ρ_N @ 110°F / 1000 psia = 62.04833 lbm/ft^3 — Reference 7.5
ρ_C @ 60°F / 1000 psia = 62.56809 lbm/ft^3 — Reference 7.5

Note that the calibration density determined above (62.3808 lbm/ft^3) is bounded by these conservative densities ρ_N, and ρ_C.

Substituting values in Eq. 1 yields:

$$PMEb = \left(\frac{30(62.04833 - 62.56809)}{144}\right)\left(\frac{100\%\ Span}{1300\ psi}\right)$$

PMEb = -0.008% Span

Per Reference 7.4, uncertainties less than ±0.050% Span are considered negligible. Therefore:

PMEb = N/A

6.0 ASSUMPTIONS

6.1 *UNVERIFIED ASSUMPTION* - It is assumed that a Unit 1 LEFM plant modification will be implemented using the same converters, transmitters, transmitter calibrations, and configurations as presented in this calculation. In addition it is assumed that the vertical distance between transmitter centerline and process tap for the Unit 1 transmitters will not exceed 30 feet.

6.2 It is assumed that pipe mounted process vibrations for the transmitters addressed in this calculations are limited to 1 g between 15 and 2000 Hz in any axis.

6.3 It is assumed that transmitter RFI at the location of all transmitters addressed in this calculation is limited to 20 to 1000 MHz, and field strength of 30 V/m.

6.4 It is assumed that transmitter head correction (calibration values offset) is calculated and applied as part of the initial calibration of each transmitter addressed in this calculation, in accordance with the procedure stipulated in Reference 7.2.

6.5 Not used

6.6 Reference 7.6 does not provide a time-dependent drift specification for the I/E converter, and no historical data is available for analysis. This device is a modern electronic module used for high accuracy situations; and drift should be near zero. Therefore, the drift term for these converters is conservatively set equal to the Reference Accuracy term.

6.7 It is assumed that the worst case power supply variation supplied to Converter 1 is ±5% of the supply voltage. This is considered conservative, since this is the worst case power variation allowed by the device specifications.

6.8 It is assumed that Converter 1 RFI at the location of the Caldon hardware addressed in this calculation is limited to 400 MHz, 5 Watts, 3 feet from the device.

6.9 The loop configuration is assumed to consist of the transmitter, I/E converter, and A/D converter, as presented in Section 3.0. This is based on the Unit 2 schematic drawings, Reference 7.9. It is assumed that this configuration will be as built for Units 1 and 2.

7.0 REFERENCES

7.1 Rosemount 3051 Product Data Sheet 00813-0100-4001, Rev. HA, March 2008 (excerpt included in this calculation as Attachment 1)

7.2 BGE Master Calibration Data Sheets (MCDS's):

COMPONENT	REVISION
1-PT-1131A	0*
1-PT-1131B	0*
1-PT-1141A	0*
1-PT-1141B	0*
2-PT-1131A	0
2-PT-1131B	0
2-PT-1141A	0
2-PT-1141B	0

*Unit 1 MCDS's not yet produced (see Assumption 6.1). Initial issue for these new instruments will be Rev. 0.

7.3 BG&E Updated Final Safety Analysis Report, Table 9-18, Revision 38

7.4 Calvert Cliffs Engineering Standard ES-028, "Instrument Loop Uncertainty and Setpoint Methodology", Revision 1

7.5 ASME Steam Tables, 1967

7.6 Specifications for Analog Devices Single-Channel Signal Conditioning Module 5B32, printed from the http://analog.com website on 4/9/2009, including email clarification, dated 4/13/2009 (Attachment 2)

7.7 Burr-Brown Product Data Sheet PDS-1304B for ADS7825 4 Channel, 16-Bit Sampling CMOS A/D Converter, October 1997 (Excerpt included as Attachment 3)

7.8 Burr-Brown Uncertainty Analysis for Model ADS7825 A/D Converter for 0-5 Volt Input (Attachment 4)

7.9 Cameron Drawing 9A-202B796, "Electronics Unit LEFM √ + Schematic," Sheets 1 (Rev. 02), 8 (Rev. 02), 9 (Rev. 02), and 12 (Rev. 02)

8.0 IDENTIFICATION OF COMPUTER CODES

NONE

9.0 CALCULATION

This calculation determines the Total Device Uncertainty (TDU) and Segment Uncertainty (LU) for Main Feedwater Pressure transmitters that provide input to the LEFM.

9.1 TOTAL DEVICE UNCERTAINTIES

Main Feedwater Pressure Transmitter Uncertainty

The normal uncertainties associated with the sensor (TDU_S) are given as:

$$TDU_S = \pm \sqrt{RA_S^2 + ST_S^2 + MTE_S^2 + DR_S^2 + TE_S + VE_S^2 + RFI_S^2}$$

$TDU_S = \pm\ 0.454\ \%\ Span$

I/E Converter Uncertainty

The normal uncertainties associated with the I/E converter (TDU_{P1}) are given as:

$$TDU_{P1} = \pm \sqrt{RA_{P1}^2 + ST_{P1}^2 + MTE_{P1}^2 + DR_{P1}^2 + TE_{P1} + RFI_{P1}^2}$$

$TDU_{P1} = \pm\ 0.667\ \%\ Span$

A/D Converter Uncertainty

The normal uncertainties associated with the A/D converter (TDU_{P2}) are directly provided in Section 5.3.1:

$TDU_{P2} = \pm\ 0.400\ \%\ Span$

9.2 SEGMENT UNCERTAINTIES

The calibration procedures for this instrument loop have not been developed. Therefore, one segment is analyzed per device. Therefore loop segment uncertainty (LU) is equal to TDU. Accordingly, LU terms are presented below with results in % Span units and in engineering units (psi), based on a calibrated span of 0 to 1300 psi.

Segment 1: Sensor

The segment uncertainty (LU1) is given as:

$LU1 = \pm TDU_S$, therefore:

$LU1 = \pm\ 0.454\%\ Span = \pm\ 5.902\ psi$

Segment 2: I/E Converter

The segment uncertainty (LU2) is given as:

LU2 = ± TDU_{P1}, therefore:

LU2 = ± 0.667% Span = ± 8.671 psi

Segment 3: A/D Converter

The segment uncertainty (LU3) is given as:

LU3 = ± TDU_{P2}, therefore:

LU3 = ± 0.400% Span = ± 5.200 psi

9.3 TOTAL LOOP UNCERTAINTY

The Total Loop Uncertainty for the Main Feedwater Pressure digital indication is computed from combining the Total Device Uncertainties from the transmitter, I/E converter and A/D converter. The TLU term is presented below with results in % Span units and in engineering units (psi), based on a calibrated span of 0 to 1300 psi.

$$TLU = \pm\sqrt{TDU_S^2 + TDU_{P1}^2 + TDU_{P2}^2}$$

TLU = ± 0.901% Span = ± 11.713 psi

10.0 CONCLUSIONS

The total device uncertainty (TDU_S) and segment uncertainty (LU1) for the Main Feedwater Pressure transmitters are as follows:

TDU_S = ± 0.454% Span = ± 5.902 psi

LU1 = ± 0.454% Span = ± 5.902 psi

The total device uncertainty (TDU_{P1}) and segment uncertainty (LU2) for the Main Feedwater Pressure I/E converters are as follows:

TDU_{P1} = ± 0.667% Span = ± 8.671 psi

LU2 = ± 0.667% Span = ± 8.671 psi

The total device uncertainty (TDU_{P2}) and segment uncertainty (LU3) for the Main Feedwater Pressure A/D converters are as follows:

TDU_{P2} = ± 0.400% Span = ± 5.200 psi

LU3 = ± 0.400% Span = ± 5.200 psi

The total loop uncertainty (TLU) for the Main Feedwater Pressure digital indications on the Caldon LEFM √ + system and the Plant Computer are as follows:

TLU = ± 0.901% Span = ± 11.713 psi

ATTACHMENTS

Attachment 1 –	Excerpt from Rosemount 3051 Product Data Sheet 00813-0100-4001, Rev. HA, March 2008 [4 pages]
Attachment 2 –	Specifications for Analog Devices Single-Channel Signal Conditioning Module 5B32, printed from the http://analog.com website on 4/9/2009, including email clarification, dated 4/13/2009 [5 pages]
Attachment 3 –	Excerpt from Burr-Brown Product Data Sheet PDS-1304B for ADS7825 4 Channel, 16-Bit Sampling CMOS A/D Converter, October 1997 [3 pages]
Attachment 4 –	Burr-Brown Uncertainty Analysis for Model ADS7825 A/D Converter for 0-5 Volt Input [4 pages]

Specifications

PERFORMANCE SPECIFICATIONS

Total Performance is based on combined errors of reference accuracy, ambient temperature effect, and static pressure effect.
This product data sheet covers both HART and fieldbus protocols unless specified.

Conformance To Specification (±3σ (Sigma))

Technology leadership, advanced manufacturing techniques and statistical process control ensure specification conformance to at least ±3σ.

Reference Accuracy(1)

Models		Standard	High Accuracy Option
3051CD, 3051CG			
	Range 0 (CD)	±0.10% of span For spans less than 2:1, accuracy = ±0.05% of URL	
	Range 1	±0.10% of span For spans less than 15:1, accuracy = $\pm\left[0.025 + 0.005\left(\frac{URL}{Span}\right)\right]$% of Span	
	Ranges 2-5	±0.065% of span For spans less than 10:1, accuracy = $\pm\left[0.015 + 0.005\left(\frac{URL}{Span}\right)\right]$% of Span	Ranges 2-4 High Accuracy Option, P8 ±0.04% of span For spans less than 5:1, accuracy = $\pm\left[0.015 + 0.005\left(\frac{URL}{Span}\right)\right]$% of Span
3051T			
	Ranges 1-4	±0.065% of span For spans less than 10:1, accuracy = $\pm\left[0.0075\left(\frac{URL}{Span}\right)\right]$% of Span	Ranges 2-4 High Accuracy Option, P8 ±0.04% of span For spans less than 5:1, accuracy = $\pm\left[0.0075\left(\frac{URL}{Span}\right)\right]$% of Span
	Range 5	±0.075% of span For spans less than 10:1, accuracy = $\pm\left[0.0075\left(\frac{URL}{Span}\right)\right]$% of Span	
3051CA			
	Ranges 1-4	±0.065% of span For spans less than 10:1, accuracy = $\pm\left[0.0075\left(\frac{URL}{Span}\right)\right]$% of Span	Ranges 2-4 High Accuracy Option, P8 ±0.04% of span For spans less than 5:1, accuracy = $\pm\left[0.0075\left(\frac{URL}{Span}\right)\right]$% of Span
3051H/3051L			
	All Ranges	±0.075% of span For spans less than 10:1, accuracy = $\pm\left[0.025 + 0.005\left(\frac{URL}{Span}\right)\right]$% of Span	

(1) For FOUNDATION fieldbus transmitters, use calibrated range in place of span. For zero based spans, reference conditions, silicone oil fill, SST materials, Coplanar flange (3051C) or 1/2 in. - 18 NPT (3051T) process connections, digital trim values set to equal range points.

Product Data Sheet
00813-0100-4001, Rev HA
March 2008

Rosemount 3051

Total Performance

For ±50 °F (28 °C) temperature changes, up to 1000 psi (6,9 MPa) line pressure (CD only), from 1:1 to 5:1 rangedown.

Models		Total Performance
3051C		
	Ranges 2-5	±0.15% of span
3051T		
	Ranges 1-4	±0.15% of span

Long Term Stability

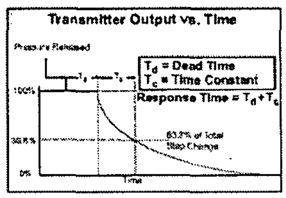
Models		Long Term Stability
3051C		
	Ranges 2-5	±0.125% of URL for 5 years ±50 °F (28 °C) temperature changes, and up to 1000 psi (6,9 MPa) line pressure.
3051CD Low/Draft Range		
	Ranges 0-1	±0.2% of URL for 1 year
3051T		
	Ranges 1-4	±0.125% of URL for 5 years ±50 °F (28 °C) temperature changes, and up to 1000 psi (6,9 MPa) line pressure.
Rosemount 3051H		
	Ranges 2-3	±0.1% of URL for 1 year
	Ranges 4-5	±0.2% of URL for 1 year

Dynamic Performance

	4 - 20 mA (*HART* protocol)[1]	Fieldbus protocol[3]
Total Response Time ($T_d + T_c$)[2]:		
3051C, Ranges 2-5:	100 ms	152 ms
Range 1:	255 ms	307 ms
Range 0:	700 ms	752 ms
3051T:	100 ms	152 ms
3051H/L:	Consult factory	Consult factory
Dead Time (Td)	45 ms (nominal)	97 ms
Update Rate	22 times per second	22 times per second

(1) Dead time and update rate apply to all models and ranges; analog output only
(2) Nominal total response time at 75 °F (24 °C) reference conditions.
(3) Transmitter fieldbus output only, segment macro-cycle not included.

Typical HART Transmitter Response Time



Line Pressure Effect per 1000 psi (6,9 MPa)

For line pressures above 2000 psi (13.7 MPa) and Ranges 4-5, see user manual (Rosemount publication number 00809-0100-4001).

Models		Line Pressure Effect
3051CD		Zero Error[1]
	Range 0	±0.125% of URL/100 psi (6,89 bar)
	Range 1	±0.25% of URL/1000 psi (68,9 bar)
	Ranges 2-3	±0.05% of URL/1000 psi (68,9 bar) for line pressures from 0 to 2000 psi (0 to 13,7 MPa)
		Span Error
	Range 0	±0.15% of reading/100 psi (6,89 bar)
	Range 1	±0.4% of reading/1000 psi (68,9 bar)
	Ranges 2-3	±0.1% of reading/1000 psi (68,9 bar)
3051HD		Zero Error[1]
	All Ranges	±0.1% of URL/1000 psi (68,9 bar) for line pressures from 0 to 2000 psi (0 to 13,7 MPa)
		Span Error
	All Ranges	±0.1% of reading/1000 psi (68,9 bar)

(1) Can be calibrated out at line pressure.

Ambient Temperature Effect per 50°F (28°C)

Models		Ambient Temperature Effect
3051CD/CG		
	Range 0	±(0.25% URL + 0.05% span)
	Range 1	±(0.1% URL + 0.25% span)
	Ranges 2-5	±(0.0125% URL + 0.0625% span) from 1:1 to 5:1
		±(0.025% URL + 0.125% span) from 5:1 to 100:1
3051T		
	Range 1	±(0.025% URL + 0.125% span) from 1:1 to 10:1
		±(0.05% URL + 0.125% span) from 10:1 to 100:1
	Range 2-4	±(0.025% URL + 0.125% span) from 1:1 to 30:1
		±(0.035% URL + 0.125% span) from 30:1 to 100:1
	Range 5	±(0.1% URL + 0.15% span)
3051CA		
	All Ranges	±(0.025% URL + 0.125% span) from 1:1 to 30:1
		±(0.035% URL + 0.125% span) from 30:1 to 100:1
3051H		
	All Ranges	±(0.025% URL + 0.125% span + 0.35 inH_2O) from 1:1 to 30:1
		±(0.035% URL + 0.125% span + 0.35 inH_2O) from 1:1 to 30:1
3051L		See Rosemount Inc. Instrument Toolkit® software.

Mounting Position Effects

Models	Mounting Position Effects
3051C	Zero shifts up to ±1.25 inH_2O (3.11 mbar), which can be calibrated out. No span effect.
3051H	Zero shifts up to ±5 inH_2O (12.43 mbar), which can be calibrated out. No span effect.
3051L	With liquid level diaphragm in vertical plane, zero shift of up to 1 inH_2O (2.49 mbar). With diaphragm in horizontal plane, zero shift of up to 5 inH_2O (12.43 mbar) plus extension length on extended units. All zero shifts can be calibrated out. No span effect.
3051T/CA	Zero shifts up to 2.5 inH_2O (6.22 mbar), which can be calibrated out. No span effect.

Vibration Effect

All Models

Measurement effect due to vibrations is negligible except at resonance frequencies. When at resonance frequencies, vibration effect is less than ±0.1% of URL per g when tested between 15 and 2000 Hz in any axis relative to pipe-mounted process conditions.

Power Supply Effect

All Models

Less than ±0.005% of calibrated span per volt.

RFI Effects

All Models

±0.1% of span from 20 to 1000 MHz and for field strength up to 30 V/m.

Transient Protection (Option Code T1)

All Models:

Meets IEEE C62.41, Category B
- 6 kV crest (0.5 μs - 100 kHz)
- 3 kV crest (8 × 20 microseconds)
- 6 kV crest (1.2 × 50 microseconds)

Meets IEEE C37.90.1, Surge Withstand Capability
- SWC 2.5 kV crest, 1.25 MHz wave form

General Specifications:
- Response Time: < 1 nanosecond
- Peak Surge Current: 5000 amps to housing
- Peak Transient Voltage: 100 V dc
- Loop Impedance: < 25 ohms
- Applicable Standards: IEC61000-4-4, IEC61000-4-5

NOTE:
Calibrations at 68 °F (20 °C) per ASME Z210.1 (ANSI)

Product Data Sheet
00813-0100-4001, Rev HA
March 2008

FUNCTIONAL SPECIFICATIONS

Range and Sensor Limits

TABLE 1. 3051CD, 3051CG, 3051L, and 3051H Range and Sensor Limits

Range	Minimum Span	Range and Sensor Limits						
			Lower (LRL)					
	3051CD(1), CG, L, H	Upper (URL)	3051C Differential	3051C/ Gage	3051L Differential	3051L Gage	3051H Differential	3051H Gage
0	0.1 inH$_2$O (0.25 mbar)	3.0 inH$_2$O (7.47 mbar)	–3.0 inH$_2$O (-7.47 mbar)	NA	NA	NA	NA	NA
1	0.5 inH$_2$O (1.2 mbar)	25 inH$_2$O (62.3 mbar)	–25 inH$_2$O (–62.1 mbar)	–25 inH$_2$O (–62.1 mbar)	NA	NA	NA	NA
2	2.5 inH$_2$O (6.2 mbar)	250 inH$_2$O (0.62 bar)	–250 inH$_2$O (–0.62 bar)	–250 inH$_2$O (–0.62 bar)	–250 inH$_2$O (–0.62 bar)	–250 inH$_2$O (–0.62 bar)	–250 inH$_2$O (–0.62 bar)	–250 inH$_2$O (–0.62 bar)
3	10 inH$_2$O (24.9 mbar)	1000 inH$_2$O (2.49 bar)	–1000 inH$_2$O (–2.49 bar)	0.5 psia (34.5 mbar abs)	–1000 inH$_2$O (–2.49 bar)	0.5 psia (34.5 mbar abs)	–1000 inH$_2$O (–2.49 bar)	0.5 psia (34.5 mbar abs)
4	3 psi (0.20 bar)	300 psi (20.6 bar)	–300 psi (–20.6 bar)	0.5 psia (34.5 mbar abs)	–300 psi (–20.6 bar)	0.5 psia (34.5 mbar abs)	–300 psi (–20.6 bar)	0.5 psia (34.5 mbar abs)
5	20 psi (1.38 bar)	2000 psi (137.9 bar)	– 2000 psi (–137.9 bar)	0.5 psia (34.5 mbar abs)	NA	NA	– 2000 psi (–137.9 bar)	0.5 psia (34.5 mbar abs)

(1) *Range 0 only available with 3051CD. Range 1 only available with 3051CD or 3051CG.*

TABLE 2. Range and Sensor Limits

Range	3051CA Minimum Span	3051CA Range and Sensor Limits Upper (URL)	3051CA Lower (LRL)
1	0.3 psia (20.6 mbar)	30 psia (2.07 bar)	0 psia (0 bar)
2	1.5 psia (0.103 bar)	150 psia (10.3 bar)	0 psia (0 bar)
3	8 psia (0.55 bar)	800 psia (55.2 bar)	0 psia (0 bar)
4	40 psia (2.76 bar)	4000 psia (275.8 bar)	0 psia (0 bar)

Range	3051T Minimum Span	3051T Range and Sensor Limits Upper (URL)	3051T Lower (LRL)	3051T Lower(1) (LRL) (Gage)
1	0.3 psi (20.6 mbar)	30 psi (2.07 bar)	0 psia (0 bar)	–14.7 psig (–1.01 bar)
2	1.5 psi (0.103 bar)	150 psi (10.3 bar)	0 psia (0 bar)	–14.7 psig (–1.01 bar)
3	8 psi (0.55 bar)	800 psi (55.2 bar)	0 psia (0 bar)	–14.7 psig (–1.01 bar)
4	40 psi (2.76 bar)	4000 psi (275.8 bar)	0 psia (0 bar)	–14.7 psig (–1.01 bar)
5	2000 psi (137.9 bar)	10000 psi (689.4 bar)	0 psia (0 bar)	–14.7 psig (–1.01 bar)

(1) *Assumes atmospheric pressure of 14.7 psig.*

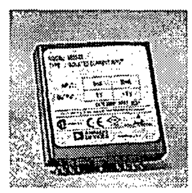
ANALOG DEVICES

5B32 Isolated Current Input

5B Series Overview | 5B Series Model Definitions | Available 5B Series Modules | 5B Series Backplanes and Mounting Cards | 5B and 7B Series Power Supplies | 5B Series Accessories | 5B Series Configuration Guide | 5B Series Custom Configuration Ranges | 7B Series Modules

Specifications

Functional Description



The 5B32 is a single-channel signal conditioning module that amplifies, protects, filters and isolates its analog input. The module measures a process-current input signal of 4-20 mA or 0-20 mA by reading the voltage across an external precision 20 Ω resistor (supplied) and generating an output of 0 to +5 V. Extra current conversion resistors are available as accessories (See Model AC1362 in the Accessories section).

Note that the 5B32 module circuitry can withstand 240 V rms at the input screw-terminals, thereby shielding computer-side circuitry from field-side overvoltage conditions. In addition, all 5B32 Series modules are mix-and-match and hot swappable, so can be inserted or removed from any socket in the same backplane without powering down the system.

Inside the 5B32 Series Module

A chopper-stabilized input amplifier provides low drift and stable gain. At the amplifier input, a stable, laser-trimmed zero-scale input offset is subtracted from the input signal to set the zero-scale value for the 4-20 mA range. For user convenience, the zero can be optionally factory-set to meet custom needs. This allows suppression of a zero-scale input value many times larger than the total span for precise expanded-scale measurements.

Internal multi-pole lowpass filtering with a four-Hz cutoff (-3dB) enhances normal-mode (noise on signal) and common-mode (noise on signal return) rejection at 50/60 Hz, enabling accurate measurement of small signals in high electrical noise.

Signal isolation by transformer coupling uses a proprietary modulation technique for linear, stable and reliable performance. The differential input circuit on the field side is fully floating, eliminating the need for input grounding. A demodulator on the computer side of the signal transformer recovers the *original signal, which is then filtered and buffered to provide a low-noise, low-impedance output signal. The output common must be kept within ±3 Vdc of* power common

Convenience Features

A series output switch eliminates the need for external multiplexing in many applications. The switch is turned on by an active-low enable input. If the switch is to be on at all times, the enable-input should be grounded to power common as it is on the 5B01 and 5B08 backplanes.

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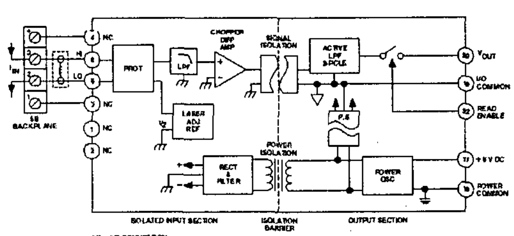

Figure 1. 5B32 Functional Block Diagram

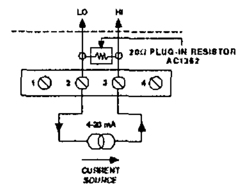

Figure 2. 5B32 Input Field Connections

Input Ranges	Output Ranges
4 mA to 20 mA	0 to +5 V (-5 V to +5 V custom)

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5B32 Models Available

	Model	Input Range	Output Range
Order Now	5B32-01	4 mA to 20 mA	0 V to +5 V
Order Now	5B32-02	0 mA to 20 mA	0 V to +5 V
	5B32-Custom	*	*

* *Custom Input/Output ranges are available.*

Refer to configuration guide.

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5B32 Specifications

Description	Model 5B32
Input Ranges	
Standard Ranges	0 mA to 20 mA or 4 mA to 20 mA
Custom Ranges	0 mA to 20 mA (refer to ordering section)
Output Ranges (R_L > 50 kΩ)[4]	-5 V to +5 V or 0 V to +5 V
Accuracy[2]	
Initial @ +25°C	±0.05% Span ±0.05% Iz[1]
Nonlinearity	±0.02% Span
Input Offset vs. Temperature	±0.0025 of Iz/°C
Output Offset vs. Temperature	±20 µV/°C
Gain vs. Temperature	±0.0025% of Reading/°C
Input Resistor[5]	
Value	20.0 Ω
Accuracy	±0.1%
Stability vs. Temperature	±0.001%/°C
Noise	
Input, 0.1 Hz to 10 Hz Bandwidth	10 nA rms
Output, 100 kHz Bandwidth	200 µV rms
Bandwidth, -3 dB	4 Hz
Output Rise Time, 10% to 90% Span	200 ms
Common-Mode Voltage (CMV)[3]	
Input-to-Output, Continuous	1500 V rms maximum
Output-to-Power, Continuous	±3 V maximum

Transient	ANSI/IEEE C37.90.1-1989
Common Mode Rejection (CMR)	
1 kΩ Source Imbalance, 50/60 Hz	100 dB
Normal Mode Rejection 50/60 Hz	60 dB
Input Protection	
Continuous	240 V rms maximum
Transient	ANSI/IEEE C37.90.1-1989
Output Resistance[4]	50 Ω
Voltage Output Protection	Continuous Short to Ground
Output Selection Time	6 µs @ C_{load} = 0 to 2,000 pF
Output Enable Control	
Max Logic "0"	+1 V
Min Logic "1"	+2.5 V
Max Logic "1"	+36 V
Input Current "0"	0.4 mA
Power Supply Voltage	+5 V ±5%
Power Supply Current	30 mA
Power Supply Sensitivity, RTI	±2 µV/%
Mechanical Dimensions	2.275" × 2.375" × 0.595" (57.8 mm × 59.1 mm × 15.1 mm)
Environmental	
Temperature Range	
Rated Performance	-25°C to +85°C
Operating	-40°C to +85°C
Storage	-40°C to +85°C
Relative Humidity	0 to 93% @ +40°C noncondensing
RFI Susceptibility	±0.5% Span error @ 400 MHz, 5 Watt, 3 ft

[1] I_0 is the nominal input current that results in a 0 V output

[2] Includes the combined effects of repeatability, hysteresis, and nonlinearity and assumes R_L > 50 kΩ. Does not include current-to-voltage input resistor (AC1362) error

[3] The output common must be kept within ±3 V of power common

[4] Loads heavier than 50 kΩ will degrade nonlinearity and gain temperature coefficient

[5] The current-to-voltage conversion resistor (AC1362) is supplied as a plug-in component for mounting external to the module. All [illegible] provide pin sockets for mounting the AC1362 resistor

Specifications subject to change without notice

[illegible]

Kirk Melson

From: "Kellogg, Jim" <Jim.Kellogg@analog.com>
Date: Monday, April 13, 2009 11:58 AM
To: "Kirk Melson" <kirk.melson@excelservices.com>
Subject: RE: Specification Clarification for 5B32

Hi Kirk,

You are correct about the Input Offset Spec. It should be 0.0025%, not 0.0025.
For the 5B32-01 module I get the following error terms vs. temperature

- Input Offset 0.0025% of 4mA → 0.1uA/°C or 0.00063%/°C
- Output Offset 20uV/°C → 0.064uA/°C or 0.00040%/°C
- Gain TC 0.0025%/°C → 0.5uA/°C or 0.003125%/°C

Total accuracy error vs. temp of 0.664uA/°C or 0.0041%/°C

Sorry for the confusion on the datasheets, I hope this helps.

Regards,
Jim

From: Kirk Melson [mailto:kirk.melson@excelservices.com]
Sent: 2009-04-13 10:47
To: Kellogg, Jim
Subject: Fw: Specification Clarification for 5B32

Jim,

Sorry, I got the email address wrong. Try this again. Could you call me when you get a chance?

Kirklyn R. Melson
Excel Services Corporation
(864)962-5701 Cell
(864)228-7100 Alternate and Fax

From: Kirk Melson
Sent: Thursday, April 09, 2009 5:50 PM
To: jim.kellog@analog.com
Cc: Bob Hunter
Subject: Specification Clarification for 5B32

Jim,

I just called a moment ago and got your voice mail. Since I would like an email response anyway, I decided to write this up in an email.

I printed the 5B32 specification from your website, and I marked it up to show where my question is. The specification in question is the Input Offset versus Temperature, which shows up in the table as 0.0025 of Iz / degree C. The specifications above this are shown as percentages. I am wondering if this specification should say 0.0025% of Iz / degree C.

4/13/2009

We are working with a Caldon Ultrasonic flowmeter system, and we need tight accuracy. The room temperature could change as much as 50 degrees F in that room. We have a 4 to 20 mAdc signal coming in. If this specification is correct, I think I compute an error just due to this effect as:

Input Offset due to Temp = (0.0025 x 4 mA) x (100% Span / 16 mAdc) x (1 degree C / 1 degree F) x 50 degrees F = 1.74% Span.

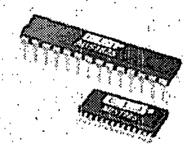
This is a huge error for this module. If the specification actually should have a "%" listed, the error goes to around 0.0174% Span, which is much more reasonable in my opinion.

Anyway, if you get just a minute, I would really appreciate your looking at this specification and clarifying it for me. I am in a bit of a time crunch on this one, so your quick attention would be greatly appreciated.

Thanks for your time and consideration.

Kirklyn R. Melson
Excel Services Corporation
(864)962-5701 Cell
(864)228-7100 Alternate and Fax

BURR-BROWN®



ADS7825

www.burr-brown.com/databook/ADS7825.html

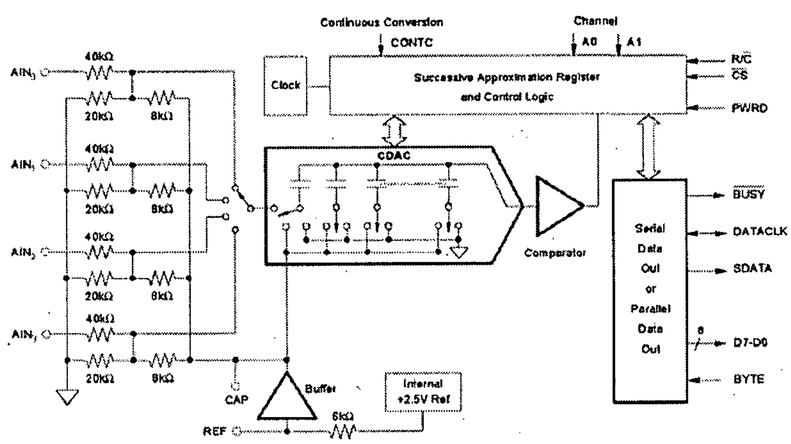
4 Channel, 16-Bit Sampling CMOS A/D Converter

FEATURES

- 25μs max SAMPLING AND CONVERSION
- SINGLE +5V SUPPLY OPERATION
- PIN-COMPATIBLE WITH 12-BIT ADS7824
- PARALLEL AND SERIAL DATA OUTPUT
- 28-PIN 0.3" PLASTIC DIP AND SOIC
- ±2.0 LSB max INL
- 50mW max POWER DISSIPATION
- 50μW POWER DOWN MODE
- ±10V INPUT RANGE, FOUR CHANNEL MULTIPLEXER
- CONTINUOUS CONVERSION MODE

DESCRIPTION

The ADS7825 can acquire and convert 16 bits to within ±2.0 LSB in 25μs max while consuming only 50mW max. Laser-trimmed scaling resistors provide the standard industrial ±10V input range and channel-to-channel matching of ±0.1%. The ADS7825 is a low-power 16-bit sampling A/D with a four channel input multiplexer, S/H, clock, reference, and a parallel/serial microprocessor interface. It can be configured in a continuous conversion mode to sequentially digitize all four channels. The 28-pin ADS7825 is available in a plastic 0.3" DIP and in a SOIC, both fully specified for operation over the industrial −40°C to +85°C range.



International Airport Industrial Park • Mailing Address: PO Box 11400, Tucson, AZ 85734 • Street Address: 6730 S. Tucson Blvd., Tucson, AZ 85706 • Tel: (520) 746-1111 • Twx: 910-952-1111
Internet: http://www.burr-brown.com/ • FAXLine: (800) 548-6133 (US/Canada Only) • Cable: BBRCORP • Telex: 066-6491 • FAX: (520) 889-1510 • Immediate Product Info: (800) 548-6132

 PDS-1304B Printed in U.S.A. October, 1997

SBAS045

SPECIFICATIONS

ELECTRICAL

At T_A = –40°C to +85°C, f_S = 40kHz, V_{S1} = V_{S2} = V_S = +5V ±5%, using external reference, CONTC = 0V, unless otherwise specified.

PARAMETER	CONDITIONS	ADS7825P, U MIN	ADS7825P, U TYP	ADS7825P, U MAX	ADS7825PB, UB MIN	ADS7825PB, UB TYP	ADS7825PB, UB MAX	UNITS
RESOLUTION				16			*(1)	Bits
ANALOG INPUT								
Voltage Range			±10V			*		V
Impedance	Channel On or Off		45.7			*		kΩ
Capacitance			35			*		pF
THROUGHPUT SPEED								
Conversion Time			20			*		µs
Acquisition Time			5			*		µs
Multiplexer Settling Time	Includes Acquisition		5			*		µs
Complete Cycle (Acquire and Convert)				25			*	µs
Complete Cycle (Acquire and Convert)	CONTC = +5V			40			*	µs
Throughput Rate		40			*			kHz
DC ACCURACY								
Integral Linearity Error				±3			±2	LSB(2)
No Missing Codes		15			16			
Transition Noise(3)			0.8			*		LSB
Full Scale Error(4)	Internal Reference			±0.5			±0.25	%
Full Scale Error Drift	Internal Reference		±7			±5		ppm/°C
Full Scale Error(4)				±0.5			±0.25	%
Full Scale Error Drift			±2			*		ppm/°C
Bipolar Zero Error				±10			*	mV
Bipolar Zero Error Drift			±2			*		ppm/°C
Channel-to-Channel Mismatch				±0.1			±0.1	%
Power Supply Sensitivity	+4.75 < V_S < +5.25			±8			*	LSB
AC ACCURACY								
Spurious-Free Dynamic Range(5)	f_{IN} = 1kHz	90			*			dB
Total Harmonic Distortion	f_{IN} = 1kHz			–90			*	dB
Signal-to-(Noise+Distortion)	f_{IN} = 1kHz	83			86			dB
Signal-to-Noise	f_{IN} = 1kHz	83			86			dB
Channel Separation(6)	f_{IN} = 1kHz	100	120		*	*		dB
–3dB Bandwidth			2			*		MHz
Useable Bandwidth(7)			90			*		kHz
SAMPLING DYNAMICS								
Aperture Delay			40			*		ns
Transient Response(8)	FS Step		5			*		µs
Overvoltage Recovery(9)			1			*		µs
REFERENCE								
Internal Reference Voltage		2.48	2.5	2.52	*	*	*	V
Internal Reference Source Current (Must use external buffer)			1			*		µA
External Reference Voltage Range for Specified Linearity		2.3	2.5	2.7	*	*	*	V
External Reference Current Drain	V_{REF} = +2.5V			100			*	µA
DIGITAL INPUTS								
Logic Levels								
V_{IL}		–0.3		+0.8	*		*	V
V_{IH}		+2.4		V_S +0.3V	*		*	V
I_{IL}				±10			*	µA
I_{IH}				±10			*	µA
DIGITAL OUTPUTS								
Data Format			Parallel in two bytes; Serial			*		
Data Coding			Binary Two's Complement			*		
V_{OL}	I_{SINK} = 1.6mA			+0.4			*	V
V_{OH}	I_{SOURCE} = 500µA	+4			*			V
Leakage Current	*High-Z State, V_{OUT} = 0V to V_S*			±5			*	µA
Output Capacitance	High-Z State			15			*	pF

SPECIFICATIONS (CONT)

ELECTRICAL

At T_A = –40°C to +85°C, f_S = 40kHz, V_{S1} = V_{S2} = V_S = +5V ±5%, using external reference, CONTC = 0V, unless otherwise specified.

		ADS7825P, U			ADS7825PB, UB			
PARAMETER	CONDITIONS	MIN	TYP	MAX	MIN	TYP	MAX	UNITS
DIGITAL TIMING								
Bus Access Time	PAR/$\overline{SER}$ = +5V			83			*	ns
Bus Relinquish Time	PAR/$\overline{SER}$ = +5V			83			*	ns
Data Clock	PAR/$\overline{SER}$ = 0V							
Internal Clock (Output only when transmitting data)	EXT/$\overline{INT}$ LOW	0.5		1.5	*		*	MHz
External Clock	EXT/$\overline{INT}$ HIGH	0.1		10	*		*	MHz
POWER SUPPLIES								
$V_{S1} = V_{S2} = V_S$		+4.75	+5	+5.25	*	*	*	V
Power Dissipation	f_S = 40kHz			50			*	mW
	PWRD HIGH		50			*		µW
TEMPERATURE RANGE								
Specified Performance		–40		+85	*		*	°C
Storage		–65		+150	*		*	°C
Thermal Resistance (θ_{JA})								
Plastic DIP			75			*		°C/W
SOIC			75			*		°C/W

NOTES: (1) An asterik (*) specifies same value as grade to the left. (2) LSB means Least Significant Bit. For the 16-bit, ±10V input ADS7825, one LSB is 305µV. (3) Typical rms noise at worst case transitions and temperatures. (4) Full scale error is the worst case of –Full Scale or +Full Scale untrimmed deviation from ideal first and last code transitions, divided by the transition voltage (not divided by the full-scale range) and includes the effect of offset error. (5) All specifications in dB are referred to a full-scale ±10V input. (6) A full scale sinewave input on one channel will be attenuated by this amount on the other channels. (7) Useable Bandwidth defined as *Full-Scale input frequency at which Signal-to-(Noise+Distortion) degrades to 60dB, or 10 bits of accuracy. (8) The ADS7825 will accurately acquire any input step if given* a full acquisition period after the step. (9) Recovers to specified performance after 2 x FS input overvoltage, and normal acquisitions can begin.

PACKAGE/ORDERING INFORMATION

PRODUCT	PACKAGE	PACKAGE DRAWING NUMBER(1)	TEMPERATURE RANGE	MAXIMUM INTEGRAL LINEARITY ERROR (LSB)	MINIMUM SIGNAL-TO-(NOISE + DISTORTION) RATIO (dB)
ADS7825P	Plastic Dip	246	–40°C to +85°C	±3	83
ADS7825PB	Plastic Dip	246	–40°C to +85°C	±2	86
ADS7825U	SOIC	217	–40°C to +85°C	±3	83
ADS7825UB	SOIC	217	–40°C to +85°C	±2	86

NOTE: (1) For detailed drawing and dimension table, please see end of data sheet, or Appendix C of Burr-Brown IC Data Book.

ABSOLUTE MAXIMUM RATINGS

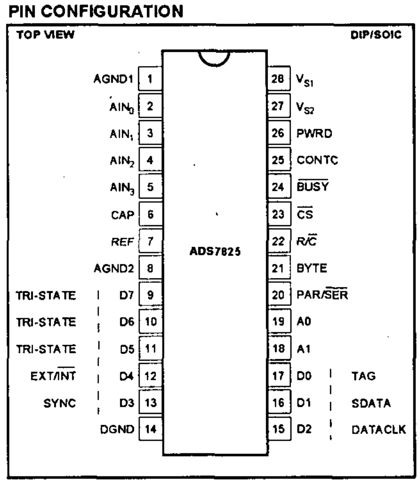
Analog Inputs: AIN_0, AIN_1, AIN_2, AIN_3	±15V
REF	(AGND2 –0.3V) to (V_S + 0.3V)
CAP	Indefinite Short to AGND2, Momentary Short to V_S
V_{S1} and V_{S2} to AGND2	7V
V_{S1} to V_{S2}	±0.3V
Difference between AGND1, AGND2 and DGND	±0.3V
Digital Inputs and Outputs	–0.3V to (V_S + 0.3V)
Maximum Junction Temperature	150°C
Internal Power Dissipation	825mW
Lead Temperature (soldering, 10s)	+300°C
Maximum Input Current to Any Pin	100mA

ELECTROSTATIC DISCHARGE SENSITIVITY

This integrated circuit can be damaged by ESD. Burr-Brown recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

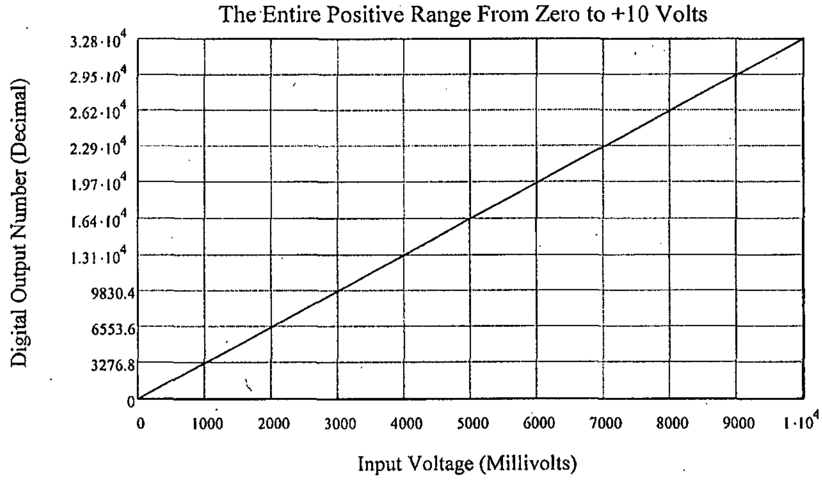
ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

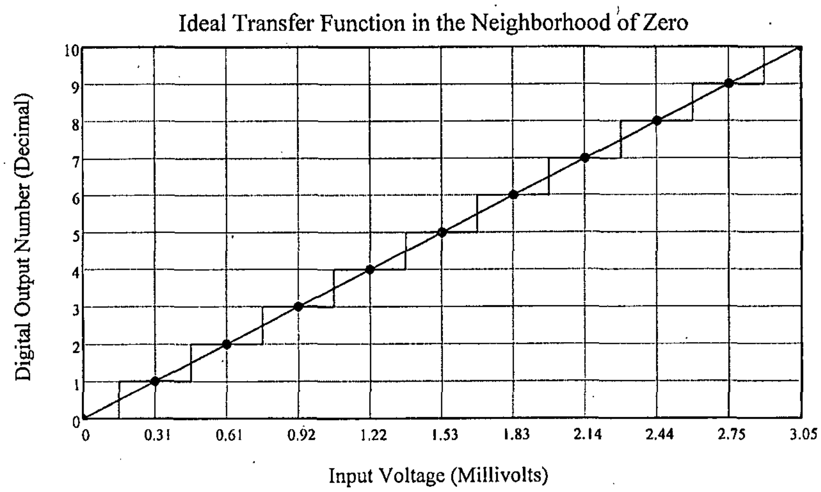
PIN CONFIGURATION

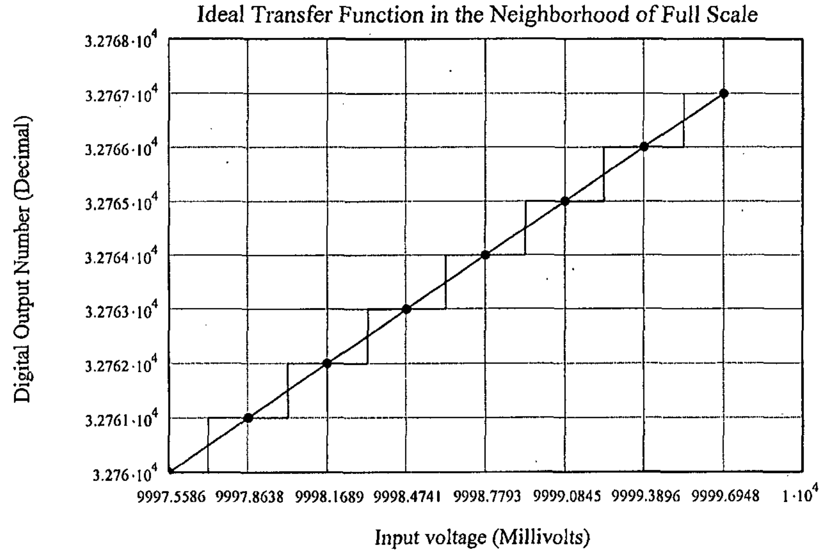


Ideal ADC Transfer Functions for the Positive Range of the Burr Brown ADS7825

$Vpfs := 10$ $N := 2^{15}$ $n := 0..(N-1)$ $LSBi := \frac{Vpfs}{N} \cdot 10^3$ $vti_n := n \cdot LSBi$







Transfer Functions Considering Only Offset Error and Full-Scale Error

Using the values from the ADS7825 data sheet: Vos = +/-10 mV (+/-33LSBi where LSBi = 20*2^(-16)) and FSE = +/-10*0.25/100 = +/-25mV (+/-82LSBi). Note 4 states that the full-scale error *includes* the offset error which leads me to believe that the full-scale error with offset zeroed out is (82 - 33)*LSBi = +/-49LSBi (since offset errors shift the ideal transfer function to the right or left). This means that there are two slopes for the worst case transfer functions which are slightly different from the slope of the ideal transfer function. This translates into slightly different values of LSB for the two cases: LSB1 for the slope corresponding to the -49 LSBi error; and, LSB2 for the slope corresponding to the +49 LSBi error given by:

$$LSB1 := \frac{10^4 - 49 \cdot LSBi}{32768} \qquad LSB1 = 0.30472$$

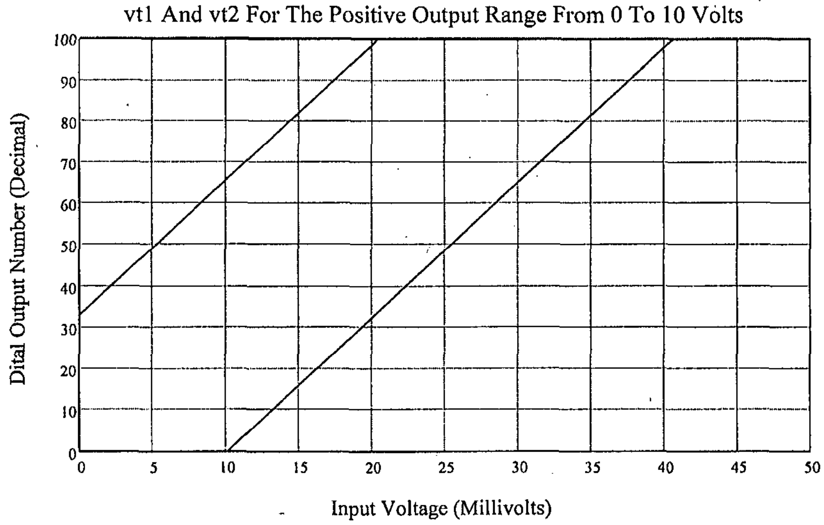
$$LSBi = 0.30518$$

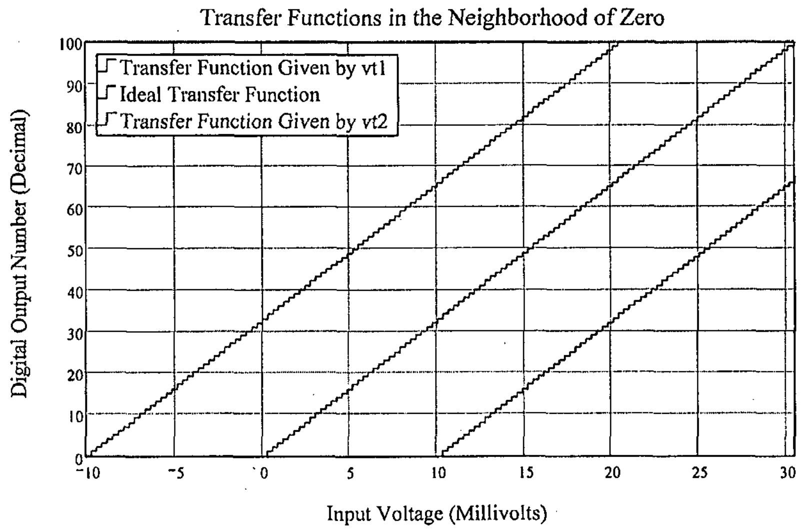
$$LSB2 := \frac{10^4 + 49 \cdot LSBi}{32768} \qquad LSB2 = 0.30563$$

Then the offsets can be added in to give the worst case transfer functions where the offset and gain errors add together so as to make the total error the greatest. These two straight lines are the envelope of the bundle of all possible straight lines which meet the offset and FSE of the part.

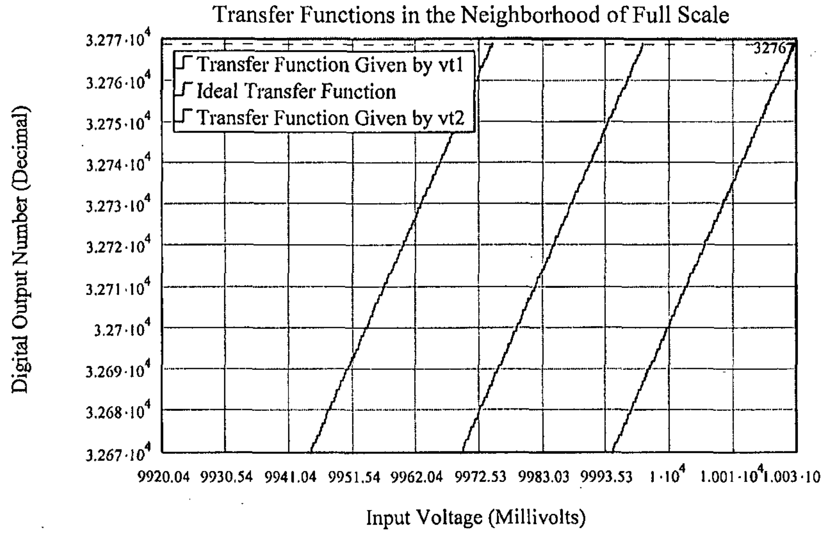
$$vt1_n := -33 \cdot LSBi + LSB1 \cdot n$$

$$vt2_n := 33 \cdot LSBi + LSB2 \cdot n$$

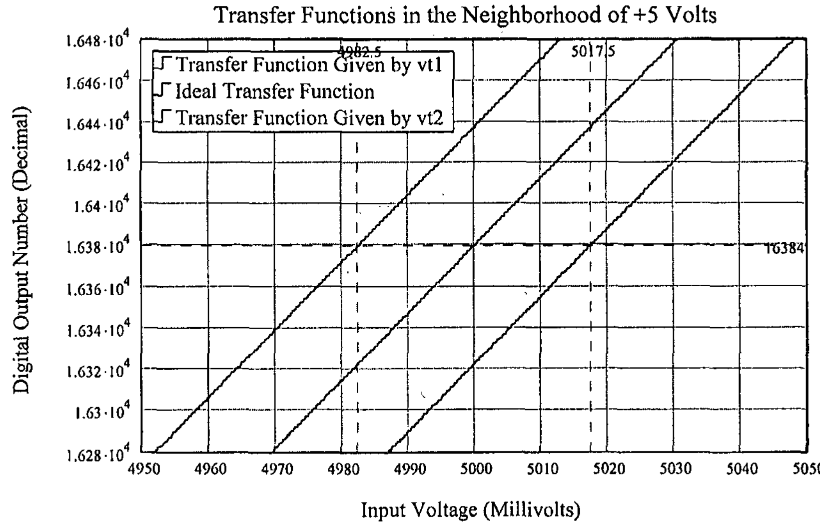

vt1 And vt2 For The Positive Output Range From 0 To 10 Volts
Dital Output Number (Decimal)
0
10
20
30
40
50
60
70
80
90
100
0
5
10
15
20
25
30
35
40
45
50
Input Voltage (Millivolts)


Transfer Functions in the Neighborhood of Zero
Transfer Function Given by vt1
Ideal Transfer Function
Transfer Function Given by vt2
Digital Output Number (Decimal)
0
10
20
30
40
50
60
70
80
90
100
−10
−5
0
5
10
15
20
25
30
Input Voltage (Millivolts)

Transfer Functions in the Neighborhood of Full Scale



Transfer Functions in the Neighborhood of +5 Volts



The worst case error at n = 16384 (where vti = 5000 mV) is +/- 17.5 mV (+/- 16.44LSBi). In general, the worst case error at any voltage V in mV is +/- (vt2-V) with vt2 evaluated at n = (V/10000)*32768.