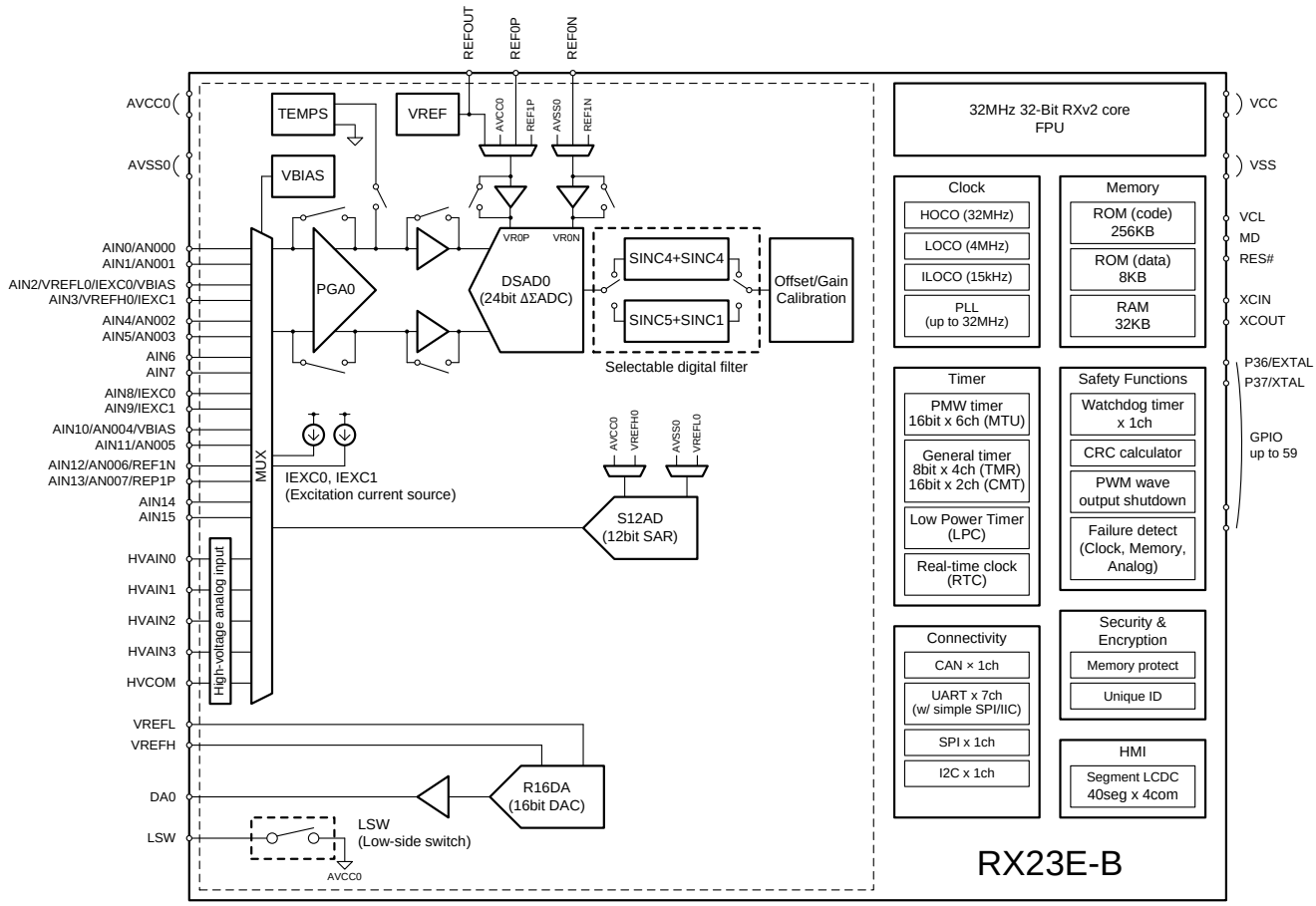
RX23E-B Group

Analog Front End Typical Characteristics

Overview

This document shows typical analog characteristics of 24-bit Δ-Σ A/D converter (DSAD), 16-bit D/A converter (DA) and analog front end (AFE) in RX23E-B.



Target device

RX23E-B

The analog characteristics in this document are the evaluation results of typical samples and are for reference.

Contents

1. RX23E-B Analog Front End Features

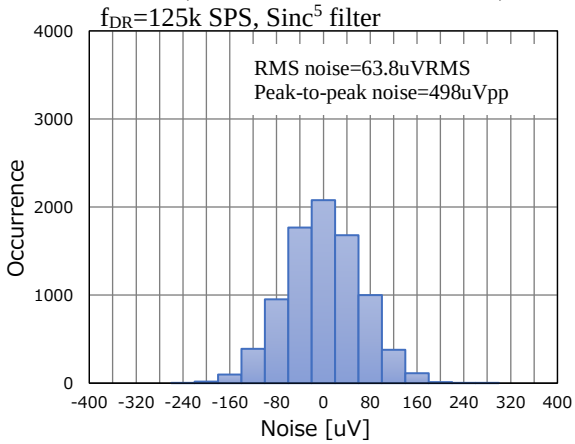
- One 24-bit delta-sigma A/D converter
- A/D converter with up to 24-bit effective resolution (gain=1, output data rate=3.8SPS)
- High-precision programmable gain instrumentation amplifier
  11nVRMS (gain=128, output data rate=3.8SPS)
- Rail-to-rail programmable gain instrumentation amplifier(gain=1 to 128)
- Programmable data rate : 3.8SPS to 125kSPS (fMOD=4MHz)
- Offset drift 4nV/°C (gain=64 to 128)
- Gain drift 1ppm/°C (gain=1 to 16 (PGA enable))
- Up to eight differential inputs, 16 single-ended inputs
- Four types of digital filters
  Fourth-order sinc filter
  Fourth-order sinc filter + fourth-order sinc filter
  Fifth-order sinc filter
  Fifth-order sinc filter + first-order sinc filter
- Simultaneous 50Hz/60Hz rejection (output data rate=10, 54SPS)
- Offset error and gain error calibration
- ±10-V input pins
- Delta-sigma A/D input disconnect detection assist
- Delta-sigma A/D reference voltage external input
- Voltage reference output voltage : 2.5V, temperature drift : 8ppm/°C (Ta=–40 to +85°C),
  output current: ±10 mA
- Excitation current sources : Up to two
  Output current : 50µA to 1000µA, current matching: ±0.2%,
  drift matching: 5 ppm/°C
- Bias voltage generator output voltage : (AVCC0+AVSS0)/2
- Temperature sensor : Accuracy ±5°C
- Low-side switch : 10Ω on-resistance
- Low power-supply-voltage detectors
- Delta-sigma A/D input voltage fault detectors
- Delta-sigma A/D reference voltage fault detectors and disconnect detectors
- Excitation current source disconnect detectors
- High-voltage analog common input disconnect detector
- 16-bit D/A converter
  One channel
  DNL=±1LSB, INL=±5LSB (max, VREFH≥4.5V)

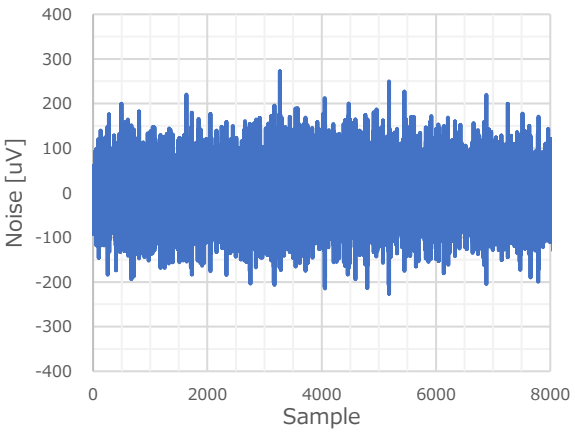
2. 24-bit Delta-Sigma A/D Converter

2.1 Noise histogram, Plot of Noise

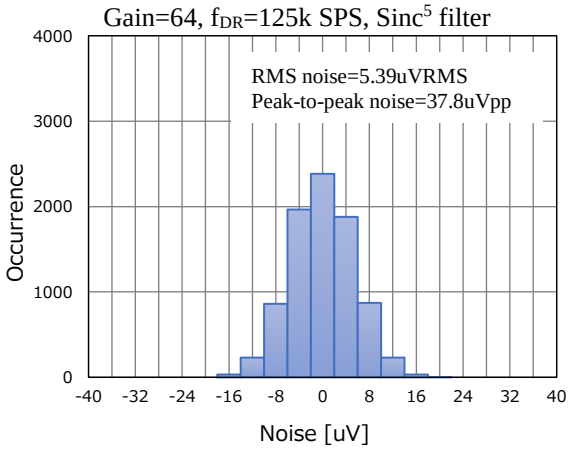
AVCC0=5V, Ta=25℃, f_{MOD}=4MHz, V_{ID}=0V, External V_{REF}=2.5V, Reference buffer disabled

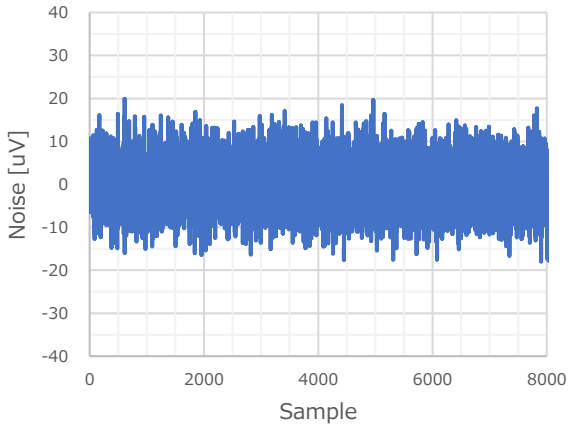
Gain=1(PGA disabled, BUF disabled),
f_{DR}=125k SPS, $Sinc^5$ filter



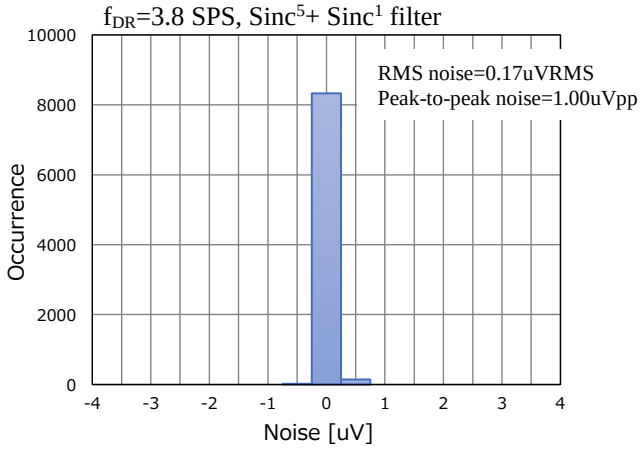


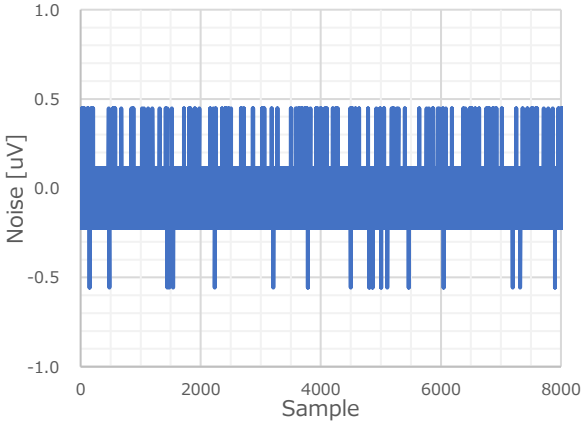
Gain=64, f_{DR}=125k SPS, $Sinc^5$ filter



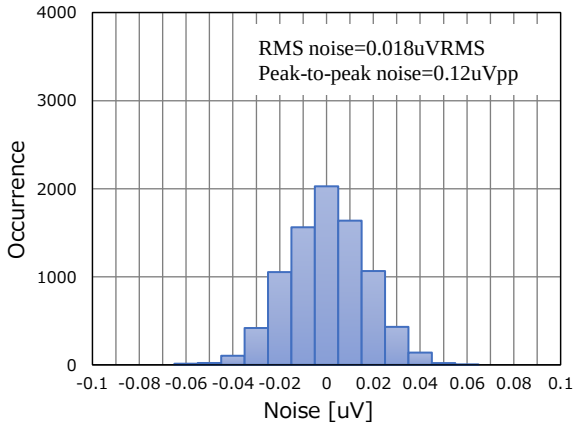


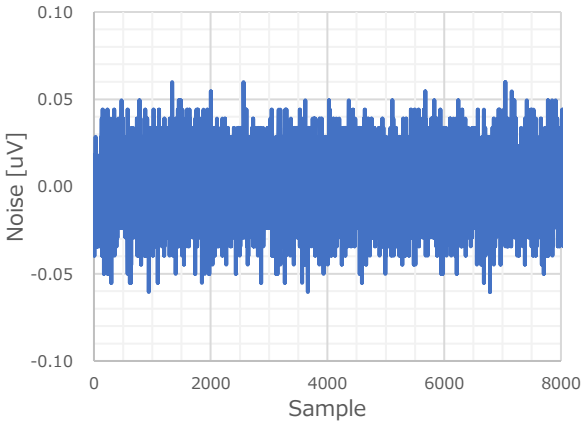
Gain=1(PGA disabled, BUF disabled),
f_{DR}=3.8 SPS, $Sinc^5$+ $Sinc^1$ filter



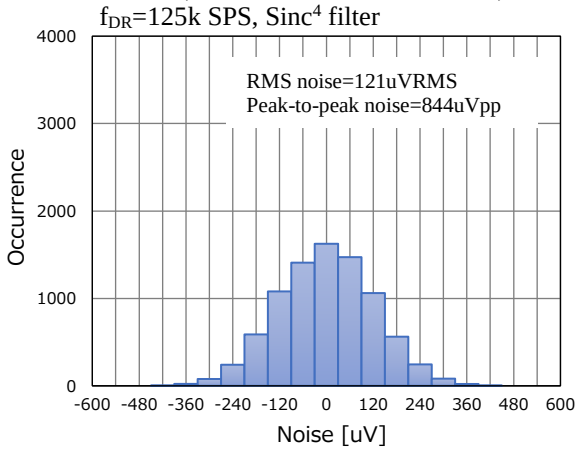


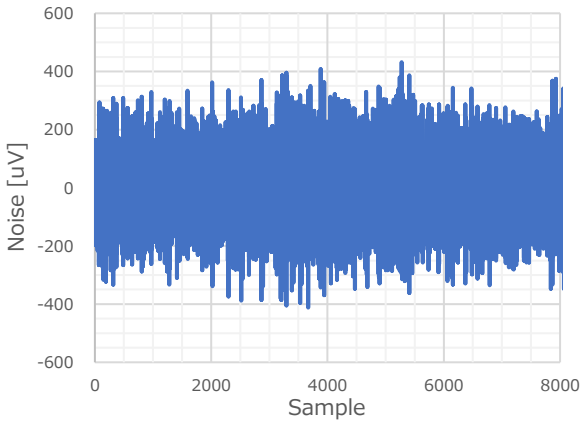
Gain=64, f_{DR}=3.8 SPS, $Sinc^5$+ $Sinc^1$ filter



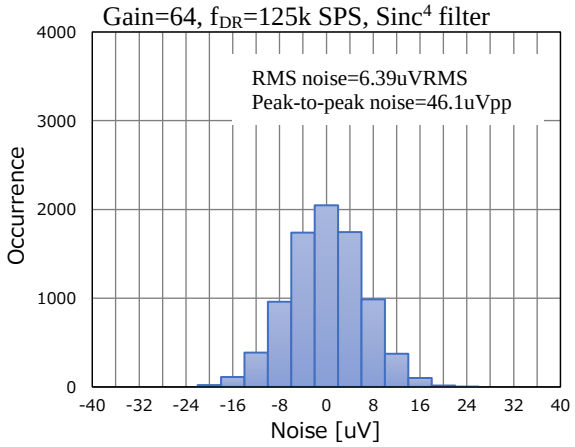


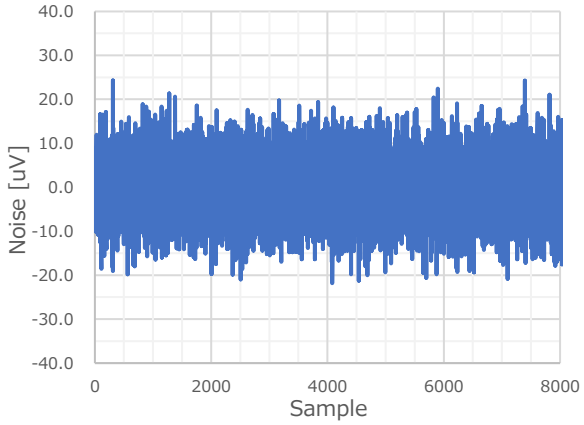
Gain=1(PGA disabled, BUF disabled),
f_{DR}=125k SPS, $Sinc^4$ filter



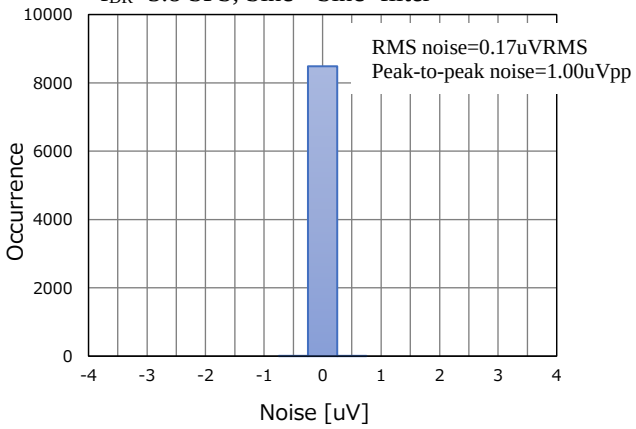


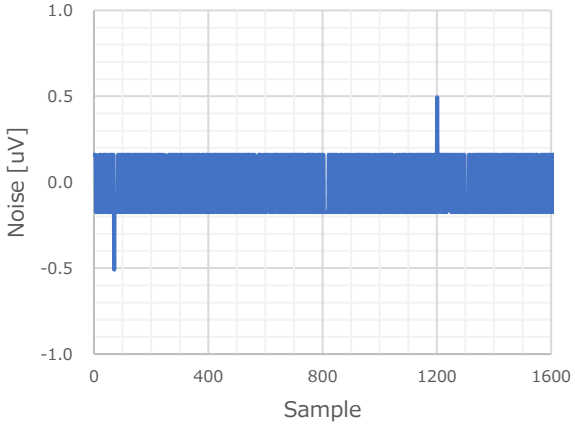
Gain=64, f_{DR}=125k SPS, $Sinc^4$ filter



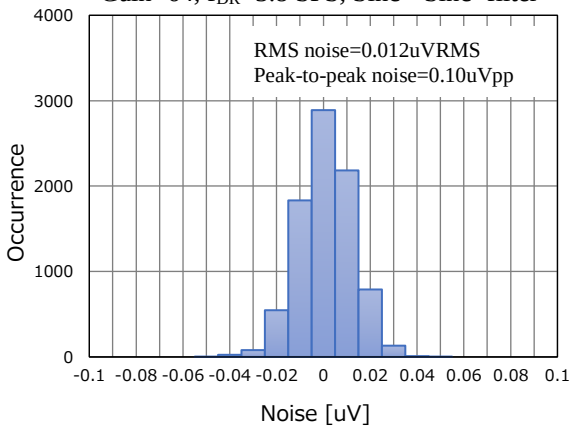


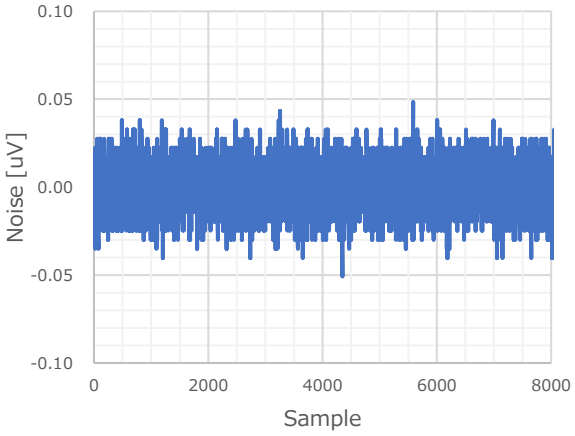
Gain=1(PGA disabled, BUF disabled),
f_{DR}=3.8 SPS, $Sinc^4$+$Sinc^4$ filter





Gain=64, f_{DR}=3.8 SPS, $Sinc^4$+$Sinc^4$ filter

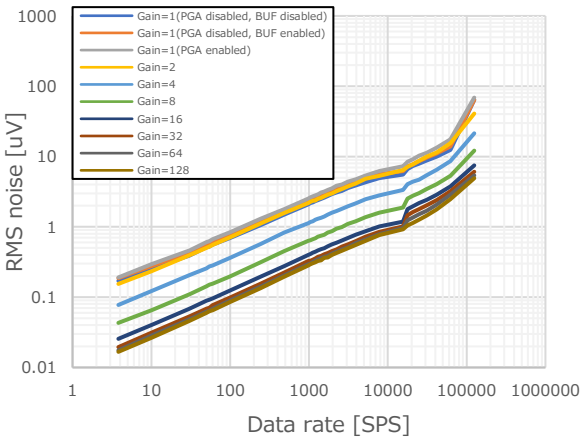




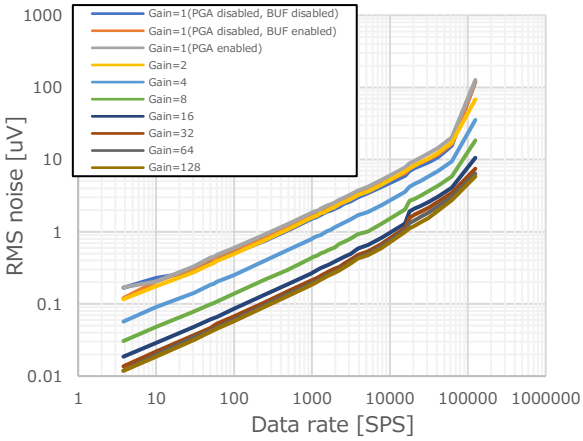
2.2 RMS noise - Date rate

AVCC0=5V, Ta=25℃, fMOD=4MHz, V_{ID}=0V, External VREF=2.5V, Reference buffer disabled

Sinc^5 filter or Sinc^5+Sinc^1 filter



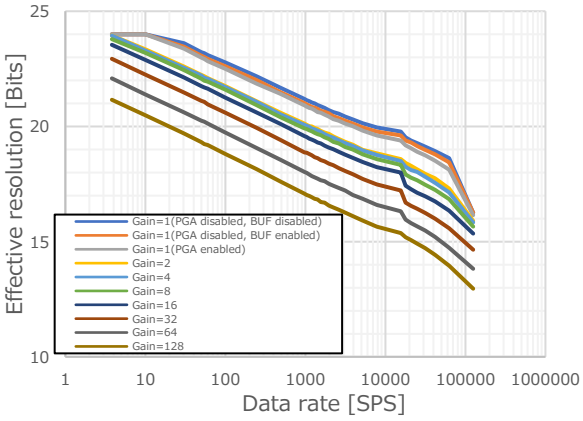
Sinc^4 filter or Sinc^4+Sinc^4 filter



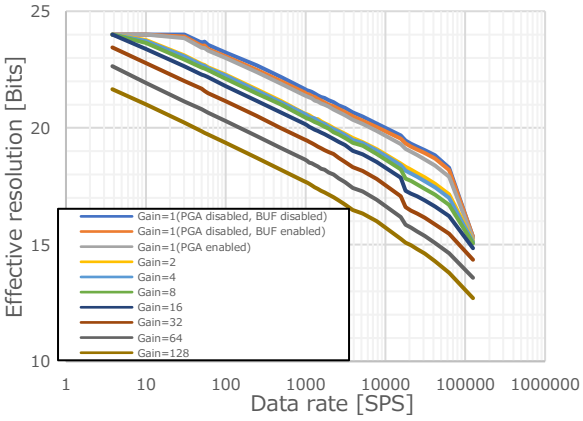
2.3 Effective resolution - Date rate

AVCC0=5V, Ta=25℃, fMOD=4MHz, V_{ID}=0V, External VREF=2.5V, Reference buffer disabled

Sinc^5 filter or Sinc^5+Sinc^1 filter



Sinc^4 filter or Sinc^4+Sinc^4 filter



2.4 Noise table

AVCC0=5V, Ta=25℃, fMOD=4MHz, V_{ID}=0V, $Sinc^5$ filter or $Sinc^5$+$Sinc^1$ filter, External VREF=2.5V, Reference buffer disabled

RMS noise[uVrms] (Peak-to-peak noise[uVpp])

Data rate [SPS]	OSR	Gain=1 (Bypass)	Gain=1 (BUF)	Gain=1 (PGA)	Gain=2	Gain=4	Gain=8	Gain=16	Gain=32	Gain=64	Gain=128
3.8	**1048576**	**0.165 (1.00)**	**0.194 (1.34)**	**0.203 (1.34)**	**0.174 (1.17)**	**0.093 (0.67)**	**0.042 (0.33)**	**0.027 (0.19)**	**0.020 (0.15)**	**0.017 (0.13)**	**0.017 (0.13)**
10.0	**399872**	**0.243 (1.32)**	**0.268 (1.76)**	**0.284 (1.97)**	**0.234 (1.76)**	**0.121 (0.88)**	**0.067 (0.47)**	**0.040 (0.27)**	**0.030 (0.23)**	**0.027 (0.21)**	**0.027 (0.19)**
50.1	**79872**	**0.481 (3.29)**	**0.534 (3.84)**	**0.573 (3.84)**	**0.481 (3.71)**	**0.249 (1.79)**	**0.137 (1.10)**	**0.085 (0.62)**	**0.068 (0.47)**	**0.062 (0.46)**	**0.060 (0.44)**
54	**73728**	**0.502 (3.87)**	**0.561 (4.46)**	**0.597 (4.76)**	**0.500 (3.87)**	**0.263 (1.93)**	**0.141 (1.12)**	**0.089 (0.69)**	**0.070 (0.50)**	**0.064 (0.48)**	**0.062 (0.50)**
60	**66560**	**0.529 (3.95)**	**0.594 (3.95)**	**0.637 (4.61)**	**0.529 (3.95)**	**0.271 (2.14)**	**0.151 (1.11)**	**0.094 (0.72)**	**0.074 (0.55)**	**0.067 (0.51)**	**0.064 (0.48)**
100	**39936**	**0.663 (4.67)**	**0.732 (5.22)**	**0.788 (6.04)**	**0.675 (5.08)**	**0.348 (2.61)**	**0.191 (1.41)**	**0.120 (0.94)**	**0.094 (0.70)**	**0.087 (0.65)**	**0.084 (0.65)**
977	**4096**	**1.931 (14.1)**	**2.216 (15.9)**	**2.403 (18.7)**	**2.067 (15.5)**	**1.078 (8.33)**	**0.599 (4.50)**	**0.384 (2.89)**	**0.316 (2.51)**	**0.293 (2.22)**	**0.277 (2.06)**
1953	**2048**	**2.697 (20.1)**	**3.050 (23.1)**	**3.325 (27.6)**	**2.896 (22.9)**	**1.489 (10.7)**	**0.832 (6.59)**	**0.535 (4.00)**	**0.442 (3.27)**	**0.402 (2.89)**	**0.390 (2.98)**
3906	**1024**	**3.636 (27.9)**	**4.098 (31.8)**	**4.507 (31.6)**	**3.938 (30.7)**	**2.052 (15.4)**	**1.145 (8.83)**	**0.740 (5.53)**	**0.602 (4.63)**	**0.563 (4.03)**	**0.537 (4.26)**
15625	**256**	**5.226 (40.2)**	**5.936 (48.0)**	**6.801 (50.5)**	**5.927 (47.4)**	**3.170 (24.2)**	**1.791 (13.3)**	**1.154 (8.68)**	**0.988 (7.57)**	**0.921 (6.94)**	**0.884 (6.67)**
17857	**224**	**6.076 (45.4)**	**6.764 (48.9)**	**7.896 (59.1)**	**6.624 (47.8)**	**3.771 (28.9)**	**2.376 (17.4)**	**1.721 (12.8)**	**1.417 (11.3)**	**1.205 (9.54)**	**1.012 (7.93)**
31250	**128**	**8.214 (60.2)**	**8.876 (66.4)**	**10.65 (78.2)**	**9.046 (67.3)**	**5.059 (39.4)**	**3.158 (22.8)**	**2.311 (19.9)**	**1.936 (13.8)**	**1.661 (12.9)**	**1.399 (10.8)**
41667	**96**	**9.363 (67.5)**	**10.27 (78.1)**	**12.50 (95.7)**	**10.84 (83.0)**	**6.065 (45.2)**	**3.816 (28.4)**	**2.743 (20.7)**	**2.314 (16.7)**	**2.002 (15.5)**	**1.699 (13.5)**
62500	**64**	**11.76 (87.5)**	**13.09 (95.4)**	**16.36 (126)**	**14.50 (106)**	**8.139 (57.6)**	**4.996 (37.5)**	**3.531 (27.1)**	**3.071 (22.7)**	**2.638 (21.0)**	**2.364 (16.9)**
125000	**32**	**63.20 (468)**	**64.38 (472)**	**66.39 (495)**	**39.73 (320)**	**21.06 (156)**	**11.65 (88.4)**	**7.214 (58.2)**	**5.870 (48.2)**	**5.167 (40.5)**	**4.829 (39.9)**

Effective resolution [Bits] (Noise-free resolution [Bits])

Data rate [SPS]	OSR	Gain=1 (Bypass)	Gain=1 (BUF)	Gain=1 (PGA)	Gain=2	Gain=4	Gain=8	Gain=16	Gain=32	Gain=64	Gain=128
3.8	**1048576**	**24.0 (22.2)**	**24.0 (21.8)**	**24.0 (21.8)**	**23.8 (21.0)**	**23.7 (20.8)**	**23.8 (20.8)**	**23.4 (20.7)**	**22.9 (20.0)**	**22.1 (19.2)**	**21.2 (18.2)**
10.0	**399872**	**24.0 (21.9)**	**24.0 (21.4)**	**24.0 (21.3)**	**23.3 (20.4)**	**23.3 (20.4)**	**23.2 (20.4)**	**22.9 (20.1)**	**22.3 (19.4)**	**21.4 (18.5)**	**20.5 (17.7)**
50.1	**79872**	**23.3 (20.5)**	**23.2 (20.3)**	**23.1 (20.3)**	**22.3 (19.4)**	**22.3 (19.4)**	**22.1 (19.1)**	**21.8 (18.9)**	**21.1 (18.3)**	**20.3 (17.4)**	**19.3 (16.4)**
54	**73728**	**23.2 (20.3)**	**23.1 (20.1)**	**23.0 (20.0)**	**22.3 (19.3)**	**22.2 (19.3)**	**22.1 (19.1)**	**21.7 (18.8)**	**21.1 (18.2)**	**20.2 (17.3)**	**19.3 (16.3)**
60	**66560**	**23.2 (20.3)**	**23.0 (20.3)**	**22.9 (20.0)**	**22.2 (19.3)**	**22.1 (19.2)**	**22.0 (19.1)**	**21.7 (18.7)**	**21.0 (18.1)**	**20.1 (17.2)**	**19.2 (16.3)**
100	**39936**	**22.8 (20.0)**	**22.7 (19.9)**	**22.6 (19.7)**	**21.8 (18.9)**	**21.8 (18.9)**	**21.6 (18.8)**	**21.3 (18.3)**	**20.7 (17.8)**	**19.8 (16.9)**	**18.8 (15.9)**
977	**4096**	**21.3 (18.4)**	**21.1 (18.3)**	**21.0 (18.0)**	**20.2 (17.3)**	**20.1 (17.2)**	**20.0 (17.1)**	**19.6 (16.7)**	**18.9 (15.9)**	**18.0 (15.1)**	**17.1 (14.2)**
1953	**2048**	**20.8 (17.9)**	**20.6 (17.7)**	**20.5 (17.5)**	**19.7 (16.7)**	**19.7 (16.8)**	**19.5 (16.5)**	**19.2 (16.3)**	**18.4 (15.5)**	**17.6 (14.7)**	**16.6 (13.7)**
3906	**1024**	**20.4 (17.4)**	**20.2 (17.3)**	**20.1 (17.3)**	**19.3 (16.3)**	**19.2 (16.3)**	**19.1 (16.1)**	**18.7 (15.8)**	**18.0 (15.0)**	**17.1 (14.2)**	**16.1 (13.2)**
15625	**256**	**19.9 (16.9)**	**19.7 (16.7)**	**19.5 (16.6)**	**18.7 (15.7)**	**18.6 (15.7)**	**18.4 (15.5)**	**18.0 (15.1)**	**17.3 (14.3)**	**16.4 (13.6)**	**15.4 (12.5)**
17857	**224**	**19.7 (16.8)**	**19.5 (16.6)**	**19.3 (16.4)**	**18.5 (15.7)**	**18.3 (15.4)**	**18.0 (15.1)**	**17.5 (14.6)**	**16.8 (13.8)**	**16.0 (13.0)**	**15.2 (12.3)**
31250	**128**	**19.2 (16.3)**	**19.1 (16.2)**	**18.8 (16.0)**	**18.1 (15.2)**	**17.9 (14.8)**	**17.6 (14.7)**	**17.0 (13.9)**	**16.3 (13.5)**	**15.5 (12.6)**	**14.8 (11.8)**
41667	**96**	**19.0 (16.2)**	**18.9 (16.0)**	**18.6 (15.7)**	**17.8 (14.9)**	**17.7 (14.8)**	**17.3 (14.4)**	**16.8 (13.9)**	**16.0 (13.2)**	**15.3 (12.3)**	**14.5 (11.5)**
62500	**64**	**18.7 (15.8)**	**18.5 (15.7)**	**18.2 (15.3)**	**17.4 (14.5)**	**17.2 (14.4)**	**16.9 (14.0)**	**16.4 (13.5)**	**15.6 (12.8)**	**14.9 (11.9)**	**14.0 (11.2)**
125000	**32**	**16.3 (13.4)**	**16.2 (13.4)**	**16.2 (13.3)**	**15.9 (12.9)**	**15.9 (13.0)**	**15.7 (12.8)**	**15.4 (12.4)**	**14.7 (11.7)**	**13.9 (10.9)**	**13.0 (9.9)**

AVCC0=5V, Ta=25℃, fMOD=4MHz, V_{ID}=0V, $Sinc^4$ filter or $Sinc^4$+$Sinc^4$ filter, External VREF=2.5V, Reference buffer disabled

RMS noise[uVrms] (Peak-to-peak noise[uVpp])

Data rate [SPS]	OSR	Gain=1 (Bypass)	Gain=1 (BUF)	Gain=1 (PGA)	Gain=2	Gain=4	Gain=8	Gain=16	Gain=32	Gain=64	Gain=128
3.8	**1048576**	**0.160 (0.50)**	**0.168 (1.00)**	**0.179 (1.00)**	**0.141 (0.92)**	**0.061 (0.42)**	**0.031 (0.23)**	**0.019 (0.14)**	**0.014 (0.10)**	**0.012 (0.09)**	**0.011 (0.09)**
10.0	**399872**	**0.192 (1.24)**	**0.252 (1.48)**	**0.236 (1.48)**	**0.177 (1.24)**	**0.094 (0.62)**	**0.047 (0.31)**	**0.030 (0.20)**	**0.022 (0.16)**	**0.019 (0.14)**	**0.018 (0.14)**
50.1	**79872**	**0.359 (2.43)**	**0.406 (2.73)**	**0.431 (3.03)**	**0.352 (2.58)**	**0.178 (1.29)**	**0.096 (0.72)**	**0.059 (0.42)**	**0.046 (0.34)**	**0.042 (0.30)**	**0.041 (0.31)**
54	**73728**	**0.346 (2.51)**	**0.390 (2.72)**	**0.421 (3.34)**	**0.352 (2.51)**	**0.182 (1.41)**	**0.098 (0.71)**	**0.062 (0.46)**	**0.048 (0.35)**	**0.044 (0.33)**	**0.042 (0.32)**
60	**66560**	**0.387 (2.52)**	**0.427 (3.15)**	**0.463 (3.15)**	**0.374 (2.67)**	**0.193 (1.34)**	**0.106 (0.75)**	**0.065 (0.47)**	**0.051 (0.37)**	**0.046 (0.34)**	**0.044 (0.33)**
100	**39936**	**0.470 (3.34)**	**0.523 (3.64)**	**0.572 (4.55)**	**0.469 (3.49)**	**0.242 (1.74)**	**0.133 (0.95)**	**0.083 (0.66)**	**0.065 (0.47)**	**0.059 (0.46)**	**0.057 (0.46)**
977	**4096**	**1.407 (10.9)**	**1.562 (12.9)**	**1.691 (12.4)**	**1.442 (11.1)**	**0.748 (5.90)**	**0.408 (3.10)**	**0.256 (1.98)**	**0.207 (1.54)**	**0.190 (1.40)**	**0.181 (1.43)**
1953	**2048**	**1.959 (15.9)**	**2.217 (16.7)**	**2.406 (17.2)**	**2.021 (17.0)**	**1.065 (7.99)**	**0.591 (4.56)**	**0.374 (3.00)**	**0.298 (2.12)**	**0.272 (2.09)**	**0.265 (2.06)**
3906	**1024**	**2.760 (21.4)**	**3.114 (22.9)**	**3.519 (27.1)**	**3.057 (22.1)**	**1.592 (11.6)**	**0.897 (6.78)**	**0.561 (4.19)**	**0.462 (3.92)**	**0.427 (3.18)**	**0.414 (3.21)**
15625	**256**	**5.579 (43.7)**	**6.185 (45.2)**	**7.339 (58.1)**	**6.490 (50.6)**	**3.422 (25.5)**	**1.930 (14.1)**	**1.250 (9.74)**	**1.070 (7.57)**	**1.001 (7.56)**	**0.971 (7.80)**
17857	**224**	**6.393 (46.8)**	**7.098 (52.2)**	**8.323 (63.1)**	**7.108 (52.0)**	**3.909 (30.1)**	**2.516 (19.5)**	**1.835 (13.9)**	**1.507 (11.7)**	**1.286 (9.67)**	**1.053 (7.86)**
31250	**128**	**8.509 (63.4)**	**9.342 (71.1)**	**11.25 (81.2)**	**9.657 (70.7)**	**5.429 (40.3)**	**3.435 (25.4)**	**2.502 (20.1)**	**2.084 (16.7)**	**1.778 (13.8)**	**1.511 (11.4)**
41667	**96**	**9.997 (80.7)**	**10.97 (81.7)**	**13.29 (98.6)**	**11.71 (85.9)**	**6.542 (49.6)**	**4.074 (30.6)**	**2.973 (23.3)**	**2.471 (18.7)**	**2.151 (16.2)**	**1.819 (14.0)**
62500	**64**	**14.59 (114)**	**15.73 (128)**	**19.50 (143)**	**16.09 (129)**	**8.891 (64.6)**	**5.504 (46.8)**	**3.850 (29.5)**	**3.277 (24.5)**	**2.968 (23.7)**	**2.613 (21.2)**
125000	**32**	**122.6 (851)**	**122.1 (904)**	**122.1 (909)**	**65.91 (489)**	**34.11 (264)**	**17.67 (126)**	**10.10 (72.7)**	**7.107 (53.2)**	**5.844 (44.9)**	**5.301 (40.1)**

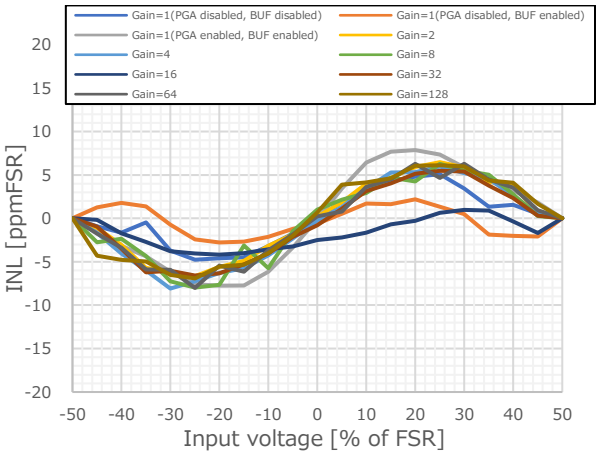
Effective resolution [Bits] (Noise-free resolution [Bits])

Data rate [SPS]	OSR	Gain=1 (Bypass)	Gain=1 (BUF)	Gain=1 (PGA)	Gain=2	Gain=4	Gain=8	Gain=16	Gain=32	Gain=64	Gain=128
3.8	**1048576**	**24.0 (23.2)**	**24.0 (22.2)**	**24.0 (22.2)**	**24.0 (21.2)**	**24.0 (21.5)**	**24.0 (21.4)**	**23.9 (21.1)**	**23.4 (20.5)**	**22.6 (19.7)**	**22.7 (18.8)**
10.0	**399872**	**24.0 (21.9)**	**24.0 (21.7)**	**24.0 (21.7)**	**23.8 (20.9)**	**23.7 (20.9)**	**23.6 (20.9)**	**23.3 (20.6)**	**22.8 (19.9)**	**22.0 (19.1)**	**21.0 (18.1)**
50.1	**79872**	**23.7 (21.0)**	**23.6 (20.8)**	**23.5 (20.7)**	**22.8 (19.9)**	**22.7 (19.9)**	**22.6 (19.7)**	**22.3 (19.5)**	**21.7 (18.8)**	**20.8 (18.0)**	**19.9 (16.9)**
54	**73728**	**23.8 (20.9)**	**23.8 (20.8)**	**23.5 (20.5)**	**22.8 (19.9)**	**22.7 (19.8)**	**22.6 (19.8)**	**22.3 (19.4)**	**21.6 (18.8)**	**20.8 (17.9)**	**19.8 (16.9)**
60	**66560**	**23.6 (20.9)**	**23.5 (20.6)**	**23.4 (20.6)**	**22.7 (19.8)**	**22.6 (19.8)**	**22.5 (19.7)**	**22.2 (19.3)**	**21.5 (18.7)**	**20.7 (17.8)**	**19.8 (16.9)**
100	**39936**	**23.3 (20.5)**	**23.2 (20.4)**	**23.1 (20.1)**	**22.3 (19.5)**	**22.3 (19.5)**	**22.2 (19.3)**	**21.8 (18.8)**	**21.2 (18.3)**	**20.3 (17.4)**	**19.4 (16.4)**
977	**4096**	**21.8 (18.8)**	**21.6 (18.6)**	**21.5 (18.6)**	**20.7 (17.8)**	**20.7 (17.7)**	**20.5 (17.6)**	**20.2 (17.3)**	**19.5 (16.6)**	**18.7 (15.8)**	**17.7 (14.7)**
1953	**2048**	**21.3 (18.3)**	**21.1 (18.2)**	**21.0 (18.1)**	**20.2 (17.2)**	**20.2 (17.3)**	**20.0 (17.1)**	**19.7 (16.7)**	**19.0 (16.2)**	**18.1 (15.2)**	**17.2 (14.2)**
3906	**1024**	**20.8 (17.8)**	**20.6 (17.7)**	**20.4 (17.5)**	**19.6 (16.8)**	**19.6 (16.7)**	**19.4 (16.5)**	**19.1 (16.2)**	**18.4 (15.3)**	**17.5 (14.6)**	**16.5 (13.6)**
15625	**256**	**19.8 (16.8)**	**19.6 (16.8)**	**19.4 (16.4)**	**18.6 (15.6)**	**18.5 (15.6)**	**18.3 (15.4)**	**17.9 (15.0)**	**17.2 (14.3)**	**16.3 (13.3)**	**15.3 (12.3)**
17857	**224**	**19.6 (16.7)**	**19.4 (16.5)**	**19.2 (16.3)**	**18.4 (15.6)**	**18.3 (15.3)**	**17.9 (15.0)**	**17.4 (14.5)**	**16.7 (13.7)**	**15.9 (13.0)**	**15.2 (12.3)**
31250	**128**	**19.2 (16.3)**	**19.0 (16.1)**	**18.8 (15.9)**	**18.0 (15.1)**	**17.8 (14.9)**	**17.5 (14.6)**	**16.9 (13.9)**	**16.2 (13.2)**	**15.4 (12.5)**	**14.7 (11.7)**
41667	**96**	**18.9 (15.9)**	**18.8 (15.9)**	**18.5 (15.6)**	**17.7 (14.8)**	**17.5 (14.6)**	**17.2 (14.3)**	**16.7 (13.7)**	**15.9 (13.0)**	**15.1 (12.2)**	**14.4 (11.4)**
62500	**64**	**18.4 (15.4)**	**18.3 (15.3)**	**18.0 (15.1)**	**17.2 (14.2)**	**17.1 (14.2)**	**16.8 (13.7)**	**16.3 (13.4)**	**15.5 (12.6)**	**14.7 (11.7)**	**13.9 (10.8)**
125000	**32**	**15.3 (12.5)**	**15.3 (12.4)**	**15.3 (12.4)**	**15.2 (12.3)**	**15.2 (12.2)**	**15.1 (12.3)**	**14.9 (12.1)**	**14.4 (11.5)**	**13.7 (10.8)**	**12.8 (9.9)**

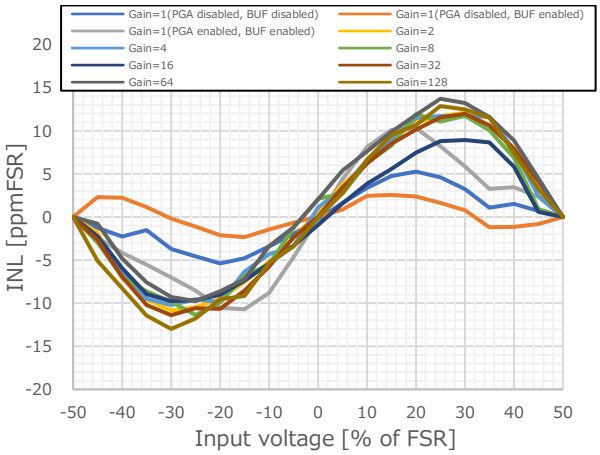
2.5 Integral nonlinearity error (INL)

AVCC0=5V, Ta=25℃, f_{MOD}=4MHz, Sinc4 filter or Sinc4+Sinc4 filter, External V_{REF}=2.5V, Reference buffer disabled

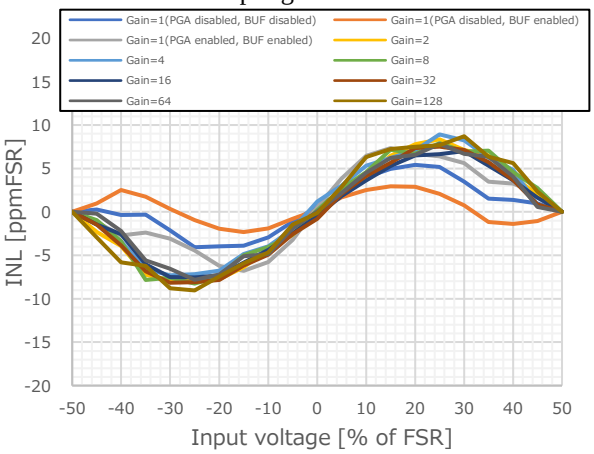
Total oversampling ratio=224 *1



Total oversampling ratio=256 *2



Total oversampling ratio=4096 *3

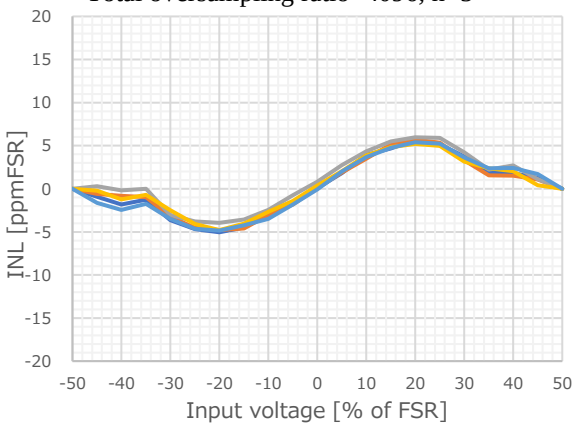


Note 1. The evaluation results for total oversampling ratio=224 are typical characteristics for total oversampling ratio=32 to 224.

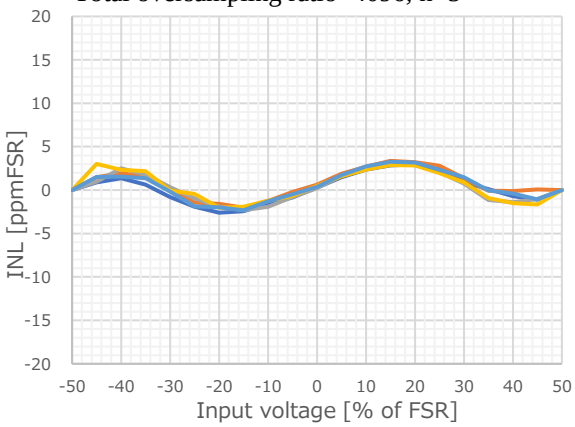
Note 2. The evaluation results for total oversampling ratio=256 are typical characteristics for total oversampling ratio=256 to 768.

Note 3. The evaluation results for total oversampling ratio=4096 are typical characteristics for total oversampling ratio=1024 to 1048576.

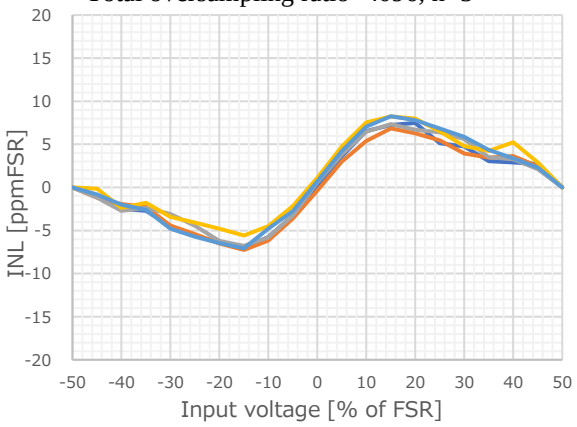
Gain=1(PGA disabled, BUF disabled),
Total oversampling ratio=4096, n=5



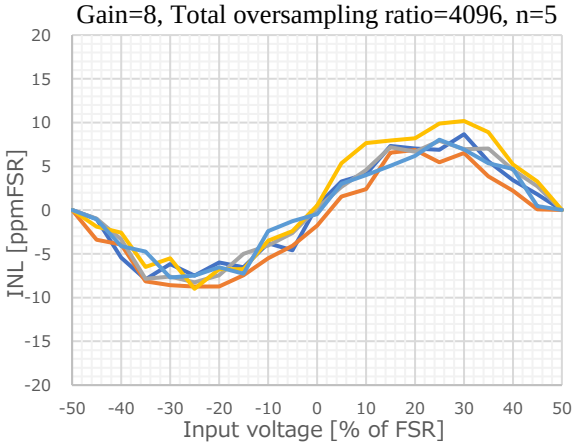
Gain=1(PGA disabled, BUF enabled),
Total oversampling ratio=4096, n=5



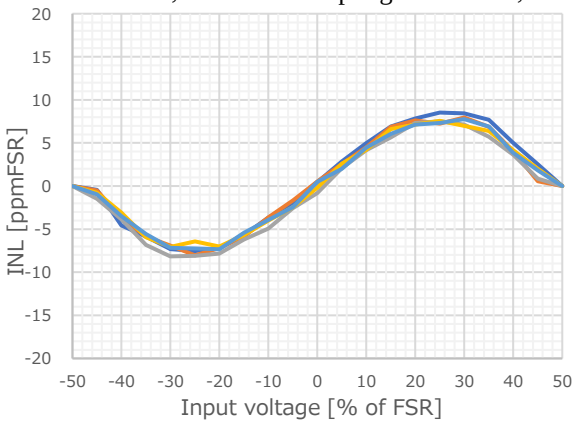
Gain=1(PGA enabled, BUF enabled),
Total oversampling ratio=4096, n=5



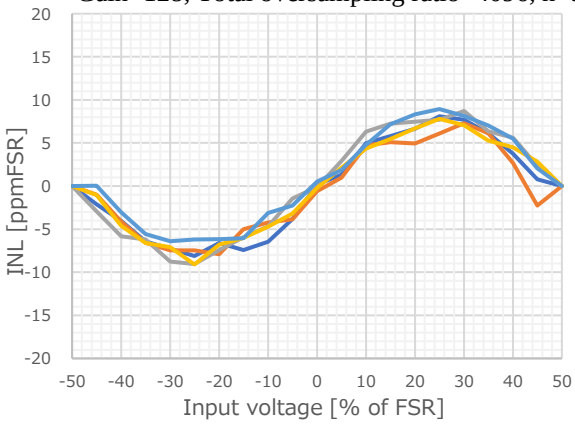
Gain=8, Total oversampling ratio=4096, n=5



Gain=32, Total oversampling ratio=4096, n=5



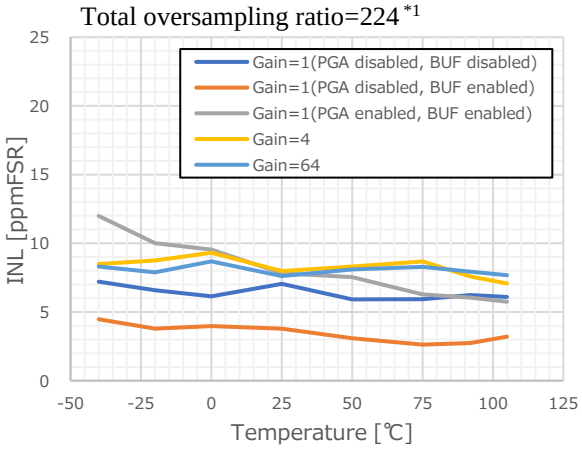
Gain=128, Total oversampling ratio=4096, n=5



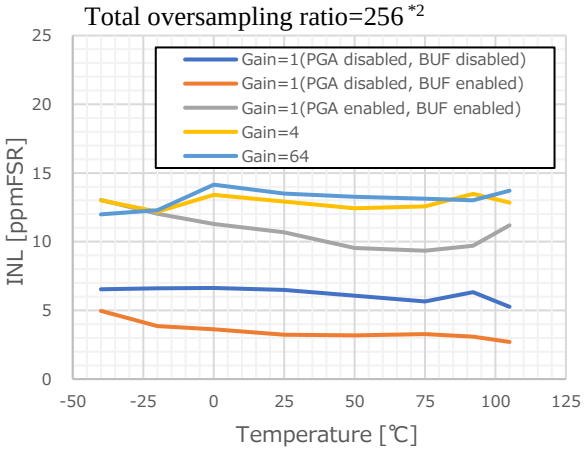
2.6 Integral nonlinearity error temperature drift

AVCC0=5V, f_{MOD}=4MHz, Sinc4 filter or Sinc4+Sinc4 filter, External V_{REF}=2.5V, Reference buffer disabled

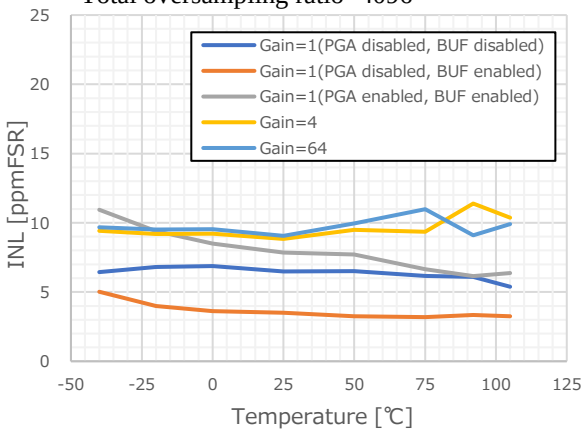
Total oversampling ratio=224 *1



Total oversampling ratio=256 *2



Total oversampling ratio=4096 *3



Note 1. The evaluation results for total oversampling ratio=224 are typical characteristics for total oversampling ratio=32 to 224.

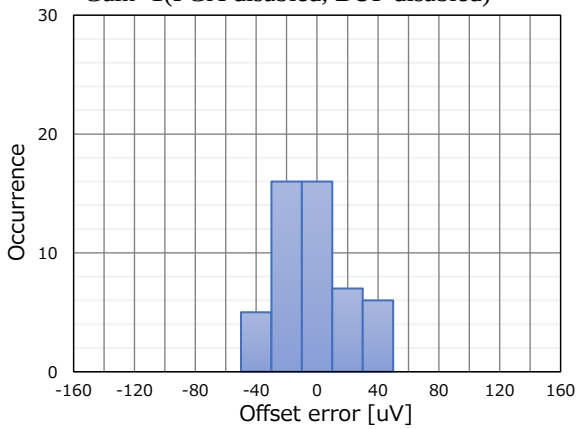
Note 2. The evaluation results for total oversampling ratio=256 are typical characteristics for total oversampling ratio=256 to 768.

Note 3. The evaluation results for total oversampling ratio=4096 are typical characteristics for total oversampling ratio=1024 to 1048576.

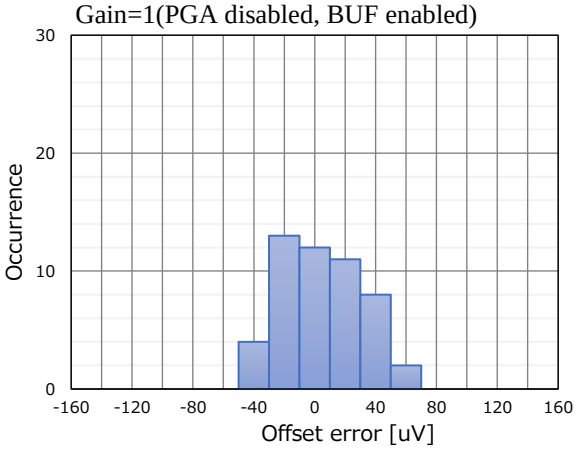
2.7 Offset error histogram

AVCC0=5V, Ta=25℃, f_{MOD}=4MHz, V_{ID}=0V, Total oversampling ratio=4096, External V_{REF}=2.5V, Reference buffer disabled

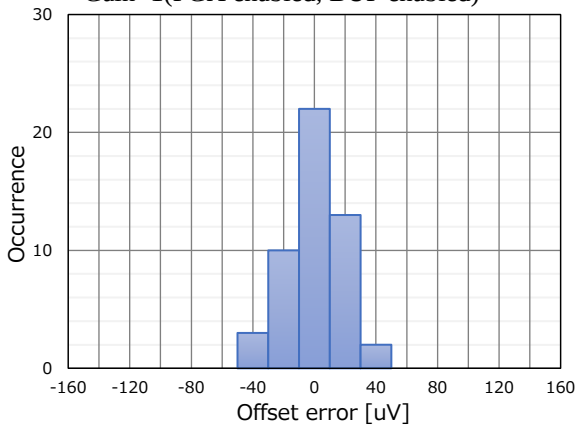
Gain=1(PGA disabled, BUF disabled)



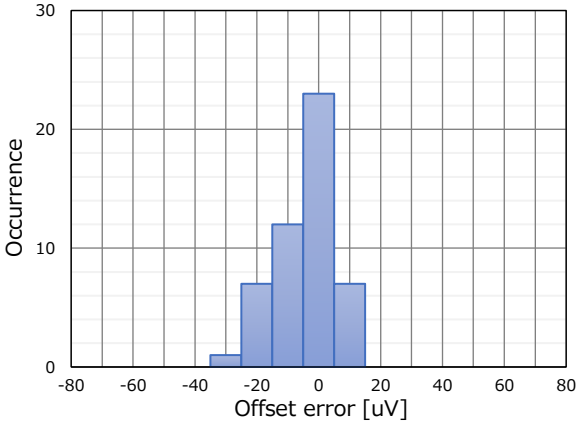
Gain=1(PGA disabled, BUF enabled)



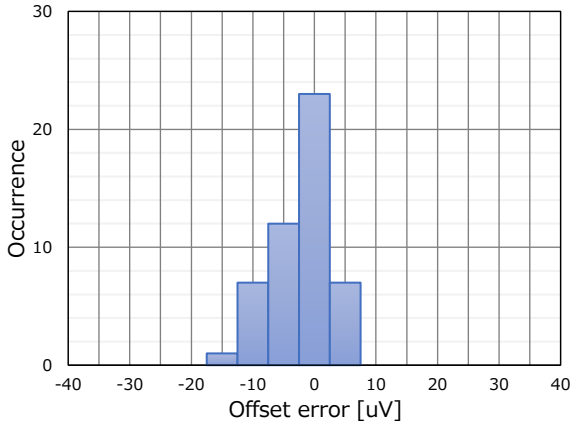
Gain=1(PGA enabled, BUF enabled)



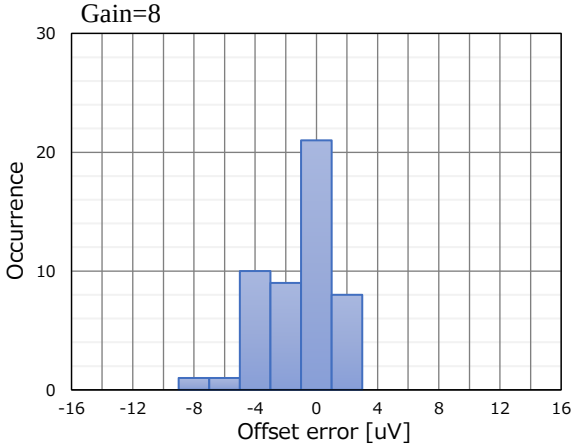
Gain=2



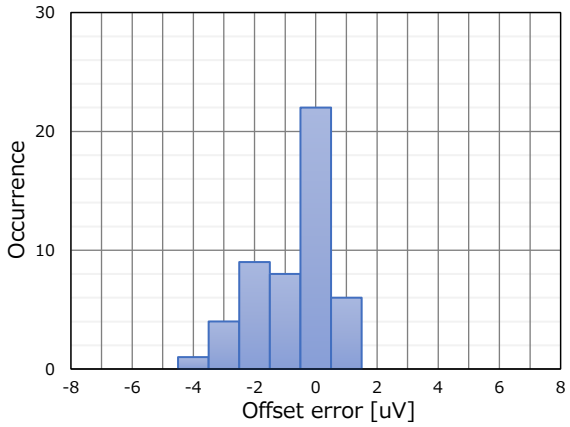
Gain=4



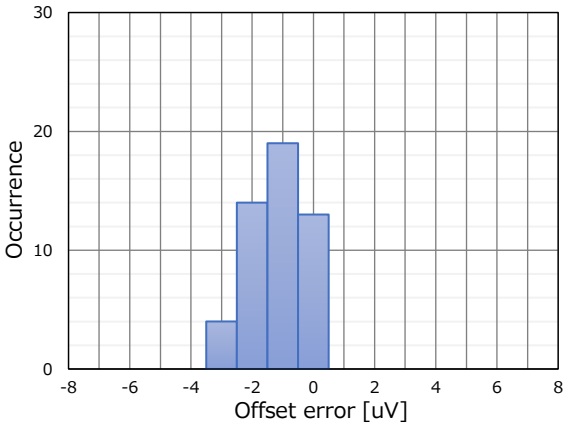
Gain=8



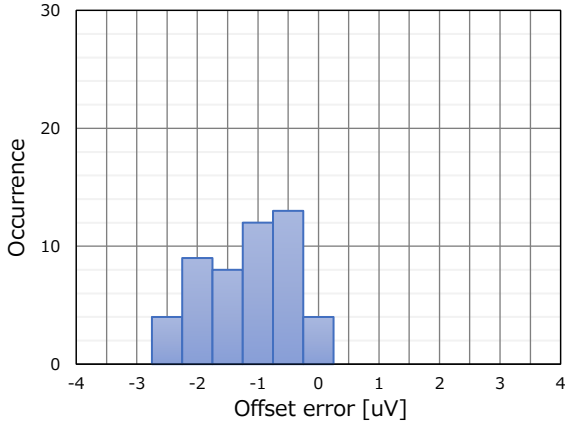
Gain=16



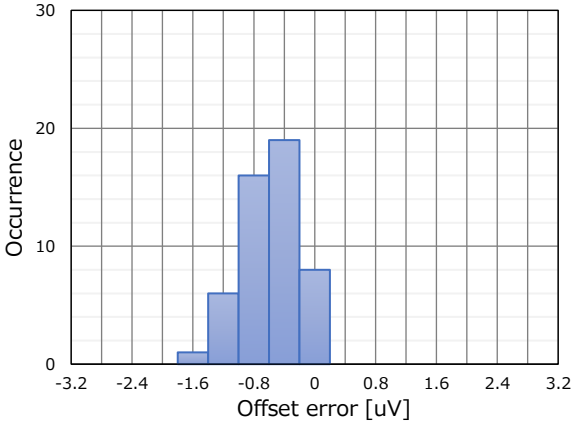
Gain=32



Gain=32

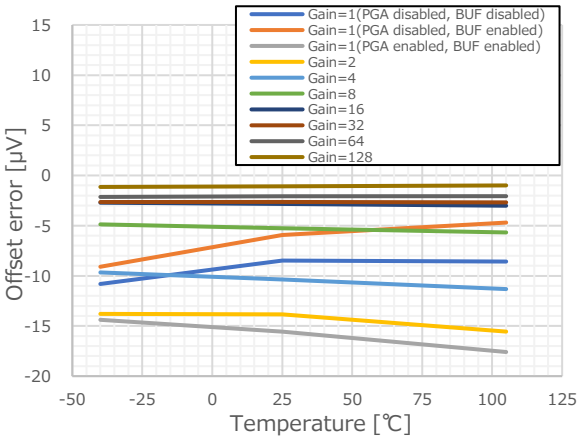


Gain=128



2.8 Offset error temperature drift

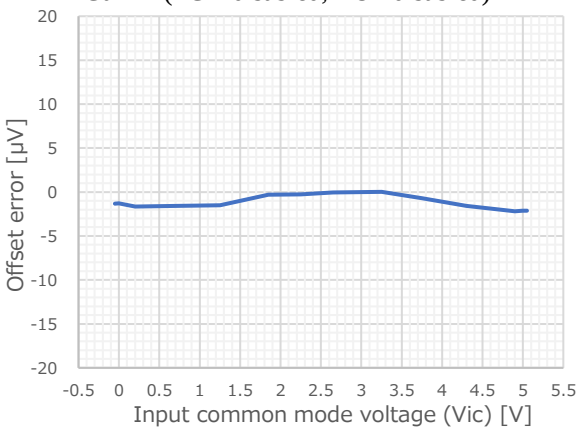
AVCC0=5V, f_{MOD}=4MHz, V_{ID}=0V, Total oversampling ratio=4096, External V_{REF}=2.5V, Reference buffer disabled



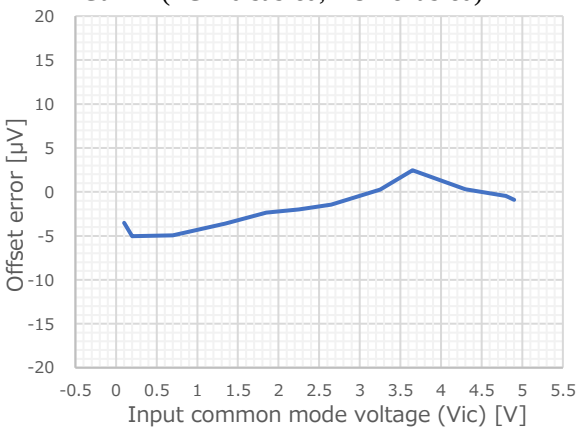
2.9 Offset error - Input common mode voltage

AVCC0=5V, Ta=25℃, f_{MOD}=4MHz, V_{ID}=0V, Total oversampling ratio=4096, External V_{REF}=2.5V, Reference buffer disabled

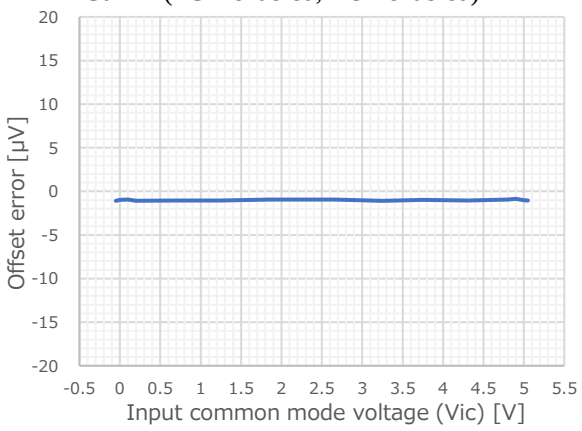
Gain=1(PGA disabled, BUF disabled)



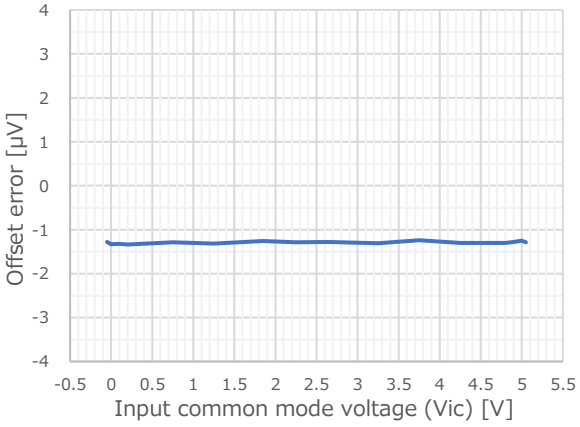
Gain=1(PGA disabled, BUF enabled)



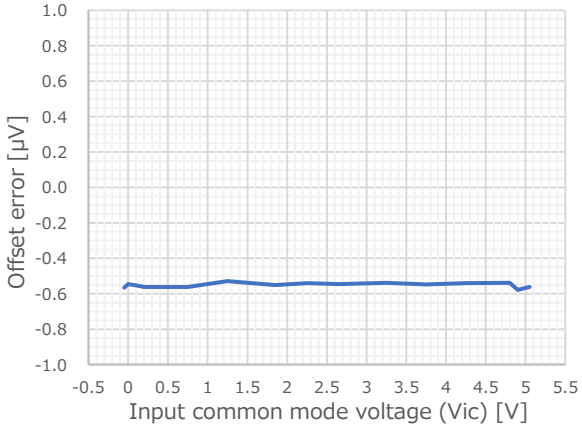
Gain=1(PGA enabled, BUF enabled)



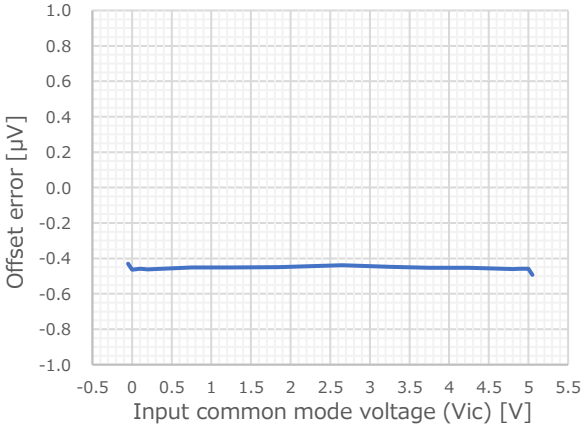
Gain=4



Gain=16



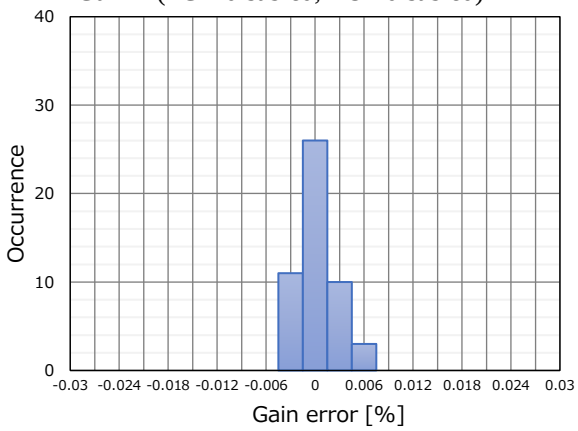
Gain=128



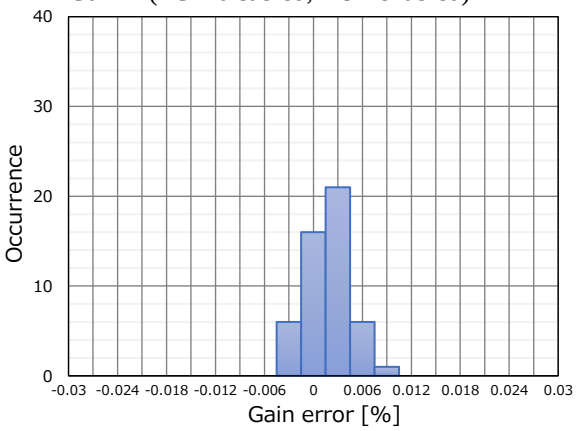
2.10 Gain error histogram

AVCC0=5V, Ta=25℃, f_{MOD}=4MHz, Total oversampling ratio=4096, External V_{REF}=2.5V, Reference buffer disabled

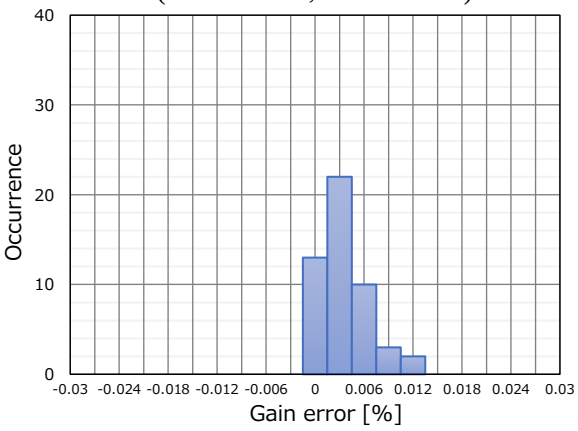
Gain=1(PGA disabled, BUF disabled)



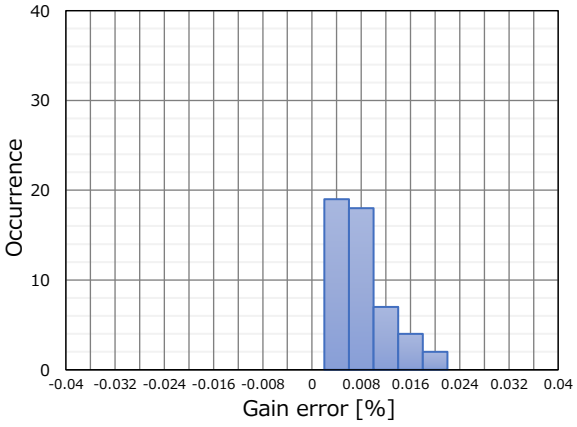
Gain=1(PGA disabled, BUF enabled)



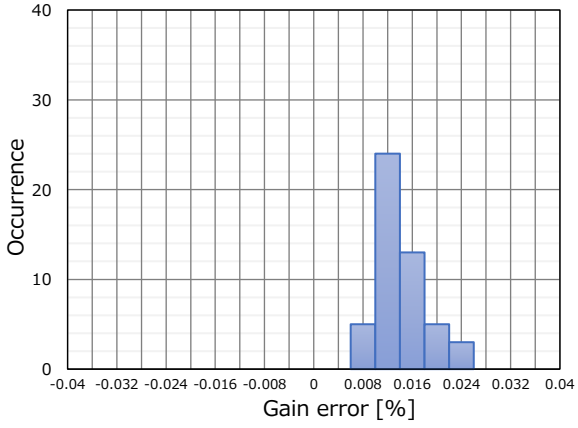
Gain=1(PGA enabled, BUF enabled)



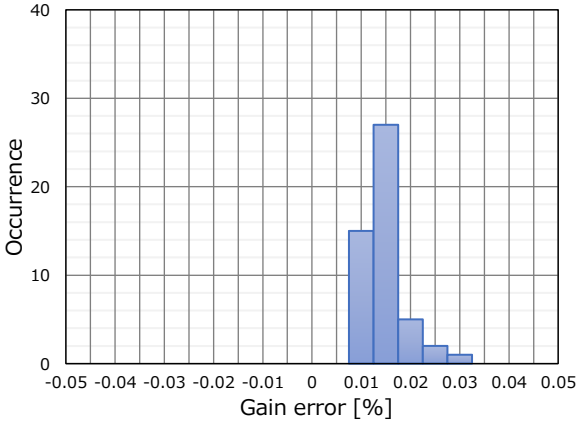
Gain=2

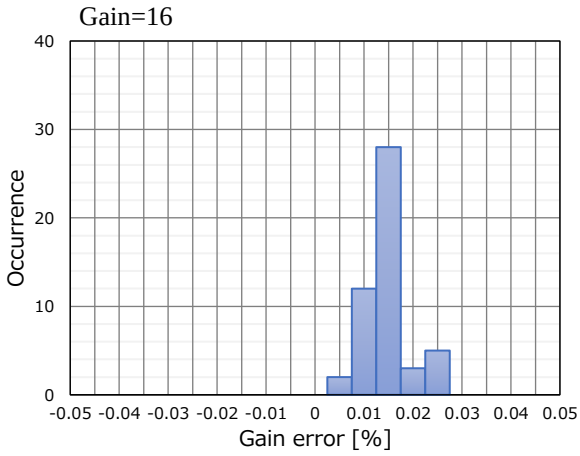


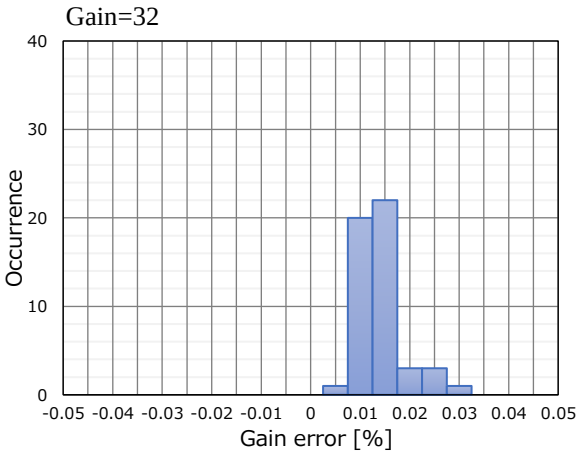
Gain=4

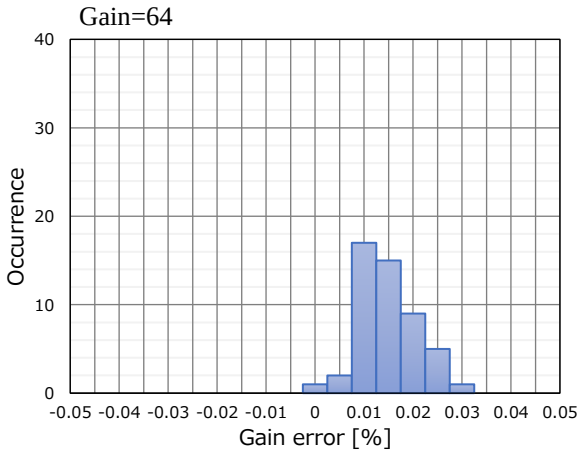


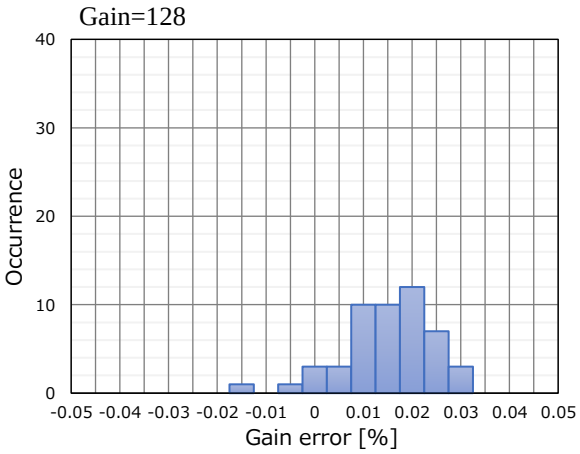
Gain=8





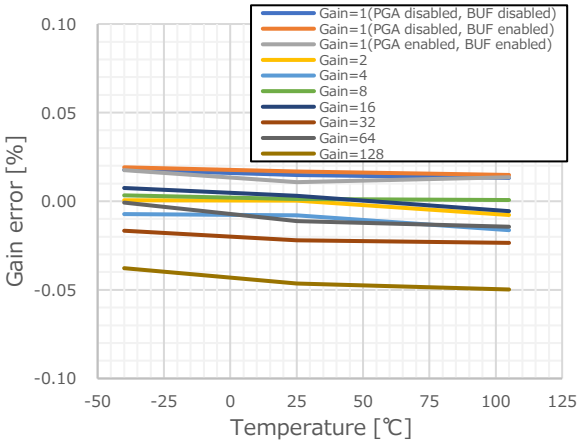






2.11 Gain error temperature drift

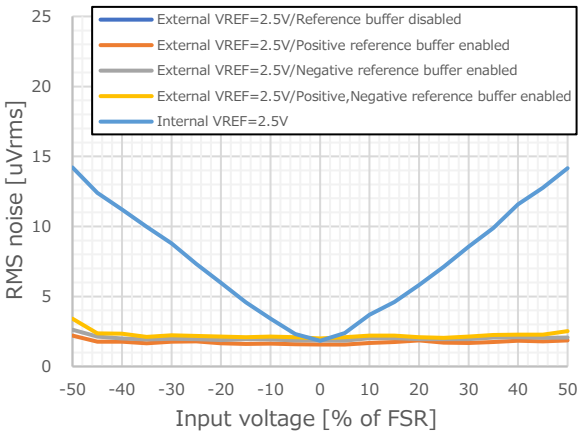
AVCC0=5V, Ta=25℃, f_{MOD}=4MHz, Total oversampling ratio=4096, External V_{REF}=2.5V, Reference buffer disabled



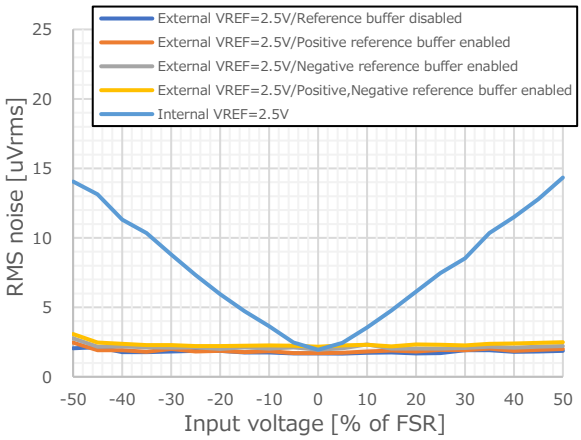
2.12 RMS noise - Input voltage

AVCC0=5V, Ta=25℃, fMOD=4MHz, Total oversampling ratio=4096, $Sinc^4$+$Sinc^4$ filter

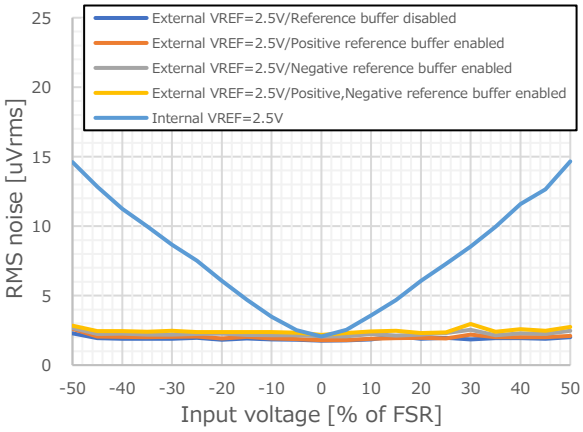
Gain=1(PGA disabled, BUF disabled)



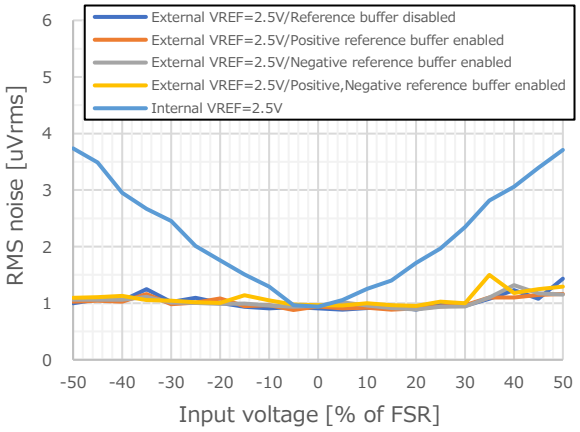
Gain=1(PGA disabled, BUF enabled)



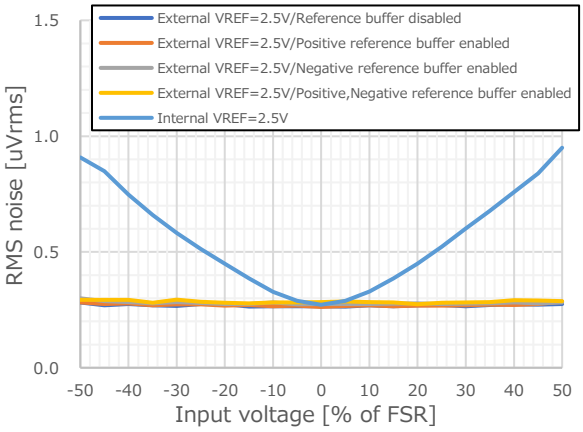
Gain=1(PGA enabled, BUF enabled)



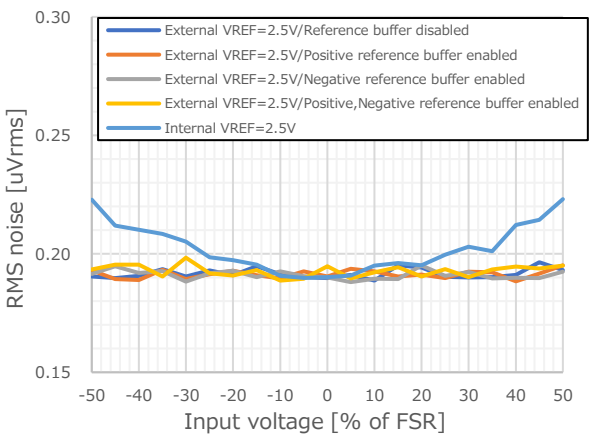
Gain=4



Gain=16



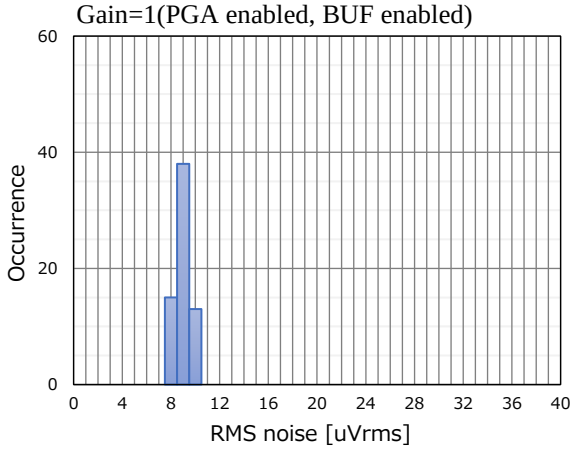
Gain=128



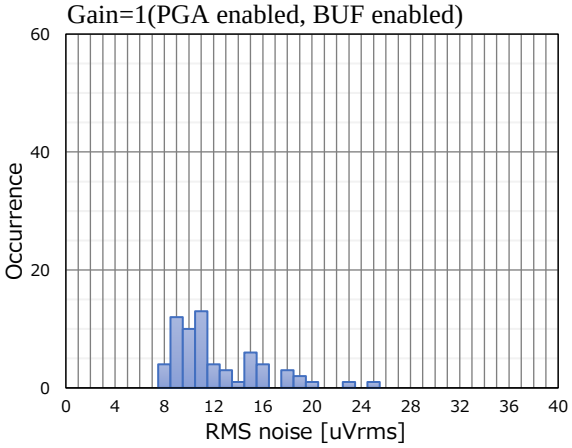
2.13 RMS noise Reference buffer dependence histogram

AVCC0=5V, Ta=25℃, fMOD=4MHz, V_{ID}=0V, Total oversampling ratio=224, Sinc4+Sinc4 filter, External VREF=2.5V

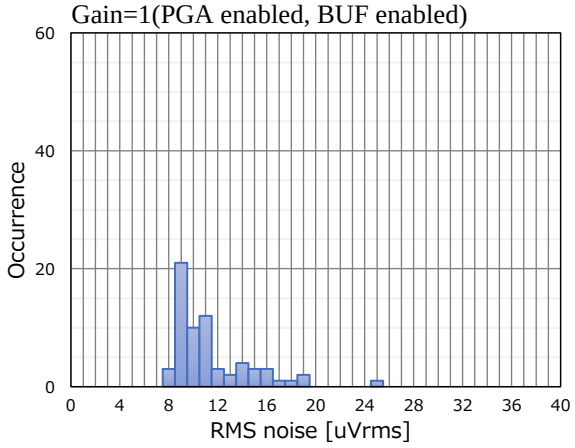
Reference buffer disabled
Gain=1(PGA enabled, BUF enabled)



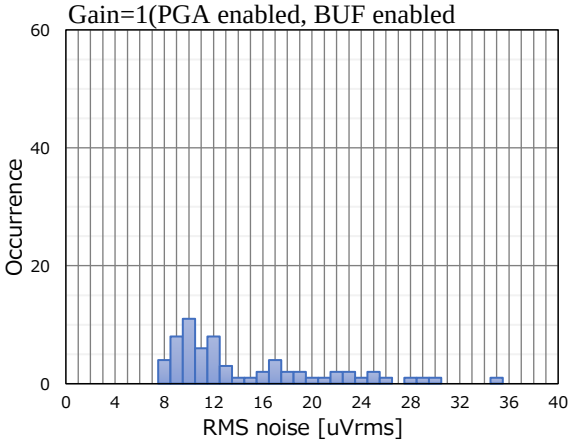
Positive reference buffer enabled
Gain=1(PGA enabled, BUF enabled)



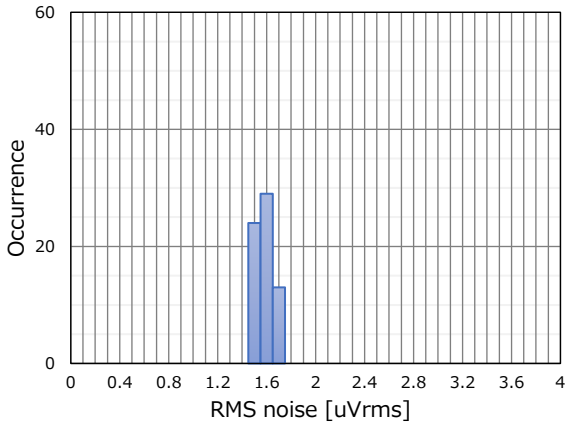
Negative reference buffer enabled
Gain=1(PGA enabled, BUF enabled)



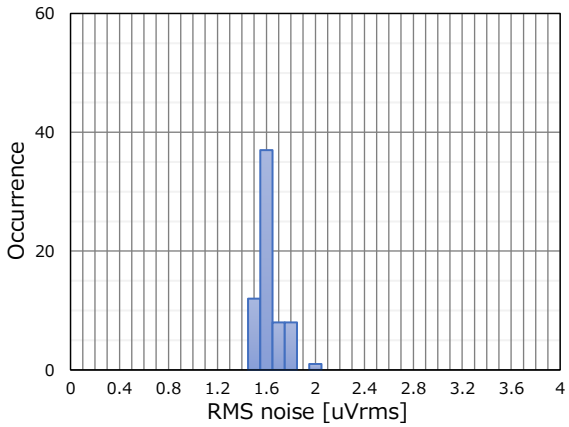
Positive, Negative reference buffer enabled
Gain=1(PGA enabled, BUF enabled



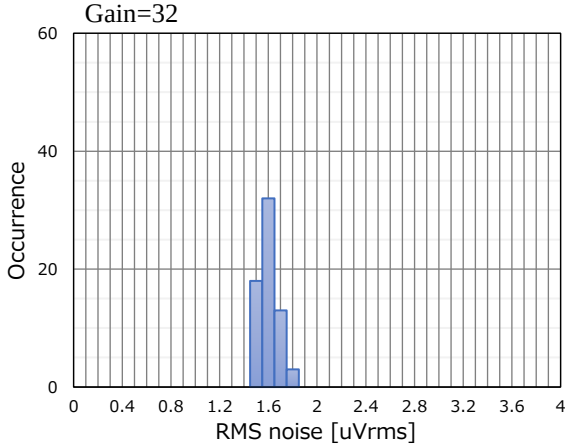
Reference buffer disabled
Gain=32



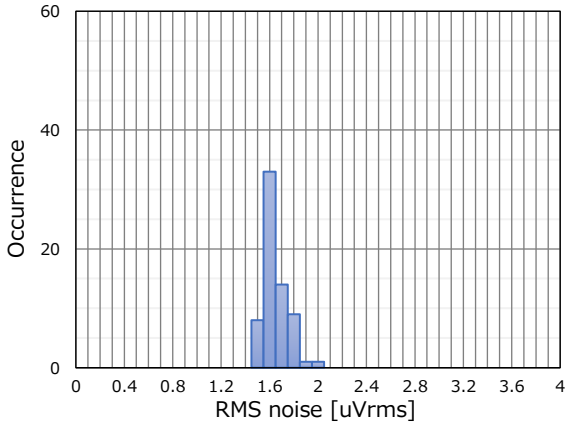
Positive reference buffer enabled
Gain=32



Negative reference buffer enabled
Gain=32



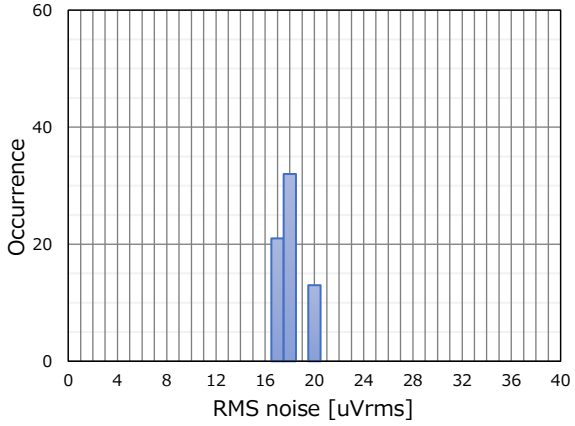
Positive, Negative reference buffer enabled
Gain=32



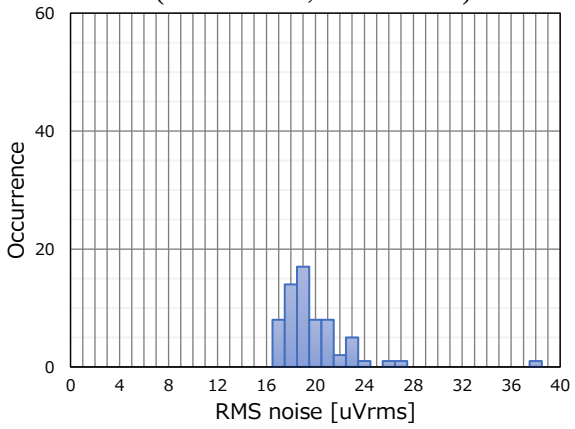
Note: The evaluation results for total oversampling ratio=224 are typical characteristics for total oversampling ratio=32 to 224.

AVCC0=5V, Ta=25℃, fMOD=4MHz, V_{ID}=0V, Total oversampling ratio=4096, Sinc4+Sinc4 filter, External VREF=2.5V

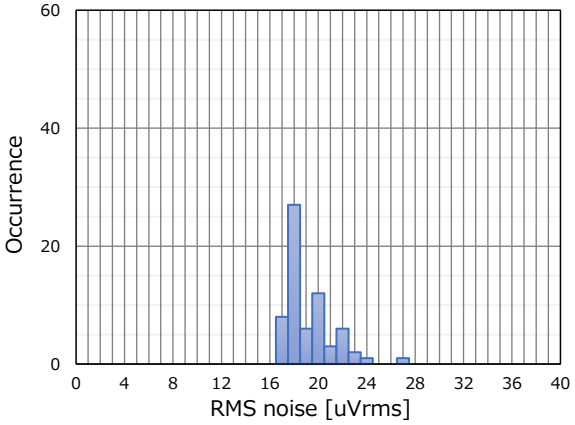
Reference buffer disabled
Gain=1(PGA enabled, BUF enabled)



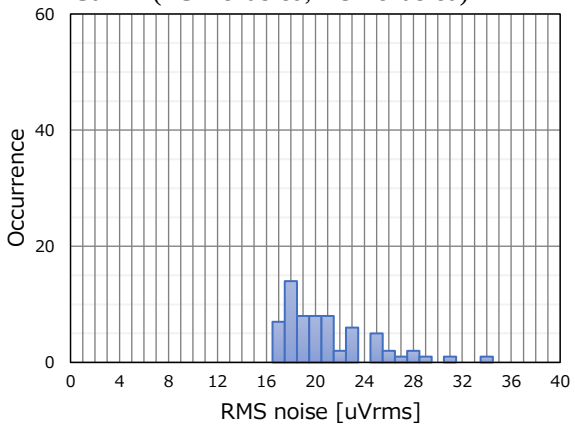
Positive reference buffer enabled
Gain=1(PGA enabled, BUF enabled)



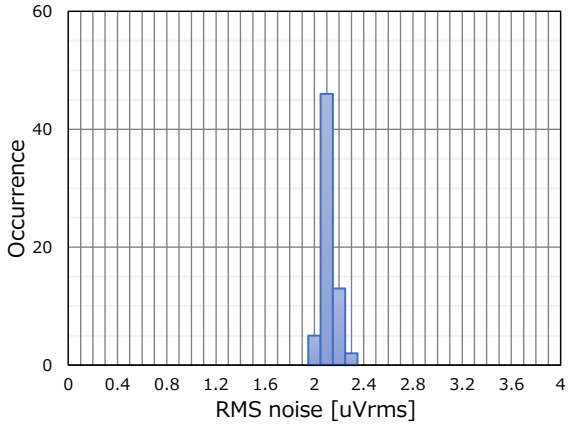
Negative reference buffer enabled
Gain=1(PGA enabled, BUF enabled)



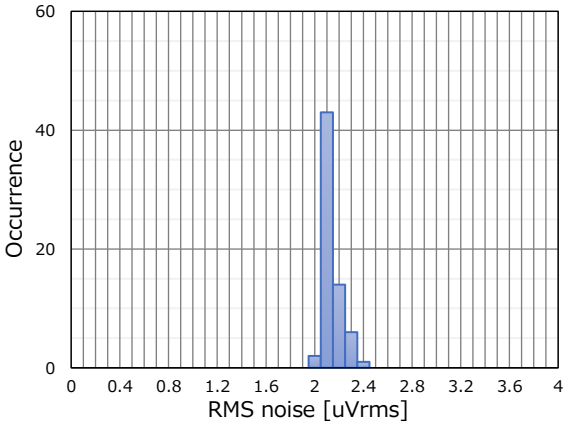
Positive, Negative reference buffer enabled
Gain=1(PGA enabled, BUF enabled)



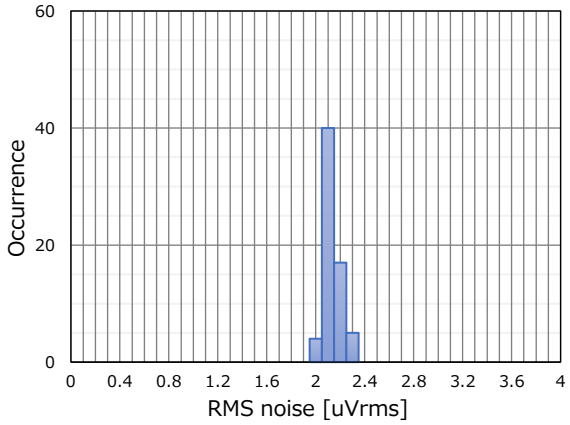
Reference buffer disabled
Gain=32



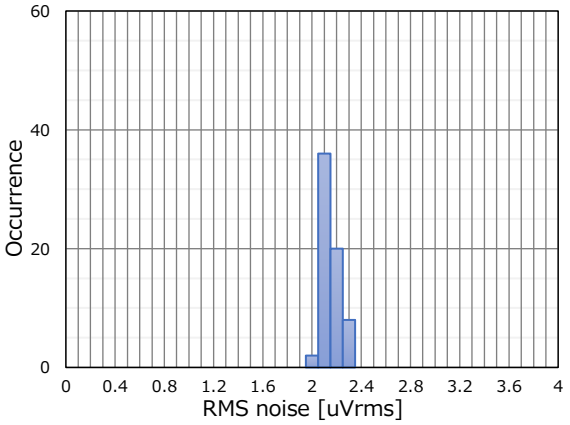
Positive reference buffer enabled
Gain=32



Negative reference buffer enabled
Gain=32



Positive, Negative reference buffer enabled
Gain=32

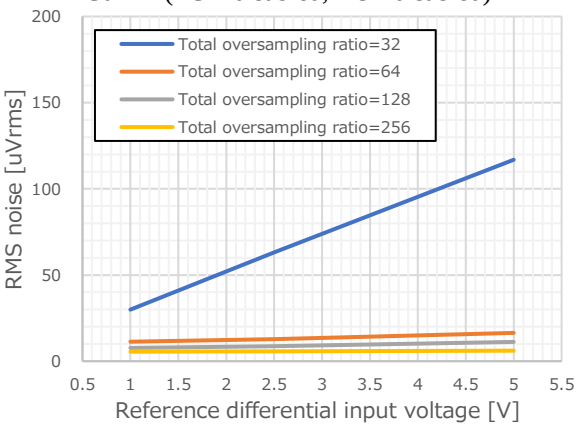


Note: The evaluation results for total oversampling ratio=4096 are typical characteristics for total oversampling ratio=256 to 1048576.

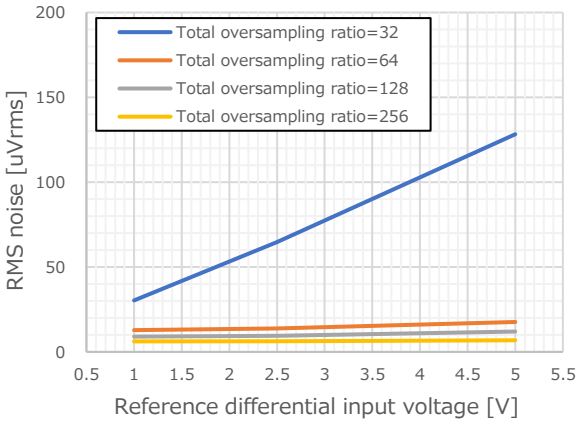
2.14 RMS noise - Reference differential input voltage

AVCC0=5V, Ta=25℃, fMOD=4MHz, V_{ID}=0V, $Sinc^5$ filter, Reference buffer disabled

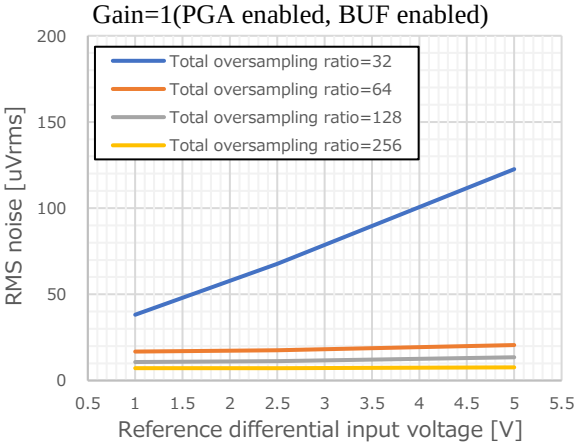
Gain=1(PGA disabled, BUF disabled)



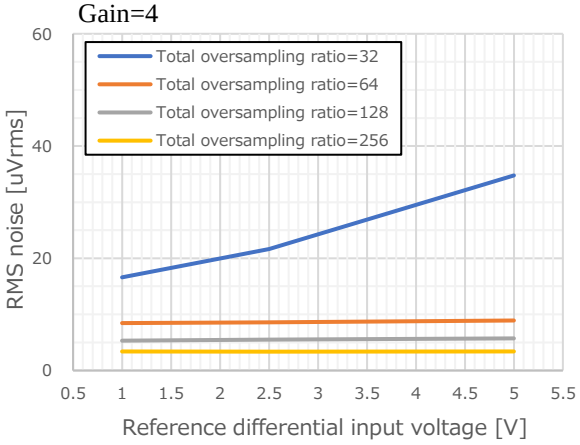
Gain=1(PGA disabled, BUF enabled)



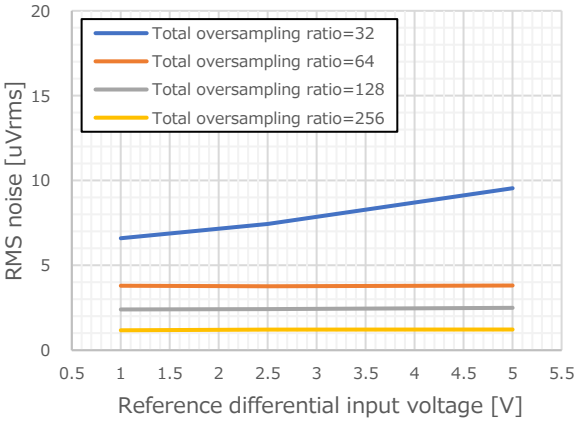
Gain=1(PGA enabled, BUF enabled)



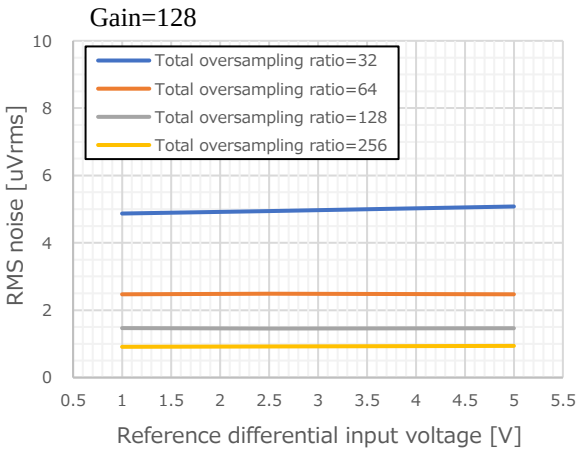
Gain=4



Gain=16



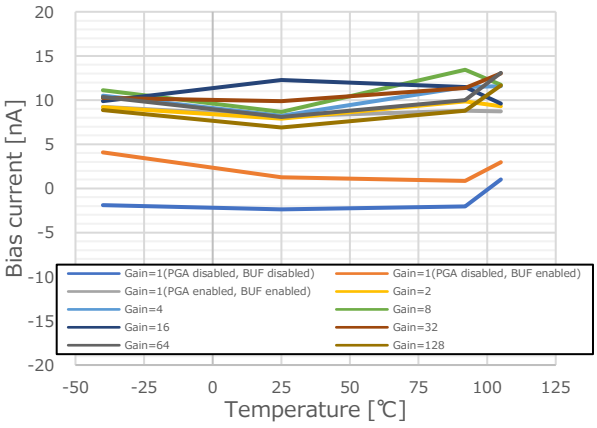
Gain=128



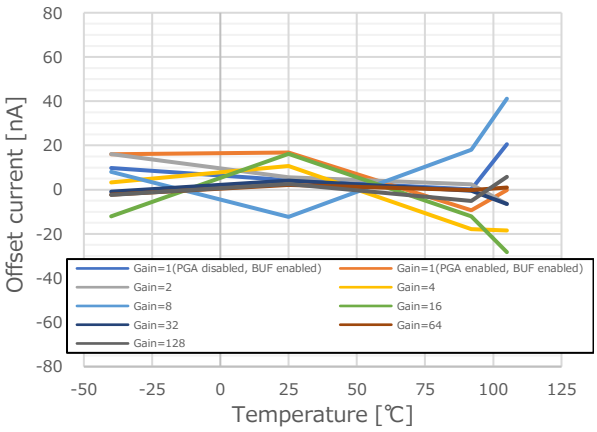
2.15 Analog input current

AVCC0=5V, f_{MOD}=4MHz, Total oversampling ratio=4096

Bias current
Vid=0V



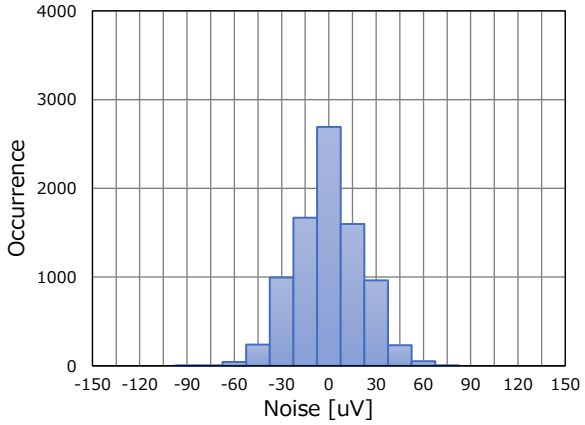
Offset current
Vid=2.5V/Gain

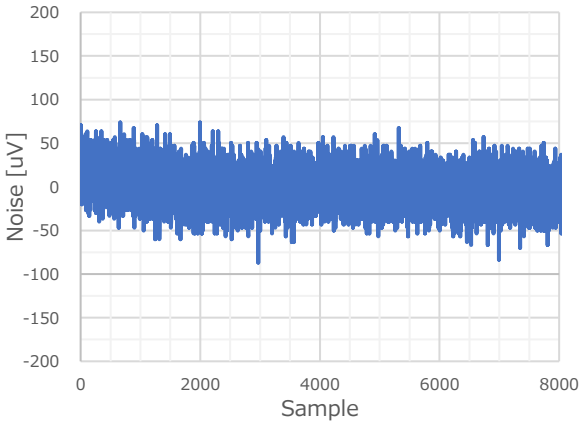


2.16 Noise histogram, Plot of Noise (High-Voltage Inputs)

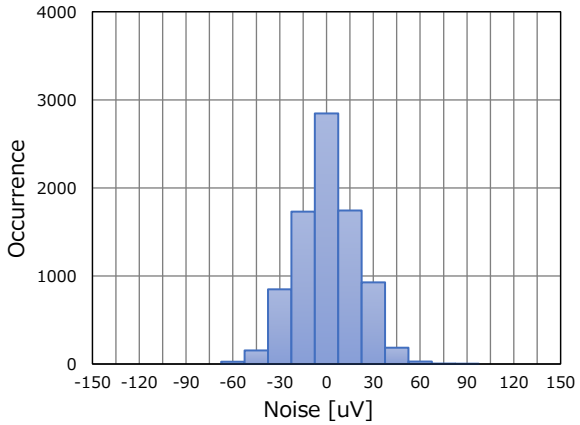
AVCC0=5V, Ta=25℃, fMOD=4MHz, V_{ID}=0V, External VREF=2.5V, Reference buffer disabled

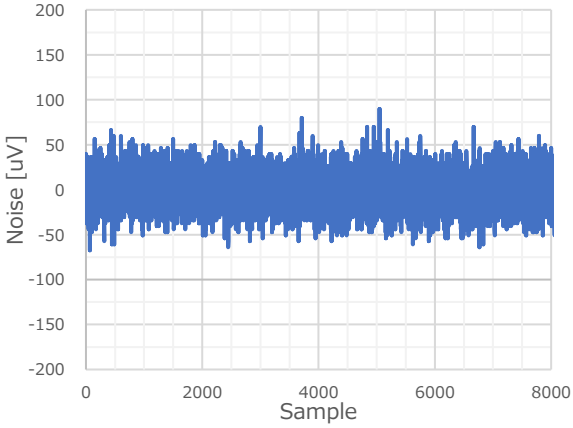
Gain=0.1(PGA disabled, BUF enabled),
f_{DR}=976.6 SPS, $Sinc^4$+$Sinc^4$ filter



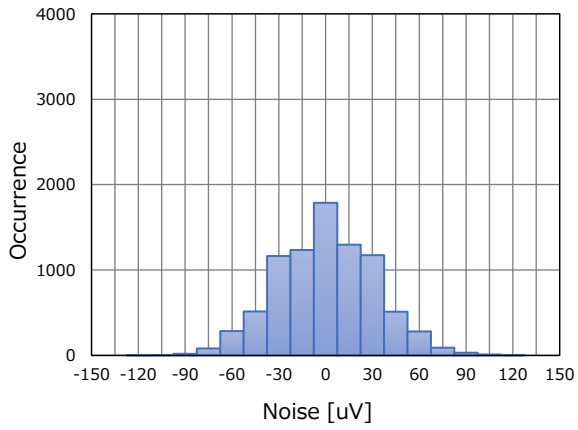


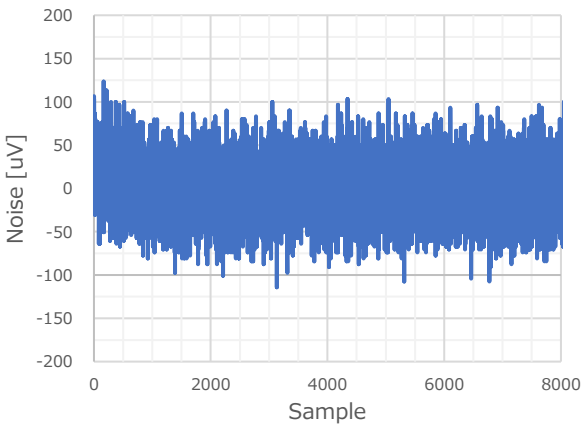
Gain=0.1(PGA enabled, BUF enabled),
f_{DR}=976.6 SPS, $Sinc^4$+$Sinc^4$ filter



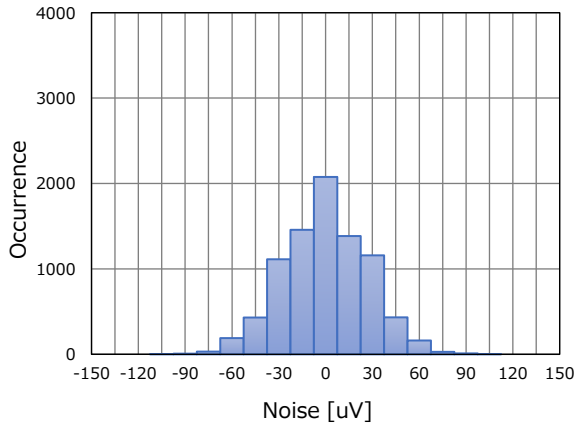


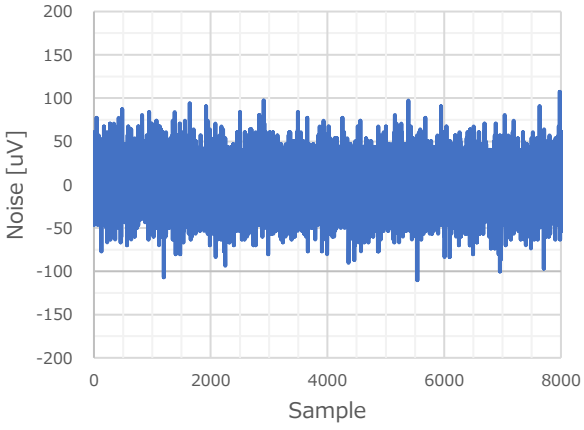
Gain=0.1(PGA disabled, BUF enabled),
f_{DR}=976.6 SPS, $Sinc^5$+$Sinc^1$ filter





Gain=0.1(PGA enabled, BUF enabled),
f_{DR}=976.6 SPS, $Sinc^5$+$Sinc^1$ filter

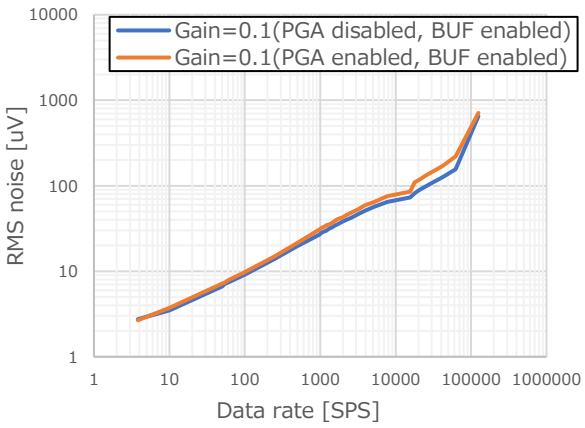




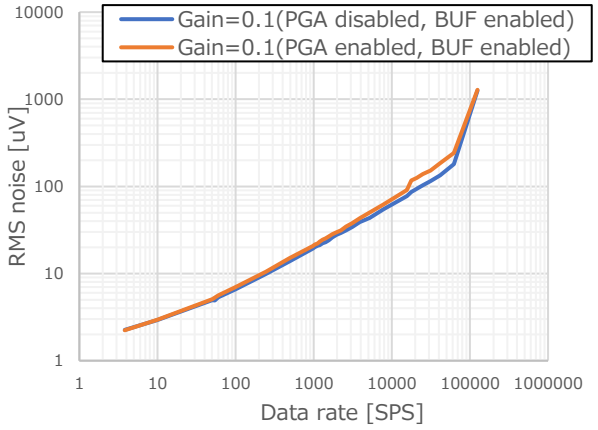
2.17 RMS noise - Date rate (High-Voltage Inputs)

AVCC0=5V, Ta=25℃, fMOD=4MHz, V_{ID}=0V, External VREF=2.5V, Reference buffer disabled

Sinc^5 filter or Sinc^5+Sinc^1 filter



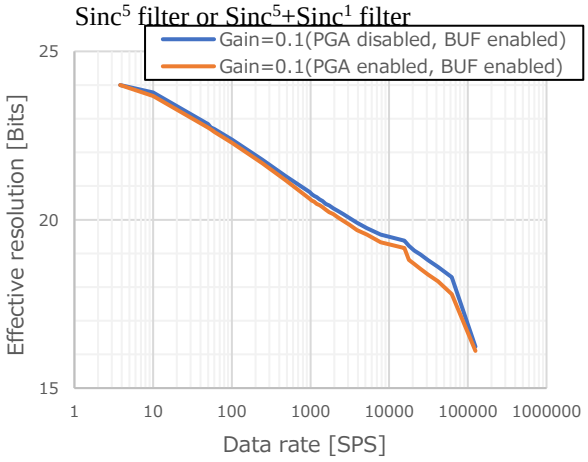
Sinc^4 filter or Sinc^4+Sinc^4 filter



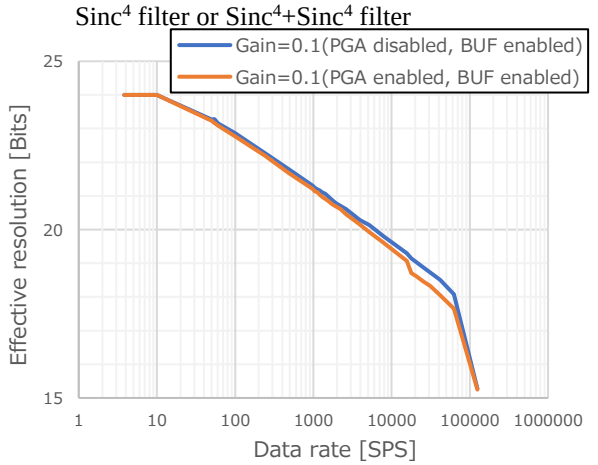
2.18 Effective resolution - Date rate (High-Voltage Inputs)

AVCC0=5V, Ta=25℃, fMOD=4MHz, V_{ID}=0V, External VREF=2.5V, Reference buffer disabled

Sinc^5 filter or Sinc^5+Sinc^1 filter



Sinc^4 filter or Sinc^4+Sinc^4 filter



2.19 Noise table (High-Voltage Inputs)

AVCC0=5V, Ta=25℃, fMOD=4MHz, V_{ID}=0V, $Sinc^5$ filter or $Sinc^5$+$Sinc^1$ filter, External VREF=2.5V, Reference buffer disabled

RMS noise[uVrms] (Peak-to-peak noise[uVpp])

Data rate [SPS]	OSR	Gain=0.1 (BUF)	Gain=0.1 (PGA)
3.8	1048576	2.656 (18.41)	2.791 (20.08)
10.0	399872	3.379 (24.13)	3.519 (24.13)
50.1	79872	6.349 (43.93)	6.763 (52.18)
54	73728	6.578 (50.57)	7.087 (47.59)
60	66560	7.099 (52.72)	7.519 (56.02)
100	39936	8.744 (63.15)	9.389 (68.66)
977	4096	25.69 (192.4)	29.47 (225.9)
1953	2048	35.69 (289.5)	40.31 (297.9)
3906	1024	47.88 (339.7)	55.15 (431.7)
15625	256	69.04 (513.7)	81.43 (622.5)
17857	224	77.43 (574.2)	103.7 (769.9)
31250	128	102.1 (801.6)	138.9 (1006)
41667	96	117.6 (914.9)	163.3 (1208)
62500	64	148.6 (1131)	208.7 (1504)
125000	32	648 (4767)	701 (5335)

Effective resolution [Bits] (Noise-free resolution [Bits])

Data rate [SPS]	OSR	Gain=0.1 (BUF)	Gain=0.1 (PGA)
3.8	1048576	24.0 (18.1)	24.0 (17.9)
10.0	399872	23.8 (17.7)	23.8 (17.7)
50.1	79872	22.9 (16.8)	22.8 (16.5)
54	73728	22.9 (16.6)	22.8 (16.7)
60	66560	22.7 (16.5)	22.7 (16.4)
100	39936	22.4 (16.3)	22.3 (16.2)
977	4096	20.9 (14.7)	20.7 (14.4)
1953	2048	20.4 (14.1)	20.2 (14.0)
3906	1024	20.0 (13.8)	19.8 (13.5)
15625	256	19.5 (13.2)	19.2 (13.0)
17857	224	19.3 (13.1)	18.9 (12.7)
31250	128	18.9 (12.6)	18.5 (12.3)
41667	96	18.7 (12.4)	18.2 (12.0)
62500	64	18.4 (12.1)	17.9 (11.7)
125000	32	16.2 (10.0)	16.1 (9.9)

AVCC0=5V, Ta=25℃, fMOD=4MHz, V_{ID}=0V, $Sinc^4$ filter or $Sinc^4$+$Sinc^4$ filter, External VREF=2.5V, Reference buffer disabled

RMS noise[uVrms] (Peak-to-peak noise[uVpp])

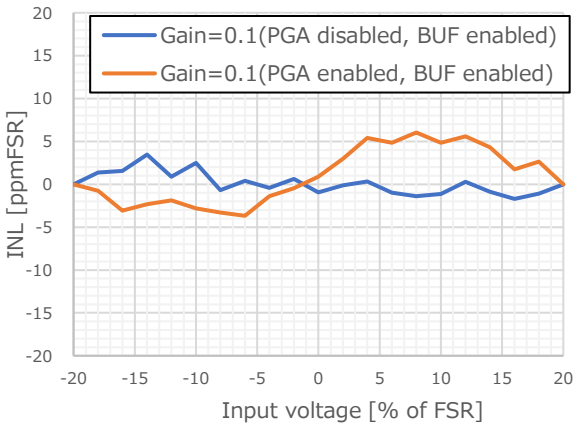
Data rate [SPS]	OSR	Gain=0.1 (BUF)	Gain=0.1 (PGA)
3.8	1048576	2.285 (13.39)	2.173 (13.39)
10.0	399872	2.871 (19.78)	2.929 (17.31)
50.1	79872	4.815 (33.37)	5.029 (36.40)
54	73728	4.795 (35.52)	4.950 (35.52)
60	66560	5.151 (37.74)	5.404 (37.74)
100	39936	6.322 (48.54)	6.759 (48.54)
977	4096	18.29 (143.9)	19.53 (157.3)
1953	2048	25.45 (189.1)	27.80 (195.8)
3906	1024	36.36 (269.4)	40.47 (311.2)
15625	256	72.33 (547.2)	87.76 (676.0)
17857	224	81.57 (588.1)	110.7 (856.4)
31250	128	108.4 (809.9)	147.3 (1029)
41667	96	124.6 (909.7)	173.6 (1285)
62500	64	175.3 (1322)	233.3 (1760)
125000	32	1274 (8976)	1285 (9287)

Effective resolution [Bits] (Noise-free resolution [Bits])

Data rate [SPS]	OSR	Gain=0.1 (BUF)	Gain=0.1 (PGA)
3.8	1048576	24.0 (18.5)	24.0 (18.5)
10.0	399872	24.0 (17.9)	24.0 (18.1)
50.1	79872	23.3 (17.2)	23.2 (17.1)
54	73728	23.3 (17.1)	23.3 (17.1)
60	66560	23.2 (17.0)	23.1 (17.0)
100	39936	22.9 (16.7)	22.8 (16.7)
977	4096	21.4 (15.1)	21.3 (15.0)
1953	2048	20.9 (14.7)	20.8 (14.6)
3906	1024	20.4 (14.2)	20.2 (14.0)
15625	256	19.4 (13.2)	19.1 (12.9)
17857	224	19.2 (13.1)	18.8 (12.5)
31250	128	18.8 (12.6)	18.4 (12.2)
41667	96	18.6 (12.4)	18.1 (11.9)
62500	64	18.1 (11.9)	17.7 (11.5)
125000	32	15.3 (9.1)	15.2 (9.1)

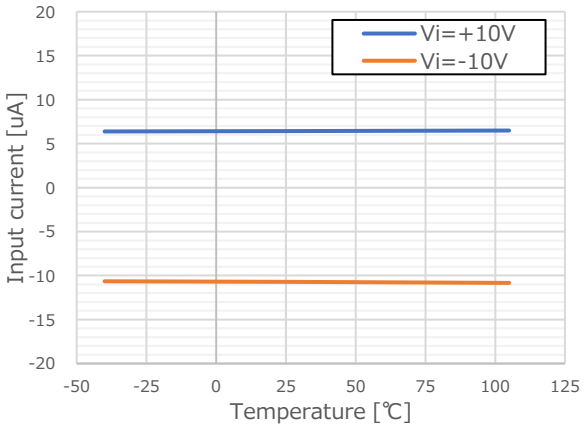
2.20 Integral nonlinearity error (INL) (High-Voltage Inputs)

AVCC0=5V, Ta=25℃, f_{MOD}=4MHz, Total oversampling ratio=4096, External V_{REF}=2.5V, Reference buffer disabled



2.21 Analog input current (High-Voltage Inputs)

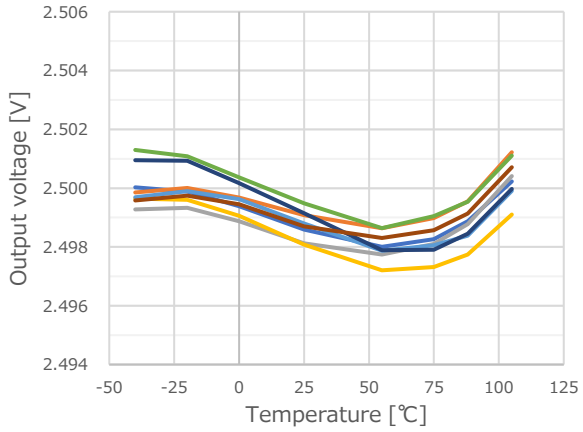
AVCC0=5V, Ta=25℃, f_{MOD}=4MHz, Total oversampling ratio=4096



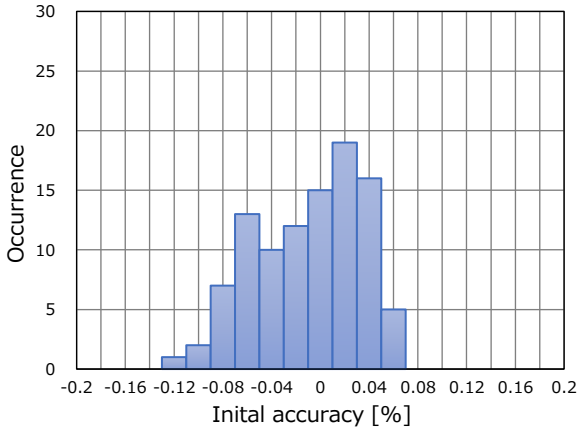
3. Voltage Reference (VREF)

AVCC0=5V

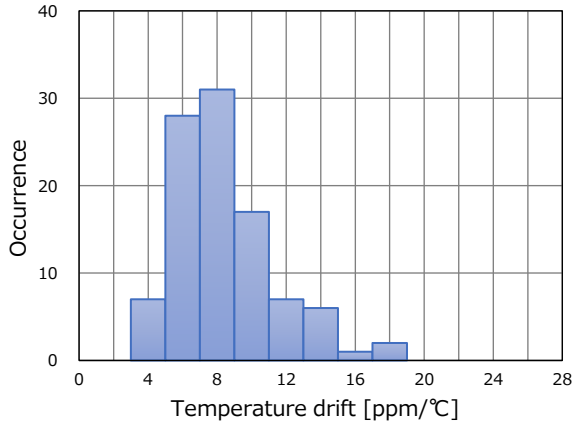
Temperature Dependence



Initial Accuracy

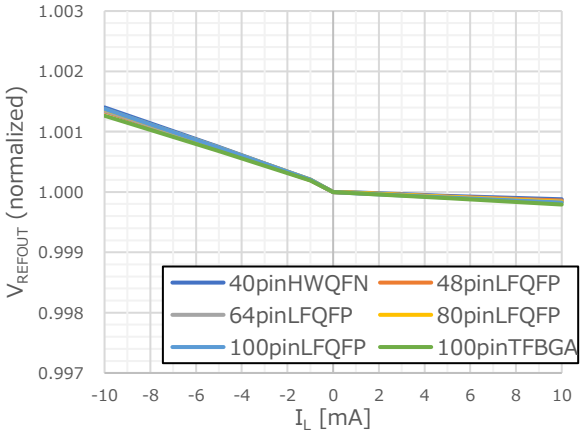


Temperature drift



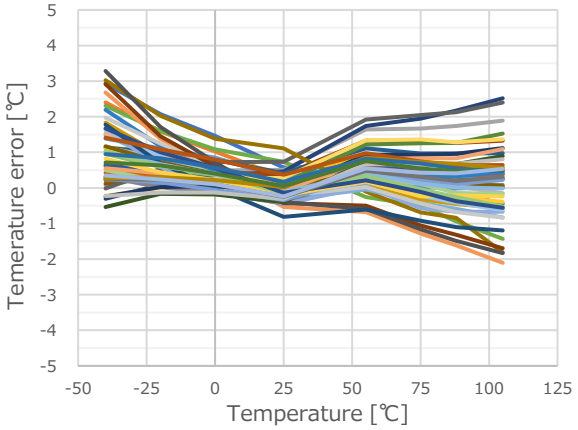
Load regulation

Ta=25℃



4. Temperature Sensor

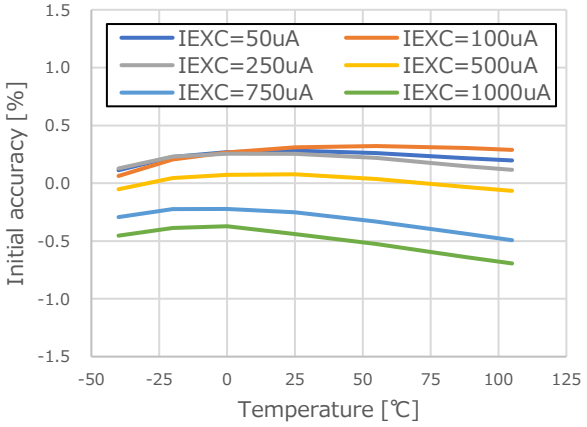
AVCC0=5V



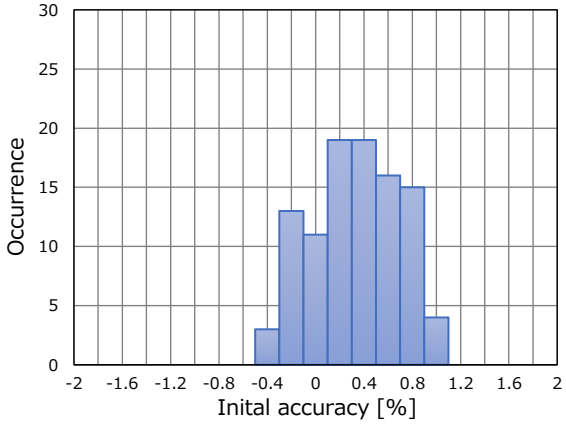
5. Excitation Current Source

AVCC0=5V

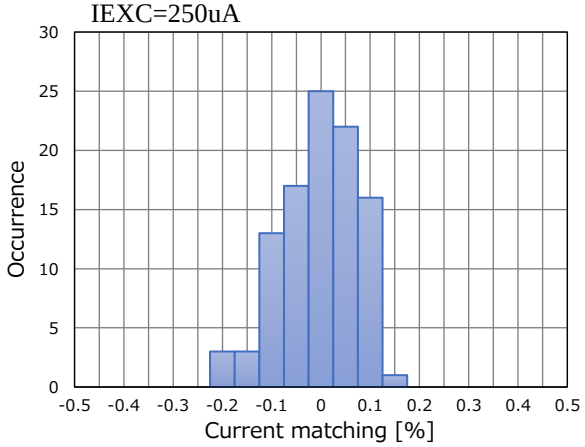
Temperature Dependence



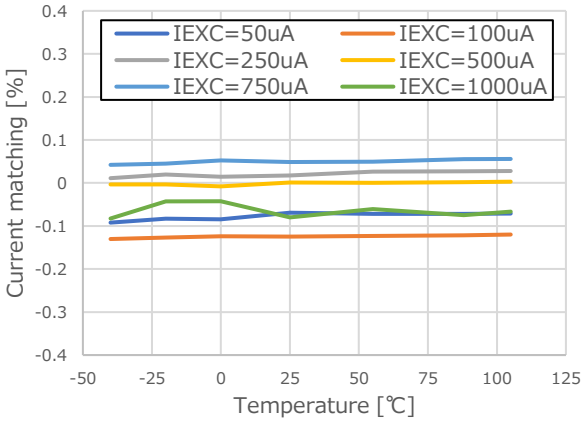
Initial Accuracy
IEXC=250uA



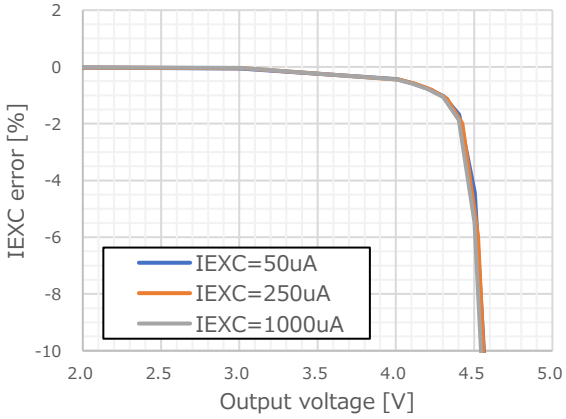
Current matching
IEXC=250uA



Drift matching



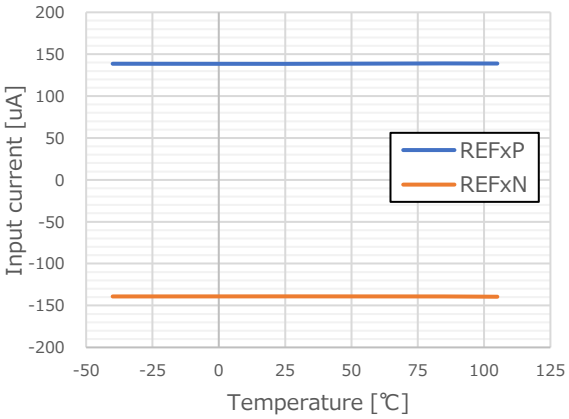
Load regulation
Ta=25℃



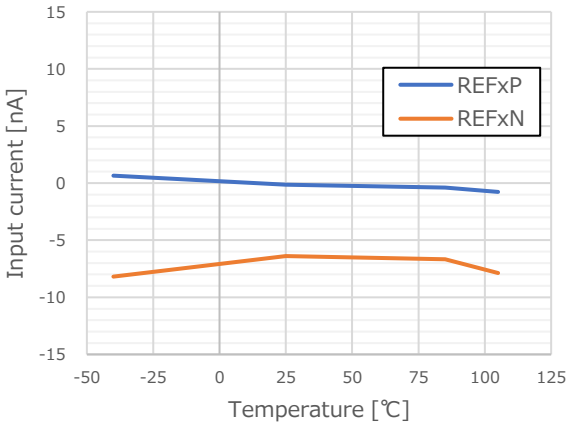
6. External reference input

AVCC0=5V, External V_{REF}=2.5V

Input current
Reference buffer disabled



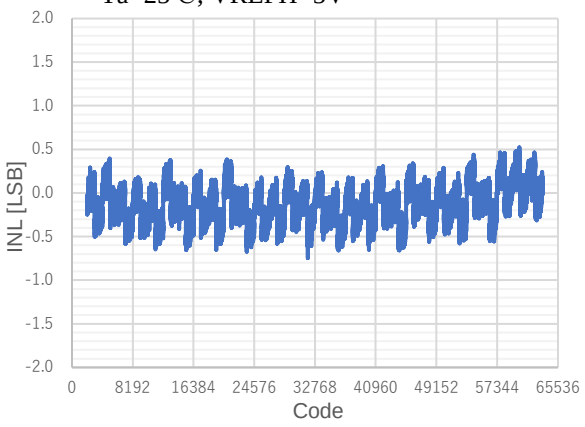
Input current
Reference buffer enabled



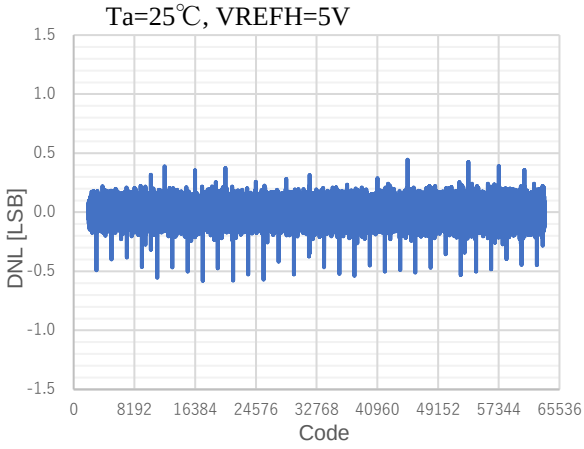
7. 16-Bit D/A Converter

AVCC0=5V

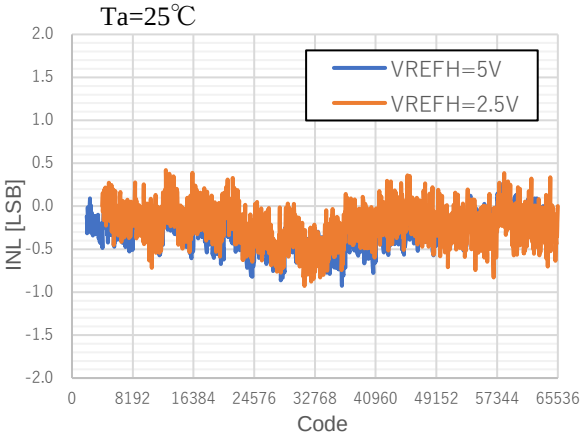
INL code dependence
Ta=25℃, VREFH=5V



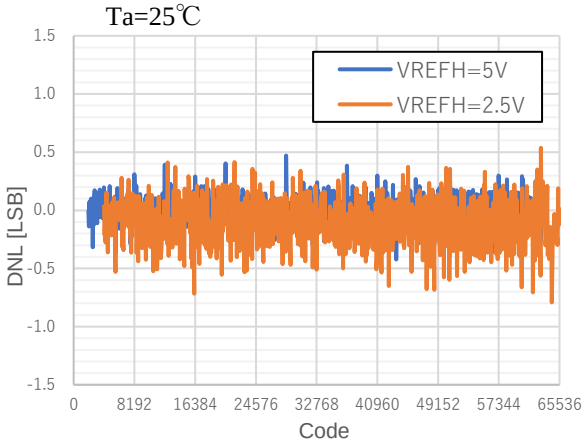
DNL code dependence
Ta=25℃, VREFH=5V



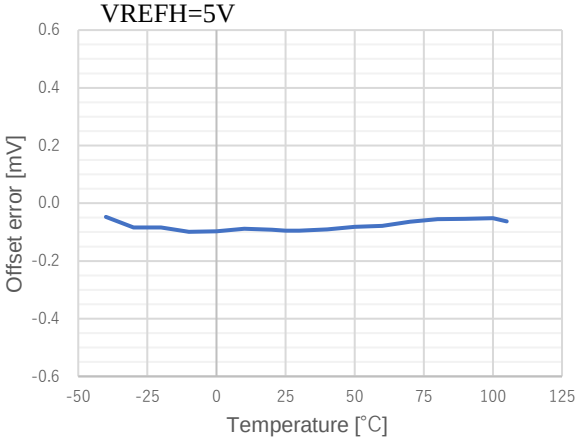
INL code dependence
Ta=25℃



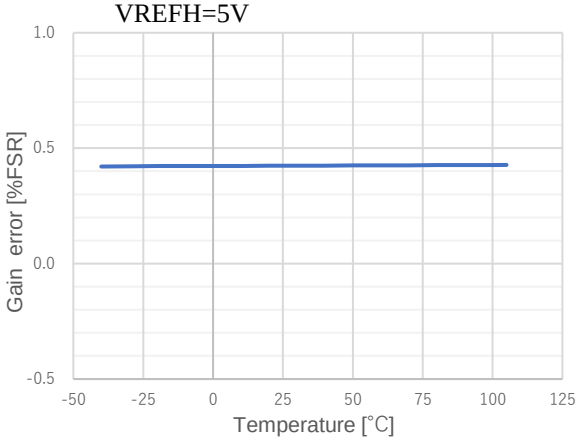
DNL code dependence
Ta=25℃



Offset error
VREFH=5V

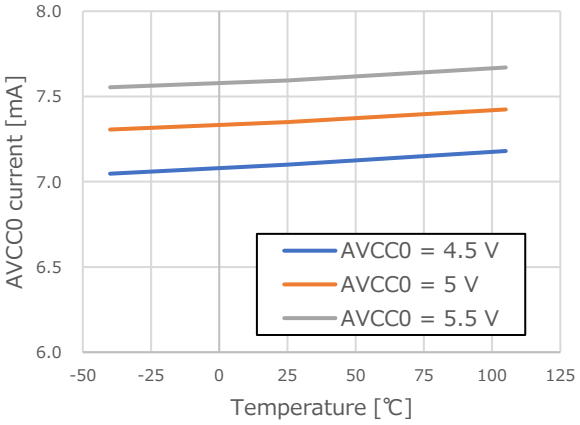


Gain error
VREFH=5V

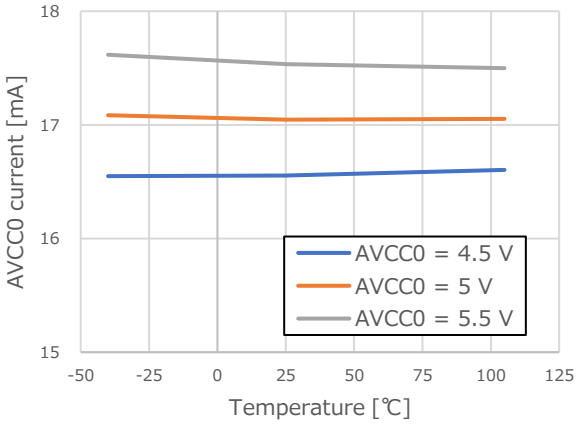


8. Operating current

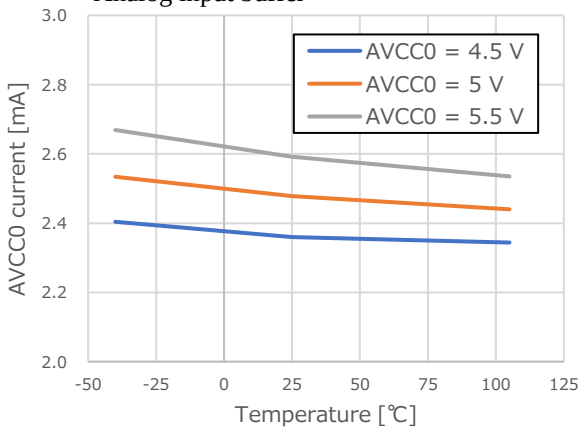
24bit Delta-Sigma A/D Converter
PGA disabled, BUF disabled



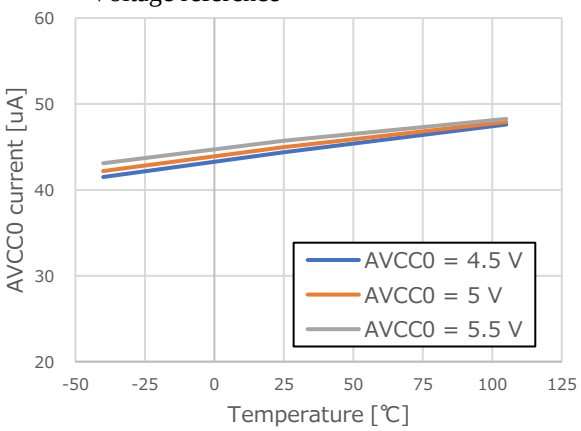
24bit Delta-Sigma A/D Converter
PGA enabled, BUF enabled



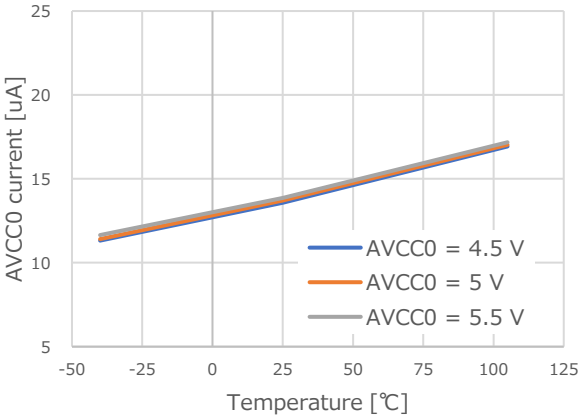
Analog input buffer



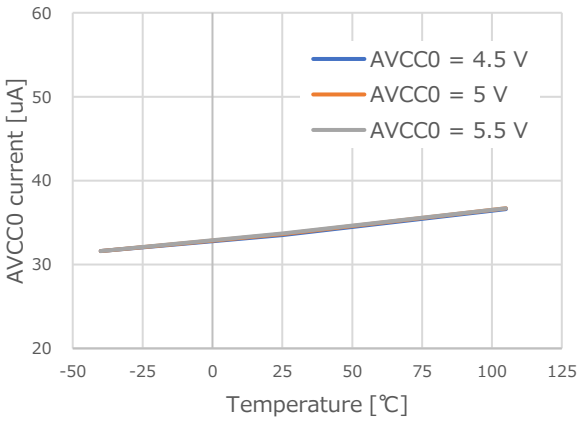
Voltage reference



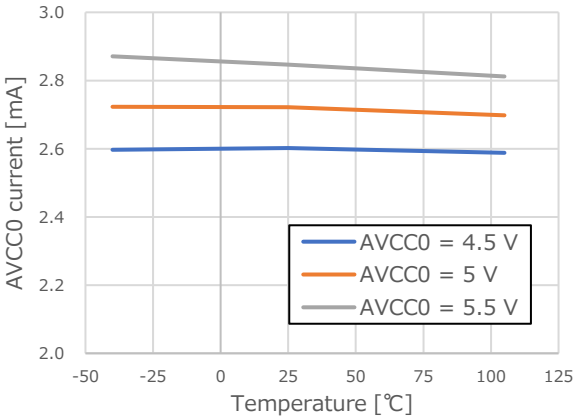
Temperature sensor



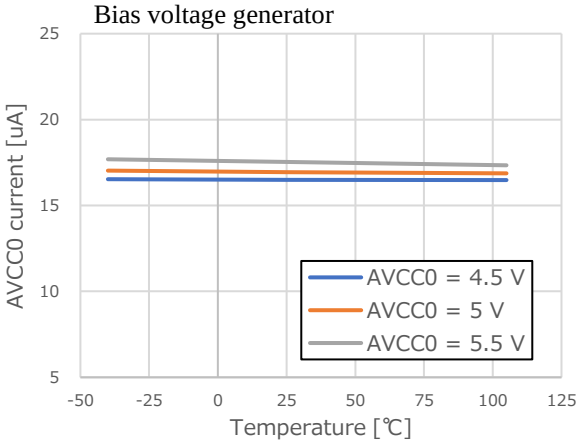
Excitation current source



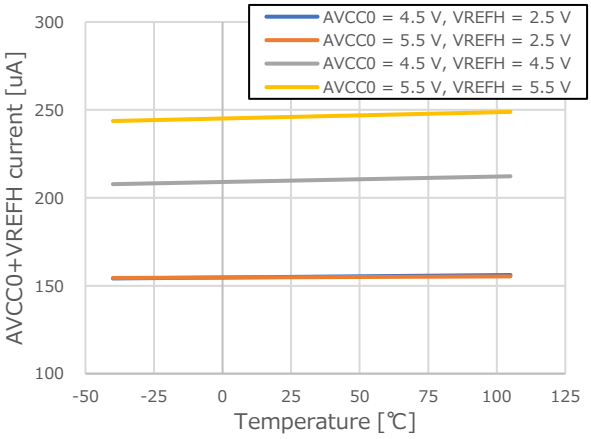
Reference buffer



Bias voltage generator



16-bit D/A converter



Revision History

Rev.	Date	Description	
		Page	Summary
1.00	Mar 29, 2024	—	First edition issued.

General Precautions in the Handling of Microprocessing Unit and Microcontroller Unit Products

The following usage notes are applicable to all Microprocessing unit and Microcontroller unit products from Renesas. For detailed usage notes on the products covered by this document, refer to the relevant sections of the document as well as any technical updates that have been issued for the products.

1. Precaution against Electrostatic Discharge (ESD)

   A strong electrical field, when exposed to a CMOS device, can cause destruction of the gate oxide and ultimately degrade the device operation. Steps must be taken to stop the generation of static electricity as much as possible, and quickly dissipate it when it occurs. Environmental control must be adequate. When it is dry, a humidifier should be used. This is recommended to avoid using insulators that can easily build up static electricity. Semiconductor devices must be stored and transported in an anti-static container, static shielding bag or conductive material. All test and measurement tools including work benches and floors must be grounded. The operator must also be grounded using a wrist strap. Semiconductor devices must not be touched with bare hands. Similar precautions must be taken for printed circuit boards with mounted semiconductor devices.
2. Processing at power-on

   The state of the product is undefined at the time when power is supplied. The states of internal circuits in the LSI are indeterminate and the states of register settings and pins are undefined at the time when power is supplied. In a finished product where the reset signal is applied to the external reset pin, the states of pins are not guaranteed from the time when power is supplied until the reset process is completed. In a similar way, the states of pins in a product that is reset by an on-chip power-on reset function are not guaranteed from the time when power is supplied until the power reaches the level at which resetting is specified.
3. Input of signal during power-off state

   Do not input signals or an I/O pull-up power supply while the device is powered off. The current injection that results from input of such a signal or I/O pull-up power supply may cause malfunction and the abnormal current that passes in the device at this time may cause degradation of internal elements. Follow the guideline for input signal during power-off state as described in your product documentation.
4. Handling of unused pins

   Handle unused pins in accordance with the directions given under handling of unused pins in the manual. The input pins of CMOS products are generally in the high-impedance state. In operation with an unused pin in the open-circuit state, extra electromagnetic noise is induced in the vicinity of the LSI, an associated shoot-through current flows internally, and malfunctions occur due to the false recognition of the pin state as an input signal become possible.
5. Clock signals

   After applying a reset, only release the reset line after the operating clock signal becomes stable. When switching the clock signal during program execution, wait until the target clock signal is stabilized. When the clock signal is generated with an external resonator or from an external oscillator during a reset, ensure that the reset line is only released after full stabilization of the clock signal. Additionally, when switching to a clock signal produced with an external resonator or by an external oscillator while program execution is in progress, wait until the target clock signal is stable.
6. Voltage application waveform at input pin

   Waveform distortion due to input noise or a reflected wave may cause malfunction. If the input of the CMOS device stays in the area between V_{IL} (Max.) and V_{IH} (Min.) due to noise, for example, the device may malfunction. Take care to prevent chattering noise from entering the device when the input level is fixed, and also in the transition period when the input level passes through the area between V_{IL} (Max.) and V_{IH} (Min.).
7. Prohibition of access to reserved addresses

   Access to reserved addresses is prohibited. The reserved addresses are provided for possible future expansion of functions. Do not access these addresses as the correct operation of the LSI is not guaranteed.
8. Differences between products

   Before changing from one product to another, for example to a product with a different part number, confirm that the change will not lead to problems. The characteristics of a microprocessing unit or microcontroller unit products in the same group but having a different part number might differ in terms of internal memory capacity, layout pattern, and other factors, which can affect the ranges of electrical characteristics, such as characteristic values, operating margins, immunity to noise, and amount of radiated noise. When changing to a product with a different part number, implement a system-evaluation test for the given product.

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