Radiation Tolerant 20-Bit, 1Msps, Low Power Plastic Package SAR ADC

FEATURES

- **10kRad (Si) Total Ionizing Dose (TID) per MIL-STD-883 TM1019 Condition A**
- **Single Event Latch-Up (SEL) Threshold Linear Energy Transfer (LET) ≥ 30.86MeV-cm²/mg at T_{CASE} = 70°C**
- **Processed Using MIL-PRF-38535 Class N and PEM-INST-001 as a Guideline**
- **TID and SEL Reports Available**
- 1Msps Throughput Rate
- ±0.5ppm INL (Typ)
- Guaranteed 20-Bit No Missing Codes
- Low Power: 21mW at 1Msps, 21µW at 1ksps
- 104dB SNR (Typ) at f_{IN} = 2kHz
- –125dB THD (Typ) at f_{IN} = 2kHz
- Digital Gain Compression (DGC)
- 2.5V Supply
- Fully Differential Input Range ±V_{REF}
- V_{REF} Input Range from 2.5V to 5.1V
- No Pipeline Delay, No Cycle Latency
- 1.8V to 5V I/O Voltages
- SPI-Compatible Serial I/O with Daisy-Chain Mode
- Internal Conversion Clock
- 16-Lead MSOP Package

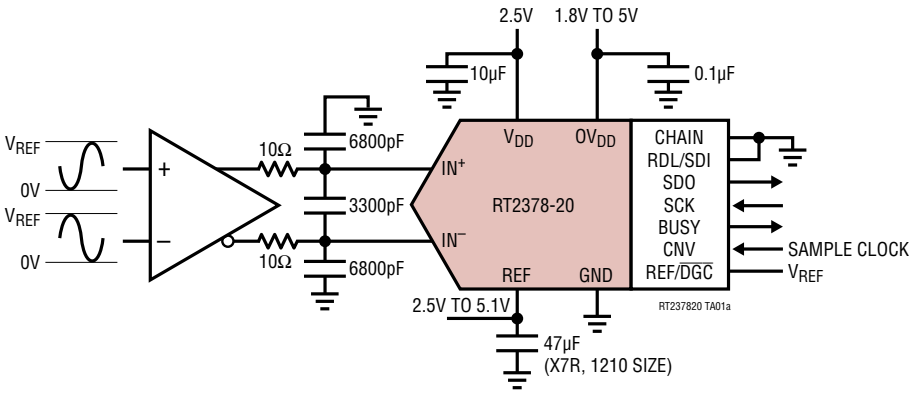
DESCRIPTION

The RT2378-20 is a low noise, low power, high speed 20-bit successive approximation register (SAR) ADC. Operating from a 2.5V supply, the RT2378-20 has a ±V_{REF} fully differential input range with V_{REF} ranging from 2.5V to 5.1V. The RT2378-20 consumes only 21mW and achieves ±2ppm INL maximum, no missing codes at 20 bits with 104dB SNR.

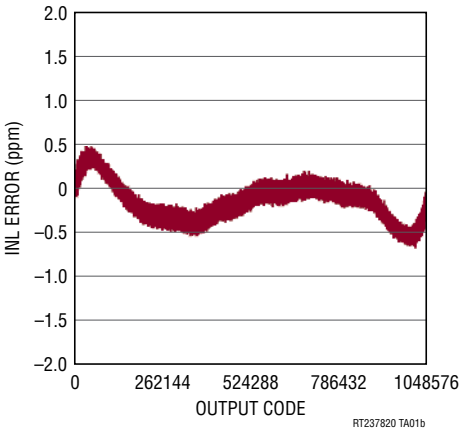
The RT2378-20 has a high speed SPI-compatible serial interface that supports 1.8V, 2.5V, 3.3V and 5V logic while also featuring a daisy-chain mode. The fast 1Msps throughput with no cycle latency makes the RT2378-20 ideally suited for a wide variety of high speed applications. An internal oscillator sets the conversion time, easing external timing considerations. The RT2378-20 automatically powers down between conversions, leading to reduced power dissipation that scales with the sampling rate.

The RT2378-20 features a unique digital gain compression (DGC) function, which eliminates the driver amplifier's negative supply while preserving the full resolution of the ADC. When enabled, the ADC performs a digital scaling function that maps zero-scale code from 0V to 0.1 • V_{REF} and full-scale code from V_{REF} to 0.9 • V_{REF}. For a typical reference voltage of 5V, the full-scale input range is now 0.5V to 4.5V, which provides adequate headroom for powering the driving amplifier from a single 5.5V supply.

TYPICAL APPLICATION



Integral Nonlinearity vs Output Code

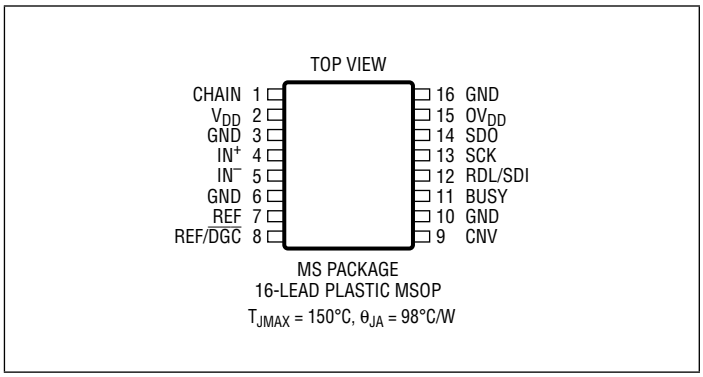


ABSOLUTE MAXIMUM RATINGS

(Notes 1, 2)

Supply Voltage (V_{DD}) 2.8V
Supply Voltage (OV_{DD}) 6V
Reference Input (REF) 6V
Analog Input Voltage (Note 3)
IN^+, IN^- ..... (GND –0.3V) to (REF + 0.3V)
REF/$\overline{DGC}$ Input (Note 3) .... (GND –0.3V) to (REF + 0.3V)
Digital Input Voltage
(Note 3) ..... (GND –0.3V) to (OV_{DD} + 0.3V)
Digital Output Voltage
(Note 3) ..... (GND –0.3V) to (OV_{DD} + 0.3V)
Operating Temperature Range
RT2378I ..... –40°C to 85°C
Storage Temperature Range ..... –65°C to 150°C

PIN CONFIGURATION



ORDER INFORMATION

LEAD FINISH	TAPE AND REEL	PART MARKING	PACKAGE DESCRIPTION	TEMPERATURE RANGE
RT2378IMS-20	RT2378IMS-20#TR	237820	16-Lead Plastic MSOP	–40°C to 85°C

Consult LTC Marketing for parts specified with wider operating temperature ranges.

For more information on lead free part marking, go to: http://www.linear.com/leadfree/
For more information on tape and reel specifications, go to: http://www.linear.com/tapeandreel/. Some packages are available in 500 unit reels through designated sales channels with #TRMPBF suffix.

ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. (Note 4)

SYMBOL	PARAMETER	CONDITIONS		SUB GROUP	MIN	TYP	MAX	UNITS
$V_{IN}+$	Absolute Input Range (IN^+)	(Note 5)	●	1, 2, 3	–0.1		V_{REF} + 0.1	V
$V_{IN}–$	Absolute Input Range (IN^-)	(Note 5)	●	1, 2, 3	–0.1		V_{REF} + 0.1	V
$V_{IN}+ – V_{IN}–$	Input Differential Voltage Range	$V_{IN} = V_{IN}+ – V_{IN}–$	●	1, 2, 3	$–V_{REF}$		$+V_{REF}$	V
V_{CM}	Common-Mode Input Range		●	1, 2, 3	$V_{REF}/2–$ 0.1	$V_{REF}/2$	$V_{REF}/2+$ 0.1	V
I_{IN}	Analog Input Leakage Current					0.01		µA
C_{IN}	Analog Input Capacitance	Sample Mode Hold Mode				45 5		pF pF
CMRR	Input Common Mode Rejection Ratio	f_{IN} = 500kHz				86		dB

CONVERTER CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. (Note 4)

SYMBOL	PARAMETER	CONDITIONS		SUB GROUP	MIN	TYP	MAX	UNITS
	Resolution		●		20			Bits
	No Missing Codes		●		20			Bits
	Transition Noise					2.3		ppm_{RMS}
INL	Integral Linearity Error	(Note 6) REF/$\overline{DGC}$ = GND (Note 6)	● ●	1, 2, 3 1, 2, 3	–2 –2	±0.5 ±0.5	2 2	ppm ppm
DNL	Differential Linearity Error	(Note 10)	●	1, 2, 3	–0.5	±0.2	0.5	ppm
BZE	Bipolar Zero-Scale Error	(Note 7)	●	1, 2, 3	–13	0	13	ppm
	Bipolar Zero-Scale Error Drift					±7		ppb/°C
FSE	Bipolar Full-Scale Error	(Note 7)	●	1, 2, 3	–100	±10	100	ppm
	Bipolar Full-Scale Error Drift					±0.05		ppm/°C

DYNAMIC ACCURACY

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C and A_{IN} = –1dBFS. (Notes 4, 8)

SYMBOL	PARAMETER	CONDITIONS		SUB GROUP	MIN	TYP	MAX	UNITS
SINAD	Signal-to-(Noise + Distortion) Ratio	f_{IN} = 2kHz, V_{REF} = 5V	●	4, 5, 6	101	104		dB
SNR	Signal-to-Noise Ratio	f_{IN} = 2kHz, V_{REF} = 5V f_{IN} = 2kHz, V_{REF} = 5V, REF/$\overline{DGC}$ = GND f_{IN} = 2kHz, V_{REF} = 2.5V	● ● ●	4, 5, 6 4, 5, 6 4, 5, 6	101 99 95.4	104 102 98		dB dB dB
THD	Total Harmonic Distortion	f_{IN} = 2kHz, V_{REF} = 5V f_{IN} = 2kHz, V_{REF} = 5V, REF/$\overline{DGC}$ = GND f_{IN} = 2kHz, V_{REF} = 2.5V	● ● ●	4, 5, 6 4, 5, 6 4, 5, 6		–125 –125 –123	–114 –114 –113	dB dB dB
SFDR	Spurious Free Dynamic Range	f_{IN} = 2kHz, V_{REF} = 5V	●	4, 5, 6	115	128		dB
	–3dB Input Bandwidth					34		MHz
	Aperture Delay					500		ps
	Aperture Jitter					4		ps
	Transient Response	Full-Scale Step				312		ns

REFERENCE INPUT

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. (Note 4)

SYMBOL	PARAMETER	CONDITIONS		SUB GROUP	MIN	TYP	MAX	UNITS
V_{REF}	Reference Voltage	(Note 5)	●	1, 2, 3	2.5		5.1	V
I_{REF}	Reference Input Current	(Note 9)	●	1, 2, 3		0.94	1.1	mA
$V_{IH\overline{DGC}}$	High Level Input Voltage REF/$\overline{DGC}$ Pin		●	1, 2, 3	$0.8V_{REF}$			V
$V_{IL\overline{DGC}}$	Low Level Input Voltage REF/$\overline{DGC}$ Pin		●	1, 2, 3			$0.2V_{REF}$	V

DIGITAL INPUTS AND DIGITAL OUTPUTS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. (Note 4)

SYMBOL	PARAMETER	CONDITIONS		SUB GROUP	MIN	TYP	MAX	UNITS
V_{IH}	High Level Input Voltage		●	1, 2, 3	0.8 • OV_{DD}			V
V_{IL}	Low Level Input Voltage		●	1, 2, 3			0.2 • OV_{DD}	V
I_{IN}	Digital Input Current	V_{IN} = 0V to OV_{DD}	●	1, 2, 3	–10		10	µA
C_{IN}	Digital Input Capacitance					5		pF
V_{OH}	High Level Output Voltage	I_O = –500µA	●	1, 2, 3	OV_{DD} – 0.2			V
V_{OL}	Low Level Output Voltage	I_O = 500µA	●	1, 2, 3			0.2	V
I_{OZ}	Hi-Z Output Leakage Current	V_{OUT} = 0V to OV_{DD}	●	1, 2, 3	–10		10	µA
I_{SOURCE}	Output Source Current	V_{OUT} = 0V				–10		mA
I_{SINK}	Output Sink Current	V_{OUT} = OV_{DD}				10		mA

POWER REQUIREMENTS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. (Note 4)

SYMBOL	PARAMETER	CONDITIONS		SUB GROUP	MIN	TYP	MAX	UNITS
V_{DD}	Supply Voltage		●	1, 2, 3	2.375	2.5	2.625	V
OV_{DD}	Supply Voltage		●	1, 2, 3	1.71		5.25	V
I_{VDD}	Supply Current	1Msps Sample Rate	●	1, 2, 3		8.4	10	mA
I_{OVDD}	Supply Current	1Msps Sample Rate (C_L = 20pF)				0.2		mA
I_{PD}	Power Down Mode	Conversion Done (I_{VDD} + I_{OVDD} + I_{REF})	●	1, 2, 3		1	90	µA
P_D	Power Dissipation	1Msps Sample Rate		1		21	25	mW
	Power Down Mode	Conversion Done (I_{VDD} + I_{OVDD} + I_{REF})		1		2.5	225	µW

ADC TIMING CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. (Note 4)

SYMBOL	PARAMETER	CONDITIONS		SUB GROUP	MIN	TYP	MAX	UNITS
f_{SMPL}	Maximum Sampling Frequency		●	9, 10, 11			1	Msps
t_{CONV}	Conversion Time		●	9, 10, 11	615		675	ns
t_{ACQ}	Acquisition Time	t_{ACQ} = t_{CYC} – t_{CONV} – t_{BUSYLH} (Note 10)	●		312			ns
t_{CYC}	Time Between Conversions		●	9, 10, 11	1			µs
t_{CNVH}	CNV High Time		●	9, 10, 11	20			ns
t_{BUSYLH}	CNV↑ to BUSY Delay	C_L = 20pF	●	9, 10, 11			13	ns
t_{CNVL}	Minimum Low Time for CNV	(Note 11)	●	9, 10, 11	20			ns
t_{QUIET}	SCK Quiet Time from CNV↑	(Note 10)	●		20			ns
t_{SCK}	SCK Period	(Notes 11, 12)	●	9, 10, 11	10			ns
t_{SCKH}	SCK High Time		●	9, 10, 11	4			ns
t_{SCKL}	SCK Low Time		●	9, 10, 11	4			ns
$t_{SSDISCK}$	SDI Setup Time From SCK↑	(Note 11)	●	9, 10, 11	4			ns
$t_{HSDISCK}$	SDI Hold Time From SCK↑	(Note 11)	●	9, 10, 11	1			ns
t_{SCKCH}	SCK Period in Chain Mode	t_{SCKCH} = $t_{SSDISCK}$ + t_{DSDO} (Note 11)	●	9, 10, 11	13.5			ns

ADC TIMING CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. (Note 4)

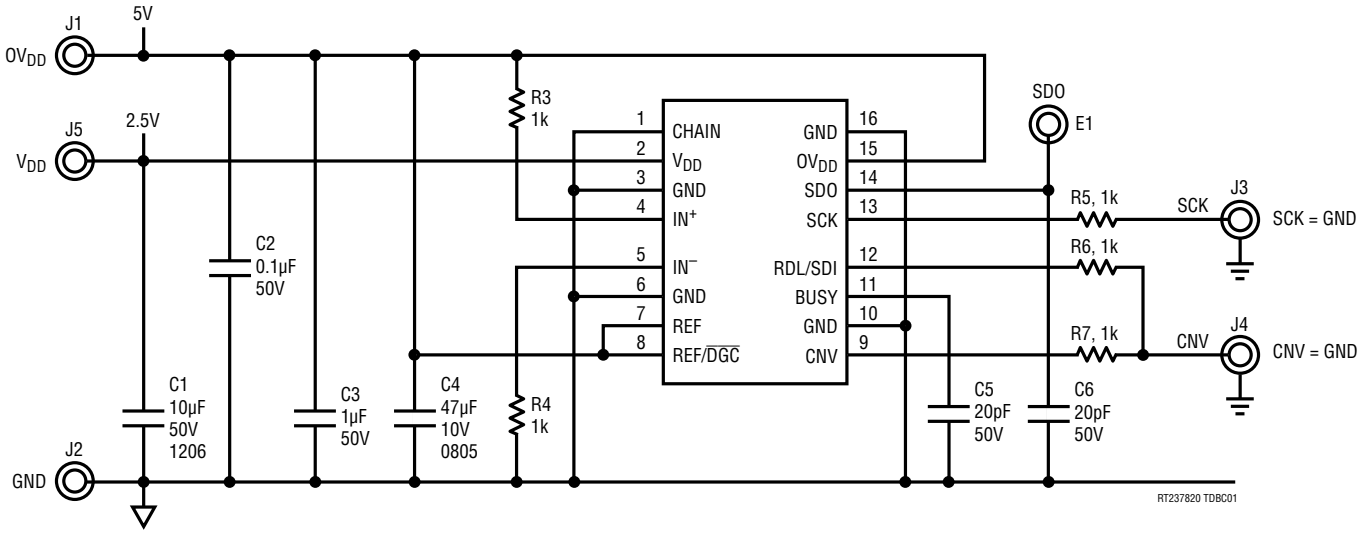
SYMBOL	PARAMETER	CONDITIONS		SUB GROUP	MIN	TYP	MAX	UNITS
t_{DSDO}	SDO Data Valid Delay from SCK↑	C_L = 20pF, OV_{DD} = 5.25V C_L = 20pF, OV_{DD} = 2.5V C_L = 20pF, OV_{DD} = 1.71V	● ● ●	9, 10, 11 9, 10, 11 9, 10, 11			7.5 8 9.5	ns ns ns
t_{HSDO}	SDO Data Remains Valid Delay from SCK↑	C_L = 20pF (Note 10)	●		1			ns
$t_{DSDOBUSYL}$	SDO Data Valid Delay from BUSY↓	C_L = 20pF (Note 10)	●				5	ns
t_{EN}	Bus Enable Time After RDL↓	(Note 11)	●	9, 10, 11			16	ns
t_{DIS}	Bus Relinquish Time After RDL↑	(Note 11)	●	9, 10, 11			13	ns

CONVERTER CHARACTERISTICS

(Post-Irradiation) The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. (Note 4)

SYMBOL	PARAMETER	CONDITIONS		10kRAD(SI) MIN	10kRAD(SI) TYP	TYP	UNITS
INL	Integral Linearity Error	(Note 6) REF/$\overline{DGC}$ = GND (Note 6)		–3.5 –3.5		3.5 3.5	ppm ppm

TOTAL DOSE BIAS CIRCUIT



ELECTRICAL TEST REQUIREMENTS

MIL-STD-883 TEST REQUIREMENTS	SUBGROUP
Final Electrical Test Requirements (Method 5004)	1,* 2, 3, 4, 5, 6, 9, 10, 11
Group A Test Requirements (Method 5005)	1, 2, 3, 4, 5, 6, 9, 10, 11
Group B and D for Class S. End Point Electrical Parameters (Method 5005)	1, 2, 3

*PDA applies to subgroup 1. See PDA Test Notes.

PDA Test Notes

The PDA is specified as 5% based on failures from Group A, Subgroup 1, tests after cooldown as the final electrical test in accordance with method 5004 of MIL-STD-883. The verified failures of Group A, Subgroup 1, after burn-in divided by the total number of devices submitted for burn-in in that lot shall be used to determine the percent for the lot.

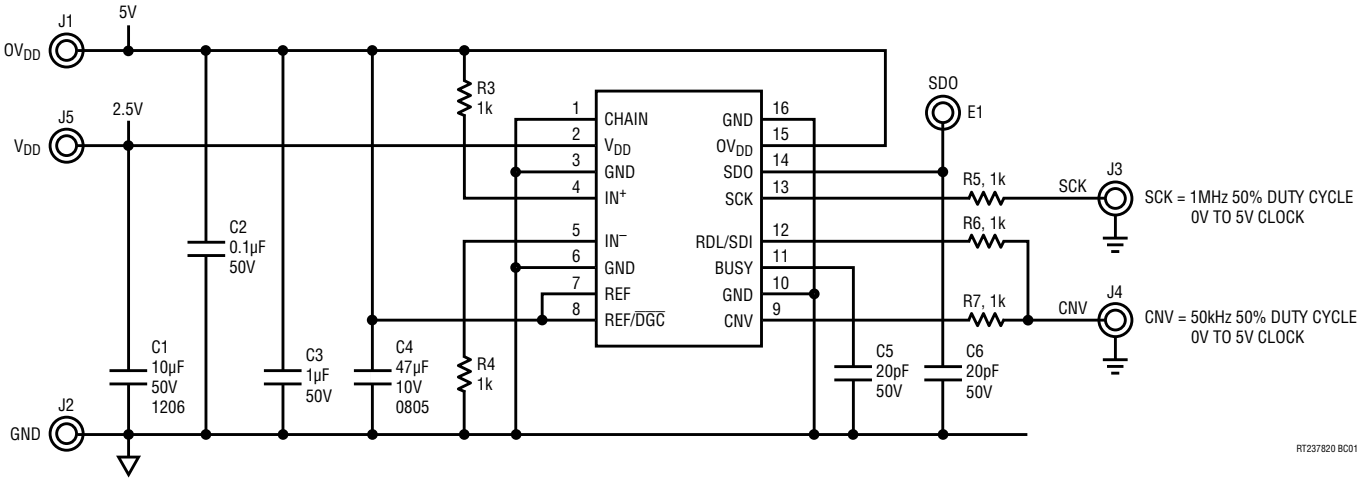
Linear Technology Corporation reserves the right to test to tighter limits than those given.

ELECTRICAL CHARACTERISTICS: BURN-IN DELTA PARAMETERS

T_A = 25°C (Note 4)

SYMBOL	PARAMETER	CONDITION		MIN	TYP	TYP	UNITS
t_{CONV}	Conversion Time			–10		10	ns

BURN-IN CIRCUIT



Note 1: Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. Exposure to any Absolute Maximum Rating condition for extended periods may effect device reliability and lifetime.

Note 2: All voltage values are with respect to ground.

Note 3: When these pin voltages are taken below ground or above REF or OV_{DD}, they will be clamped by internal diodes. This product can handle input currents up to 100mA below ground or above REF or OV_{DD} without latch-up.

Note 4: V_{DD} = 2.5V, OV_{DD} = 2.5V, REF = 5V, V_{CM} = 2.5V, f_{SMPL} = 1MHz, REF/$\overline{DGC}$ = V_{REF}.

Note 5: Recommended operating conditions.

Note 6: Integral nonlinearity is defined as the deviation of a code from a straight line passing through the actual endpoints of the transfer curve. The deviation is measured from the center of the quantization band.

Note 7: Bipolar zero-scale error is the offset voltage measured from –0.5LSB when the output code flickers between 0000 0000 0000 0000 0000 and 1111 1111 1111 1111 1111. Full-scale bipolar error is the worst-case of –FS or +FS untrimmed deviation from ideal first and last code transitions and includes the effect of offset error.

Note 8: All specifications in dB are referred to a full-scale ±5V input with a 5V reference voltage.

Note 9: f_{SMPL} = 1MHz, I_{REF} varies proportionately with sample rate.

Note 10: Guaranteed by design, not subject to test.

Note 11: Parameter tested and guaranteed at OV_{DD} = 1.71V, OV_{DD} = 2.5V and OV_{DD} = 5.25V.

Note 12: t_{SCK} of 10ns maximum allows a shift clock frequency up to 100MHz for rising capture.

Note 13: Pre and post radiation limits are identical to those listed in specification tables, except as listed in the Converter Characteristics Post Radiation table. When performing post irradiation electrical measurements for any RHA level, T_A = 25°C.

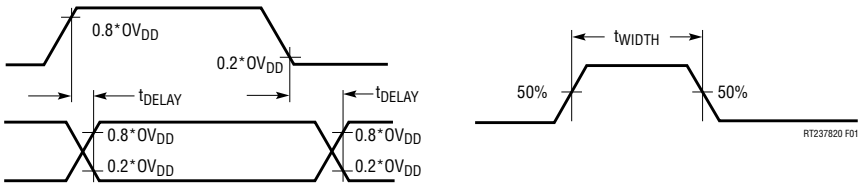
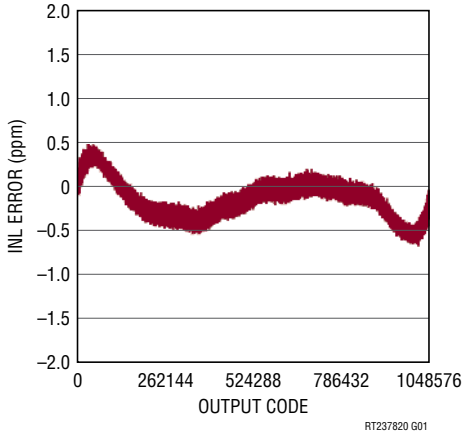


Figure 1. Voltage Levels for Timing Specifications

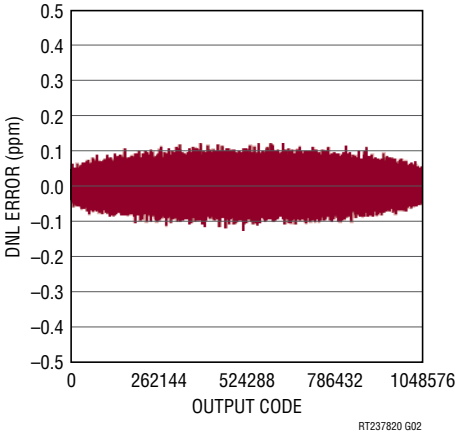
TYPICAL PERFORMANCE CHARACTERISTICS

T_A = 25°C, V_{DD} = 2.5V, OV_{DD} = 2.5V, V_{CM} = 2.5V, REF = 5V, f_{SMPL} = 1Msps, unless otherwise noted.

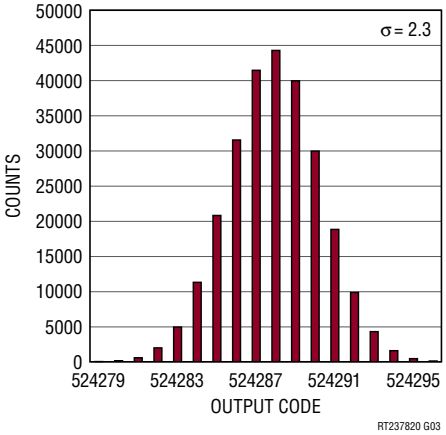
Integral Nonlinearity vs Output Code



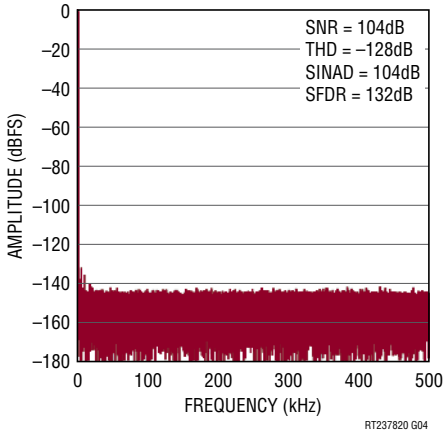
Differential Nonlinearity vs Output Code



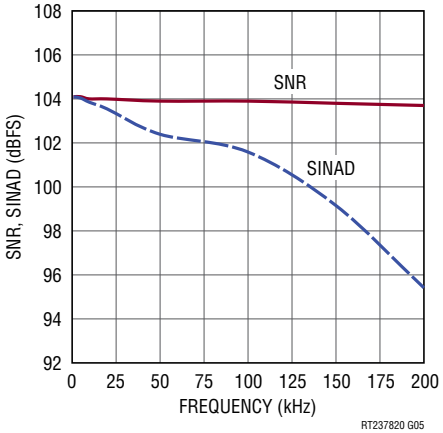
DC Histogram



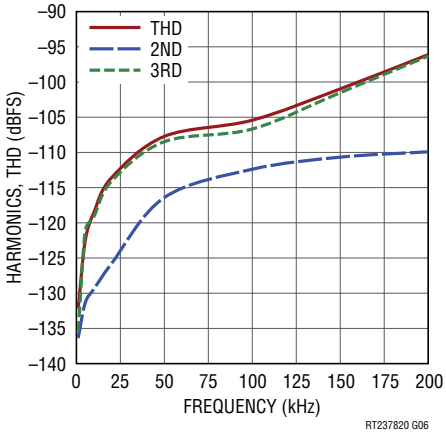
128k Point FFT f_{SMPL} = 1Msps, f_{IN} = 2kHz



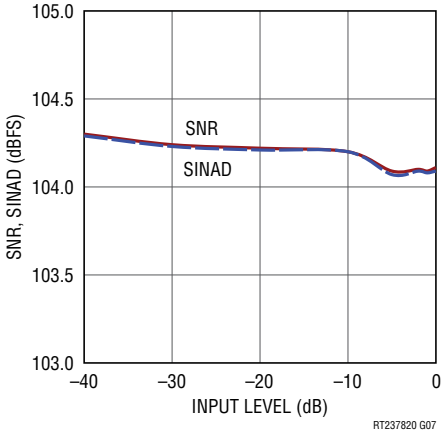
SNR, SINAD vs Input Frequency



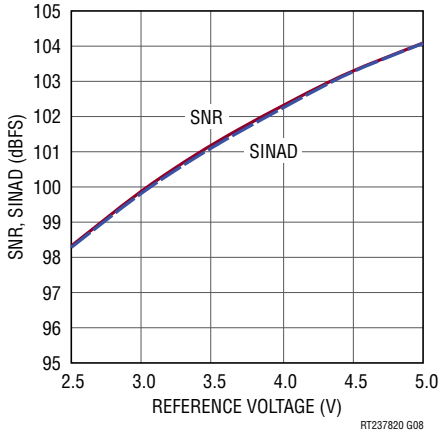
THD, Harmonics vs Input Frequency



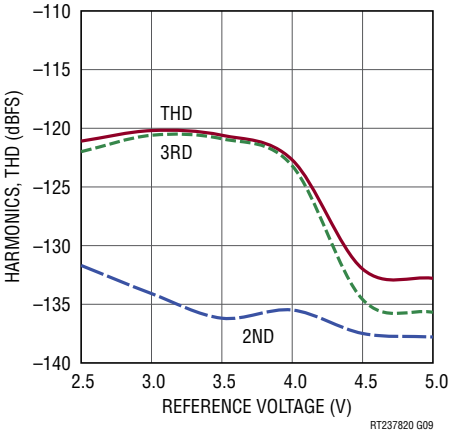
SNR, SINAD vs Input level, f_{IN} = 2kHz



SNR, SINAD vs Reference Voltage, f_{IN} = 2kHz



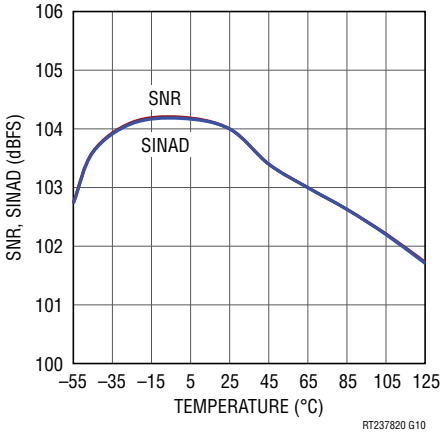
THD, Harmonics vs Reference Voltage, f_{IN} = 2kHz



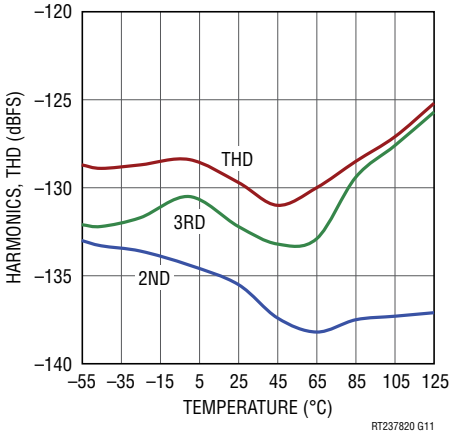
TYPICAL PERFORMANCE CHARACTERISTICS

T_A = 25°C, V_{DD} = 2.5V, OV_{DD} = 2.5V, V_{CM} = 2.5V, REF = 5V, f_{SMPL} = 1Msps, unless otherwise noted.

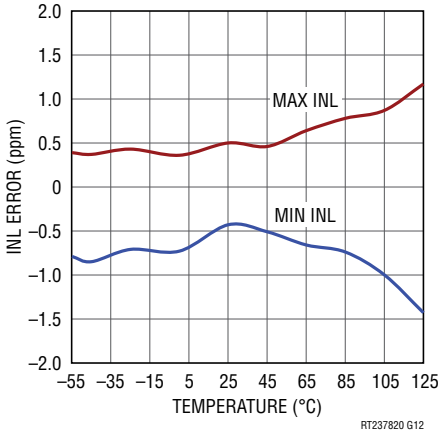
SNR, SINAD vs Temperature, f_{IN} = 2kHz



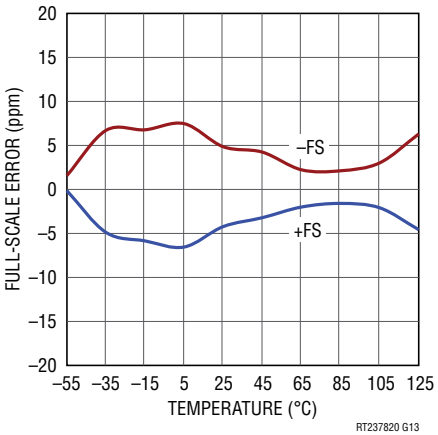
THD, Harmonics vs Temperature, f_{IN} = 2kHz



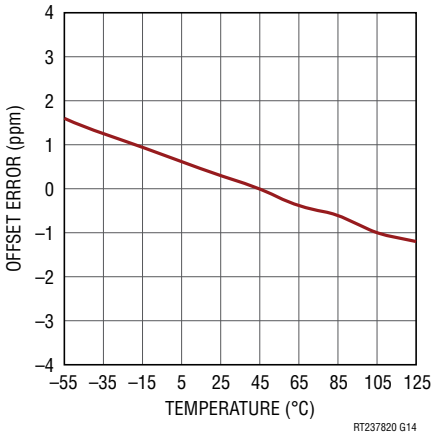
INL vs Temperature



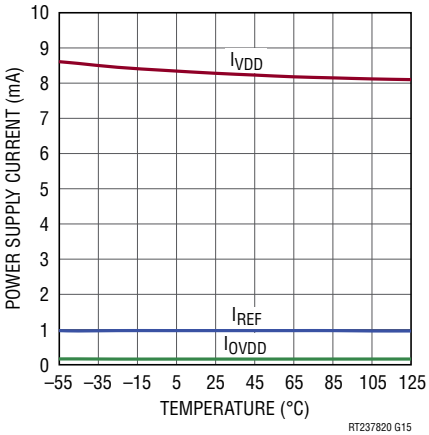
Full-Scale Error vs Temperature



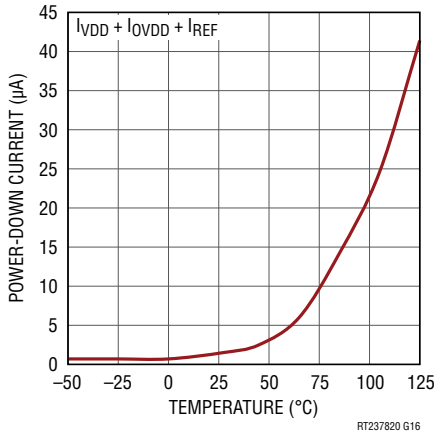
Offset Error vs Temperature



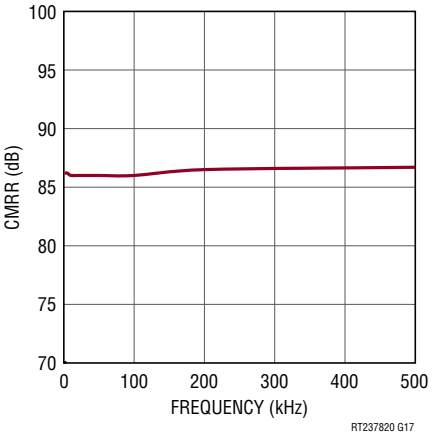
Supply Current vs Temperature



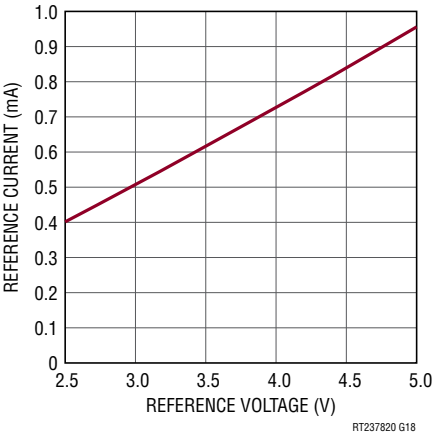
Shutdown Current vs Temperature



CMRR vs Input Frequency



Reference Current vs Reference Voltage



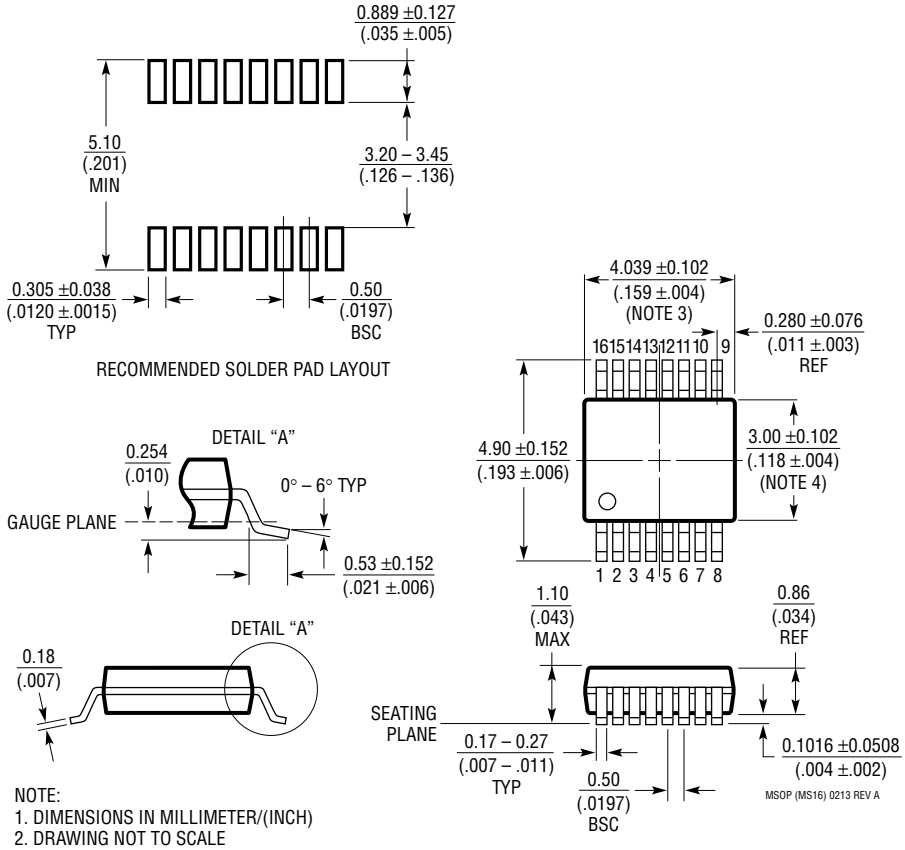
REVISION HISTORY

REV	DATE	DESCRIPTION	PAGE NUMBER
A	11/16	Updated subgroup under Power Requirements	4

PACKAGE DESCRIPTION

Please refer to http://www.linear.com/designtools/packaging/ for the most recent package drawings.

MS Package
16-Lead Plastic MSOP
(Reference LTC DWG # 05-08-1669 Rev A)



NOTE:
1. DIMENSIONS IN MILLIMETER/(INCH)
2. DRAWING NOT TO SCALE
3. DIMENSION DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS.
   MOLD FLASH, PROTRUSIONS OR GATE BURRS SHALL NOT EXCEED 0.152mm (.006") PER SIDE
4. DIMENSION DOES NOT INCLUDE INTERLEAD FLASH OR PROTRUSIONS.
   INTERLEAD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.152mm (.006") PER SIDE
5. LEAD COPLANARITY (BOTTOM OF LEADS AFTER FORMING) SHALL BE 0.102mm (.004") MAX

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