Chipsmall Limited consists of a professional team with an average of over 10 year of expertise in the distribution of electronic components. Based in Hongkong, we have already established firm and mutual-benefit business relationships with customers from,Europe,America and south Asia,supplying obsolete and hard-to-find components to meet their specific needs.

With the principle of “Quality Parts,Customers Priority,Honest Operation,and Considerate Service”,our business mainly focus on the distribution of electronic components. Line cards we deal with include Microchip,ALPS,ROHM,Xilinx,Pulse,ON,Everlight and Freescale. Main products comprise IC,Modules,Potentiometer,IC Socket,Relay,Connector.Our parts cover such applications as commercial,industrial, and automotives areas.

We are looking forward to setting up business relationship with you and hope to provide you with the best service and solution. Let us make a better world for our industry!

Contact us

Tel: +86-755-8981 8866 Fax: +86-755-8427 6832
Email & Skype: info@chipsmall.com Web: www.chipsmall.com
Address: A1208, Overseas Decoration Building, #122 Zhenhua RD., Futian, Shenzhen, China

Buffered Quad, 18-Bit, 350ksps/Ch Differential ±10.24V ADC with 30V$_{P-P}$ Common Mode Range

FEATURES

- **Simultaneous Sampling of 4 Buffered Channels**
- **350ksps per Channel Throughput**
- **500pA/12nA Max Input Leakage at 85°C/125°C**
- **±3.5LSB INL (Maximum, ±10.24V Range)**
- **Guaranteed 18-Bit, No Missing Codes**
- **Differential, Wide Common Mode Range Inputs**
- **Per-Channel SoftSpan Input Ranges:**
  - **±10.24V, 0V to 10.24V, ±5.12V, 0V to 5.12V**
  - **±12.5V, 0V to 12.5V, ±6.25V, 0V to 6.25V**
- **96.4dB Single-Conversion SNR (Typical)**
- **–110dB THD (Typical) at f_{IN} = 2kHz**
- **128dB CMRR (Typical) at f_{IN} = 200Hz**
- **Rail-to-Rail Input Overdrive Tolerance**
- Integrated Reference and Buffer (4.096V)
- SPI CMOS (1.8V to 5V) and LVDS Serial I/O
- Internal Conversion Clock, No Cycle Latency
- 175mW Power Dissipation (44mW/Ch Typical)
- 48-Lead (7mm x 7mm) LQFP Package

APPLICATIONS

- Programmable Logic Controllers
- Industrial Process Control
- Power Line Monitoring
- Test and Measurement

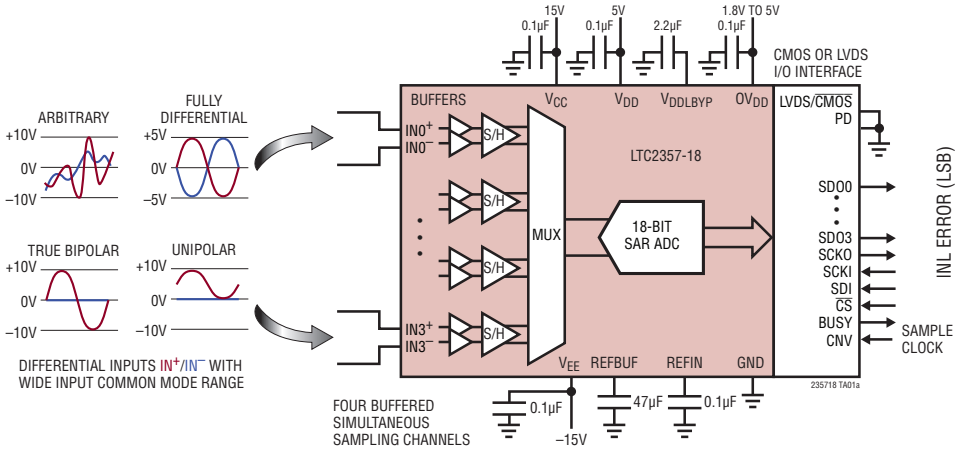
DESCRIPTION

The LTC®2357-18 is an 18-bit, low noise 4-channel simultaneous sampling successive approximation register (SAR) ADC with buffered differential, wide common mode range picoamp inputs. Operating from a 5V low voltage supply, flexible high voltage supplies, and using the internal reference and buffer, each channel of this SoftSpan™ ADC can be independently configured on a conversion-by-conversion basis to accept ±10.24V, 0V to 10.24V, ±5.12V, or 0V to 5.12V signals. Individual channels may also be disabled to increase throughput on the remaining channels.

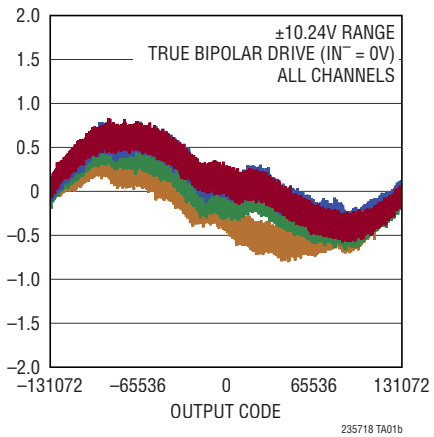
The integrated picoamp-input analog buffers, wide input common mode range and 128dB CMRR of the LTC2357-18 allow the ADC to directly digitize a variety of signals using minimal board space and power. This input signal flexibility, combined with ±3.5LSB INL, no missing codes at 18 bits, and 96.4dB SNR, makes the LTC2357-18 an ideal choice for many high voltage applications requiring wide dynamic range.

The LTC2357-18 supports pin-selectable SPI CMOS (1.8V to 5V) and LVDS serial interfaces. Between one and four lanes of data output may be employed in CMOS mode, allowing the user to optimize bus width and throughput.

TYPICAL APPLICATION



Integral Nonlinearity vs Output Code and Channel

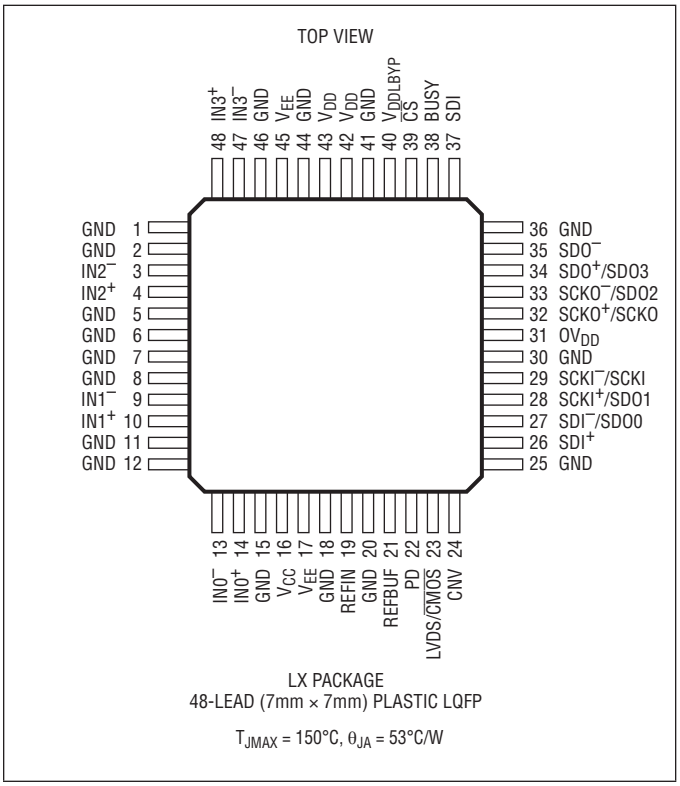


ABSOLUTE MAXIMUM RATINGS

(Notes 1, 2)

Supply Voltage (V_{CC}) .....–0.3V to (V_{EE} + 40V)
Supply Voltage (V_{EE})..... –17.4V to 0.3V
Supply Voltage Difference (V_{CC} – V_{EE}).....40V
Supply Voltage (V_{DD}) 6V
Supply Voltage (OV_{DD}).....6V
Internal Regulated Supply Bypass (V_{DDLBYP}) ... (Note 3)
Analog Input Voltage
  $IN0^+$ to $IN3^+$,
  $IN0^-$ to $IN3^-$ (Note 4) ..... (V_{EE} – 0.3V) to (V_{CC} + 0.3V)
  REFIN..... –0.3V to 2.8V
  REFBUF, CNV (Note 5) ..... –0.3V to (V_{DD} + 0.3V)
Digital Input Voltage (Note 5)..... –0.3V to (OV_{DD} + 0.3V)
Digital Output Voltage (Note 5) .. –0.3V to (OV_{DD} + 0.3V)
Power Dissipation 500mW
Operating Temperature Range
  LTC2357C ..... 0°C to 70°C
  LTC2357I .....–40°C to 85°C
  LTC2357H..... –40°C to 125°C
Storage Temperature Range .....–65°C to 150°C

PIN CONFIGURATION



LX PACKAGE
48-LEAD (7mm × 7mm) PLASTIC LQFP

T_{JMAX} = 150°C, θ_{JA} = 53°C/W

ORDER INFORMATION

http://www.linear.com/product/LTC2357-18#orderinfo

TRAY	PART MARKING*	PACKAGE DESCRIPTION	TEMPERATURE RANGE
LTC2357CLX-18#PBF	LTC2357LX-18	48-Lead (7mm × 7mm) Plastic LQFP	0°C to 70°C
LTC2357ILX-18#PBF	LTC2357LX-18	48-Lead (7mm × 7mm) Plastic LQFP	–40°C to 85°C
LTC2357HLX-18#PBF	LTC2357LX-18	48-Lead (7mm × 7mm) Plastic LQFP	–40°C to 125°C

Consult ADI Marketing for parts specified with wider operating temperature ranges. *The temperature grade is identified by a label on the shipping container.
For more information on lead free part marking, go to: http://www.linear.com/leadfree/

ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. (Note 6)

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
$V_{IN}+$	Absolute Input Range ($IN0^+$ to $IN3^+$)	(Note 7)	●	V_{EE} + 4		V_{CC} – 4	V
$V_{IN}–$	Absolute Input Range ($IN0^–$ to $IN3^–$)	(Note 7)	●	V_{EE} + 4		V_{CC} – 4	V
$V_{IN}+ – V_{IN}–$	Input Differential Voltage Range	SoftSpan 7: ±2.5 • V_{REFBUF} Range (Note 7)	●	–2.5 • V_{REFBUF}		2.5 • V_{REFBUF}	V
		SoftSpan 6: ±2.5 • V_{REFBUF}/1.024 Range (Note 7)	●	–2.5 • V_{REFBUF}/1.024		2.5 • V_{REFBUF}/1.024	V
		SoftSpan 5: 0V to 2.5 • V_{REFBUF} Range (Note 7)	●	0		2.5 • V_{REFBUF}	V
		SoftSpan 4: 0V to 2.5 • V_{REFBUF}/1.024 Range (Note 7)	●	0		2.5 • V_{REFBUF}/1.024	V
		SoftSpan 3: ±1.25 • V_{REFBUF} Range (Note 7)	●	–1.25 • V_{REFBUF}		1.25 • V_{REFBUF}	V
		SoftSpan 2: ±1.25 • V_{REFBUF}/1.024 Range (Note 7)	●	–1.25 • V_{REFBUF}/1.024		1.25 • V_{REFBUF}/1.024	V
		SoftSpan 1: 0V to 1.25 • V_{REFBUF} Range (Note 7)	●	0		1.25 • V_{REFBUF}	V
V_{CM}	Input Common Mode Voltage Range	(Note 7)	●	V_{EE} + 4		V_{CC} – 4	V
$V_{IN}+ – V_{IN}–$	Input Differential Overdrive Tolerance	(Note 8)	●	–(V_{CC} – V_{EE})		(V_{CC} – V_{EE})	V
$I_{OVERDRIVE}$	Input Overdrive Current Tolerance	$V_{IN}+ > V_{CC}$, $V_{IN}– > V_{CC}$ (Note 8)	●			10	mA
		$V_{IN}+ < V_{EE}$, $V_{IN}– < V_{EE}$ (Note 8)	●	0			mA
I_{IN}	Analog Input Leakage Current				5		pA
		C-Grade and I-Grade	●			500	pA
		H-Grade	●			12	nA
$I_{IN}^+ – I_{IN}^–$	Analog Input Leakage Offset Current	$V_{IN}^+ = V_{IN}^–$			±1		pA
		$V_{IN}^+ = V_{IN}^–$, C-Grade and I-Grade	●	–100		100	pA
		$V_{IN}^+ = V_{IN}^–$, H-Grade	●	–1.2		1.2	nA
R_{IN}	Analog Input Resistance	For Each Pin			>1000		GΩ
C_{IN}	Analog Input Capacitance				3		pF
CMRR	Input Common Mode Rejection Ratio	$V_{IN}+ = V_{IN}– = 18V_{P-P}$ 200Hz Sine	●	105	128		dB
V_{IHCNV}	CNV High Level Input Voltage		●	1.3			V
V_{ILCNV}	CNV Low Level Input Voltage		●			0.5	V
I_{INCNV}	CNV Input Current	V_{IN} = 0V to V_{DD}	●	–10		10	µA

CONVERTER CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. (Note 9)

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
	Resolution		●	18			Bits
	No Missing Codes		●	18			Bits
	Transition Noise	SoftSpans 7 and 6: ±10.24V and ±10V Ranges			1.4		LSB_{RMS}
		SoftSpans 5 and 4: 0V to 10.24V and 0V to 10V Ranges			2.8		LSB_{RMS}
		SoftSpans 3 and 2: ±5.12V and ±5V Ranges			2.1		LSB_{RMS}
		SoftSpan 1: 0V to 5.12V Range			4.2		LSB_{RMS}
INL	Integral Linearity Error	SoftSpans 7 and 6: ±10.24V and ±10V Ranges (Note 10)	●	–3.5	±1	3.5	LSB
		SoftSpans 5 and 4: 0V to 10.24V and 0V to 10V Ranges (Note 10)	●	–5	±1	5	LSB
		SoftSpans 3 and 2: ±5.12V and ±5V Ranges (Note 10)	●	–4	±1.5	4	LSB
		SoftSpan 1: 0V to 5.12V Range (Note 10)	●	–6	±1	6	LSB
DNL	Differential Linearity Error	(Note 11)	●	–0.9	±0.2	0.9	LSB

CONVERTER CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. (Note 9)

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
ZSE	Zero-Scale Error	(Note 12)	●	–900	±80	900	µV
	Zero-Scale Error Drift				±4		µV/°C
FSE	Full-Scale Error	V_{REFBUF} = 4.096V (REFBUF Overdriven) (Note 12)	●	–0.1	±0.025	0.1	%FS
	Full-Scale Error Drift	V_{REFBUF} = 4.096V (REFBUF Overdriven) (Note 12)			±2.5		ppm/°C

DYNAMIC ACCURACY

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. A_{IN} = –1dBFS. (Notes 9, 13)

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
SINAD	Signal-to-(Noise + Distortion) Ratio	SoftSpans 7 and 6: ±10.24V and ±10V Ranges, f_{IN} = 2kHz	●	92.7	96.2		dB
		SoftSpans 5 and 4: 0V to 10.24V and 0V to 10V Ranges, f_{IN} = 2kHz	●	86.9	90.3		dB
		SoftSpans 3 and 2: ±5.12V and ±5V Ranges, f_{IN} = 2kHz	●	89.3	92.5		dB
		SoftSpan 1: 0V to 5.12V Range, f_{IN} = 2kHz	●	83.6	86.6		dB
SNR	Signal-to-Noise Ratio	SoftSpans 7 and 6: ±10.24V and ±10V Ranges, f_{IN} = 2kHz	●	92.8	96.4		dB
		SoftSpans 5 and 4: 0V to 10.24V and 0V to 10V Ranges, f_{IN} = 2kHz	●	87.0	90.4		dB
		SoftSpans 3 and 2: ±5.12V and ±5V Ranges, f_{IN} = 2kHz	●	89.5	92.5		dB
		SoftSpan 1: 0V to 5.12V Range, f_{IN} = 2kHz	●	83.6	86.6		dB
THD	Total Harmonic Distortion	SoftSpans 7 and 6: ±10.24V and ±10V Ranges, f_{IN} = 2kHz	●		–110	–101	dB
		SoftSpans 5 and 4: 0V to 10.24V and 0V to 10V Ranges, f_{IN} = 2kHz	●		–111	–99	dB
		SoftSpans 3 and 2: ±5.12V and ±5V Ranges, f_{IN} = 2kHz	●		–112	–102	dB
		SoftSpan 1: 0V to 5.12V Range, f_{IN} = 2kHz	●		–113	–99	dB
SFDR	Spurious Free Dynamic Range	SoftSpans 7 and 6: ±10.24V and ±10V Ranges, f_{IN} = 2kHz	●	101	112		dB
		SoftSpans 5 and 4: 0V to 10.24V and 0V to 10V Ranges, f_{IN} = 2kHz	●	99	113		dB
		SoftSpans 3 and 2: ±5.12V and ±5V Ranges, f_{IN} = 2kHz	●	103	114		dB
		SoftSpan 1: 0V to 5.12V Range, f_{IN} = 2kHz	●	99	114		dB
	Channel-to-Channel Crosstalk	One Channel Converting 18V_{P-P} 200Hz Sine in ±10.24V Range, Crosstalk to All Other Channels			–109		dB
	–3dB Input Bandwidth				6		MHz
	Aperture Delay				1		ns
	Aperture Delay Matching				150		ps
	Aperture Jitter				3		ps_{RMS}
	Transient Response	Full-Scale Step, 0.005% Settling			420		ns

INTERNAL REFERENCE CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. (Note 9)

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
V_{REFIN}	Internal Reference Output Voltage			2.043	2.048	2.053	V
	Internal Reference Temperature Coefficient	(Note 14)	●		5	20	ppm/°C
	Internal Reference Line Regulation	V_{DD} = 4.75V to 5.25V			0.1		mV/V
	Internal Reference Output Impedance				20		kΩ
V_{REFIN}	REFIN Voltage Range	REFIN Overdriven (Note 7)		1.25		2.2	V

REFERENCE BUFFER CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. (Note 9)

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
V_{REFBUF}	Reference Buffer Output Voltage	REFIN Overdriven, V_{REFIN} = 2.048V	●	4.091	4.096	4.101	V
	REFBUF Voltage Range	REFBUF Overdriven (Notes 7, 15)	●	2.5		5	V
	REFBUF Input Impedance	V_{REFIN} = 0V, Buffer Disabled			13		kΩ
I_{REFBUF}	REFBUF Load Current	V_{REFBUF} = 5V, 4 Channels Enabled (Notes 15, 16) V_{REFBUF} = 5V, Acquisition or Nap Mode (Note 15)	●		1.4 0.36	1.5	mA mA

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 9)

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
		CMOS Digital Inputs and Outputs					
V_{IH}	High Level Input Voltage		●	0.8 • OV_{DD}			V
V_{IL}	Low Level Input Voltage		●			0.2 • OV_{DD}	V
I_{IN}	Digital Input Current	V_{IN} = 0V to OV_{DD}	●	–10		10	µA
C_{IN}	Digital Input Capacitance				5		pF
V_{OH}	High Level Output Voltage	I_{OUT} = –500µA	●	OV_{DD} – 0.2			V
V_{OL}	Low Level Output Voltage	I_{OUT} = 500µA	●			0.2	V
I_{OZ}	Hi-Z Output Leakage Current	V_{OUT} = 0V to OV_{DD}	●	–10		10	µA
I_{SOURCE}	Output Source Current	V_{OUT} = 0V			–50		mA
I_{SINK}	Output Sink Current	V_{OUT} = OV_{DD}			50		mA
		LVDS Digital Inputs and Outputs					
V_{ID}	Differential Input Voltage		●	200	350	600	mV
R_{ID}	On-Chip Input Termination Resistance	$\overline{CS}$ = 0V, V_{ICM} = 1.2V $\overline{CS}$ = OV_{DD}	●	90	106 10	125	Ω MΩ
V_{ICM}	Common-Mode Input Voltage		●	0.3	1.2	2.2	V
I_{ICM}	Common-Mode Input Current	V_{IN}+ = V_{IN}– = 0V to OV_{DD}	●	–10		10	µA
V_{OD}	Differential Output Voltage	R_L = 100Ω Differential Termination	●	275	350	425	mV
V_{OCM}	Common-Mode Output Voltage	R_L = 100Ω Differential Termination	●	1.1	1.2	1.3	V
I_{OZ}	Hi-Z Output Leakage Current	V_{OUT} = 0V to OV_{DD}	●	–10		10	µA

POWER REQUIREMENTS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. (Note 9)

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
V_{CC}	Supply Voltage		●	7.5		38	V
V_{EE}	Supply Voltage		●	–16.5		0	V
$V_{CC} – V_{EE}$	Supply Voltage Difference		●	10		38	V
V_{DD}	Supply Voltage		●	4.75	5.00	5.25	V
I_{VCC}	Supply Current	350ksps Sample Rate, 4 Channels Enabled (Note 17)	●		3.4	3.9	mA
		Acquisition Mode (Note 17)	●		5.7	6.9	mA
		Nap Mode	●		1.5	1.8	mA
		Power Down Mode	●		5	15	µA
I_{VEE}	Supply Current	350ksps Sample Rate, 4 Channels Enabled (Note 17)	●	–4.1	–3.2		mA
		Acquisition Mode (Note 17)	●	–7.1	–5.6		mA
		Nap Mode	●	–2	–1.4		mA
		Power Down Mode	●	–15	–4		µA
CMOS I/O Mode							
OV_{DD}	Supply Voltage		●	1.71		5.25	V
I_{VDD}	Supply Current	350ksps Sample Rate, 4 Channels Enabled	●		14.3	16	mA
		350ksps Sample Rate, 4 Channels Enabled, V_{REFBUF} = 5V (Note 15)	●		12.6	14.3	mA
		Acquisition Mode	●		1.8	2.5	mA
		Nap Mode	●		1.6	2.2	mA
		Power Down Mode (C-Grade and I-Grade)	●		84	275	µA
		Power Down Mode (H-Grade)	●		84	500	µA
I_{OVDD}	Supply Current	350ksps Sample Rate, 4 Channels Enabled (C_L = 25pF)	●		1.8	2.6	mA
		Acquisition or Nap Mode	●		1	20	µA
		Power Down Mode	●		1	20	µA
P_D	Power Dissipation	350ksps Sample Rate, 4 Channels Enabled	●		175	207	mW
		Acquisition Mode	●		179	223	mW
		Nap Mode	●		52	68	mW
		Power Down Mode (C-Grade and I-Grade)	●		0.56	1.9	mW
		Power Down Mode (H-Grade)	●		0.56	3	mW
LVDS I/O Mode							
OV_{DD}	Supply Voltage		●	2.375		5.25	V
I_{VDD}	Supply Current	350ksps Sample Rate, 4 Channels Enabled	●		16.4	18.1	mA
		350ksps Sample Rate, 4 Channels Enabled, V_{REFBUF} = 5V (Note 15)	●		14.9	16.7	mA
		Acquisition Mode	●		3.4	4.2	mA
		Nap Mode	●		3.2	4	mA
		Power Down Mode (C-Grade and I-Grade)	●		84	275	µA
		Power Down Mode (H-Grade)	●		84	500	µA
I_{OVDD}	Supply Current	350ksps Sample Rate, 4 Channels Enabled (R_L = 100Ω)	●		7.5	8.7	mA
		Acquisition or Nap Mode (R_L = 100Ω)	●		7	8.2	mA
		Power Down Mode	●		1	20	µA
P_D	Power Dissipation	350ksps Sample Rate, 4 Channels Enabled	●		200	232	mW
		Acquisition Mode	●		204	252	mW
		Nap Mode	●		77	98	mW
		Power Down Mode (C-Grade and I-Grade)	●		0.56	1.9	mW
		Power Down Mode (H-Grade)	●		0.56	3	mW

ADC TIMING CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. (Note 9)

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
f_{SMPL}	Maximum Sampling Frequency	4 Channels Enabled	●			350	ksps
		3 Channels Enabled	●			425	ksps
		2 Channels Enabled	●			550	ksps
		1 Channel Enabled	●			800	ksps
t_{CYC}	Time Between Conversions	4 Channels Enabled, f_{SMPL} = 350ksps	●	2855			ns
		3 Channels Enabled, f_{SMPL} = 425ksps	●	2350			ns
		2 Channels Enabled, f_{SMPL} = 550ksps	●	1815			ns
		1 Channel Enabled, f_{SMPL} = 800ksps	●	1250			ns
t_{CONV}	Conversion Time	N Channels Enabled, 1 ≤ N ≤ 4	●	450•N	500•N	550•N	ns
t_{ACQ}	Acquisition Time ($t_{ACQ} = t_{CYC} – t_{CONV} – t_{BUSYLH}$)	4 Channels Enabled, f_{SMPL} = 350ksps	●	625	835		ns
		3 Channels Enabled, f_{SMPL} = 425ksps	●	670	830		ns
		2 Channels Enabled, f_{SMPL} = 550ksps	●	685	795		ns
		1 Channel Enabled, f_{SMPL} = 800ksps	●	670	730		ns
t_{CNVH}	CNV High Time		●	40			ns
t_{CNVL}	CNV Low Time		●	750			ns
t_{BUSYLH}	CNV↑ to BUSY Delay	C_L = 25pF	●			30	ns
t_{QUIET}	Digital I/O Quiet Time from CNV↑		●	20			ns
t_{PDH}	PD High Time		●	40			ns
t_{PDL}	PD Low Time		●	40			ns
t_{WAKE}	REFBUF Wake-Up Time	C_{REFBUF} = 47µF, C_{REFIN} = 0.1µF			200		ms
CMOS I/O Mode							
t_{SCKI}	SCKI Period	(Notes 18, 19)	●	10			ns
t_{SCKIH}	SCKI High Time		●	4			ns
t_{SCKIL}	SCKI Low Time		●	4			ns
$t_{SSDISCKI}$	SDI Setup Time from SCKI↑	(Note 18)	●	2			ns
$t_{HSDISCKI}$	SDI Hold Time from SCKI↑	(Note 18)	●	1			ns
$t_{DSDOSCKI}$	SDO Data Valid Delay from SCKI↑	C_L = 25pF (Note 18)	●			7.5	ns
$t_{HSDOSCKI}$	SDO Remains Valid Delay from SCKI↑	C_L = 25pF (Note 18)	●	1.5			ns
t_{SKEW}	SDO to SCKO Skew	(Note 18)	●	–1	0	1	ns
$t_{DSDOBUSYL}$	SDO Data Valid Delay from BUSY↓	C_L = 25pF (Note 18)	●	0			ns
t_{EN}	Bus Enable Time After $\overline{CS}$↓	(Note 18)	●			15	ns
t_{DIS}	Bus Relinquish Time After $\overline{CS}$↑	(Note 18)	●			15	ns
LVDS I/O Mode							
t_{SCKI}	SCKI Period	(Note 20)	●	4			ns
t_{SCKIH}	SCKI High Time	(Note 20)	●	1.5			ns
t_{SCKIL}	SCKI Low Time	(Note 20)	●	1.5			ns
$t_{SSDISCKI}$	SDI Setup Time from SCKI	(Notes 11, 20)	●	1.2			ns
$t_{HSDISCKI}$	SDI Hold Time from SCKI	(Notes 11, 20)	●	–0.2			ns
$t_{DSDOSCKI}$	SDO Data Valid Delay from SCKI	(Notes 11, 20)	●			6	ns
$t_{HSDOSCKI}$	SDO Remains Valid Delay from SCKI	(Notes 11, 20)	●	1			ns
t_{SKEW}	SDO to SCKO Skew	(Note 11)	●	–0.4	0	0.4	ns
$t_{DSDOBUSYL}$	SDO Data Valid Delay from BUSY↓	(Note 11)	●	0			ns
t_{EN}	Bus Enable Time After $\overline{CS}$↓		●			50	ns
t_{DIS}	Bus Relinquish Time After $\overline{CS}$↑		●			15	ns

ADC TIMING CHARACTERISTICS

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 affect device reliability and lifetime.

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

Note 3: V_{DDLBYP} is the output of an internal voltage regulator, and should only be connected to a 2.2µF ceramic capacitor to bypass the pin to GND, as described in the Pin Functions section. Do not connect this pin to any external circuitry.

Note 4: When these pin voltages are taken below V_{EE} or above V_{CC}, they will be clamped by internal diodes. This product can handle input currents of up to 100mA below V_{EE} or above V_{CC} without latch-up.

Note 5: When these pin voltages are taken below GND or above V_{DD} or OV_{DD}, they will be clamped by internal diodes. This product can handle currents of up to 100mA below GND or above V_{DD} or OV_{DD} without latch-up.

Note 6: $-16.5V \le V_{EE} \le 0V$, $7.5V \le V_{CC} \le 38V$, $10V \le (V_{CC} - V_{EE}) \le 38V$, $V_{DD} = 5V$, unless otherwise specified.

Note 7: Recommended operating conditions.

Note 8: Exceeding these limits on any channel may corrupt conversion results on other channels. Driving an analog input above V_{CC} on any channel up to 10mA will not affect conversion results on other channels. Driving an analog input below V_{EE} may corrupt conversion results on other channels. Refer to Applications Information section for further details. Refer to Absolute Maximum Ratings section for pin voltage limits related to device reliability.

Note 9: $V_{CC} = 15V$, $V_{EE} = -15V$, $V_{DD} = 5V$, $OV_{DD} = 2.5V$, $f_{SMPL} = 350ksps$, internal reference and buffer, true bipolar input signal drive in bipolar SoftSpan ranges, unipolar signal drive in unipolar SoftSpan ranges, unless otherwise specified.

Note 10: 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 11: Guaranteed by design, not subject to test.

Note 12: For bipolar SoftSpan ranges 7, 6, 3, and 2, zero-scale error is the offset voltage measured from –0.5LSB when the output code flickers between 00 0000 0000 0000 0000 and 11 1111 1111 1111 1111. Full-scale error for these SoftSpan ranges is the worst-case deviation of the first and last code transitions from ideal and includes the effect of offset error. For unipolar SoftSpan ranges 5, 4, and 1, zero-scale error is the offset voltage measured from 0.5LSB when the output code flickers between 00 0000 0000 0000 0000 and 00 0000 0000 0000 0001. Full-scale error for these SoftSpan ranges is the worst-case deviation of the last code transition from ideal and includes the effect of offset error.

Note 13: All specifications in dB are referred to a full-scale input in the relevant SoftSpan input range, except for crosstalk, which is referred to the crosstalk injection signal amplitude.

Note 14: Temperature coefficient is calculated by dividing the maximum change in output voltage by the specified temperature range.

Note 15: When REFBUF is overdriven, the internal reference buffer must be disabled by setting REFIN = 0V.

Note 16: I_{REFBUF} varies proportionally with sample rate and the number of active channels.

Note 17: Portions of the analog input circuitry are powered down during conversion, reducing I_{VCC} and I_{VEE}. Refer to Applications Information section for more details.

Note 18: Parameter tested and guaranteed at $OV_{DD} = 1.71V$, $OV_{DD} = 2.5V$, and $OV_{DD} = 5.25V$.

Note 19: A t_{SCKI} period of 10ns minimum allows a shift clock frequency of up to 100MHz for rising edge capture.

Note 20: $V_{ICM} = 1.2V$, $V_{ID} = 350mV$ for LVDS differential input pairs.

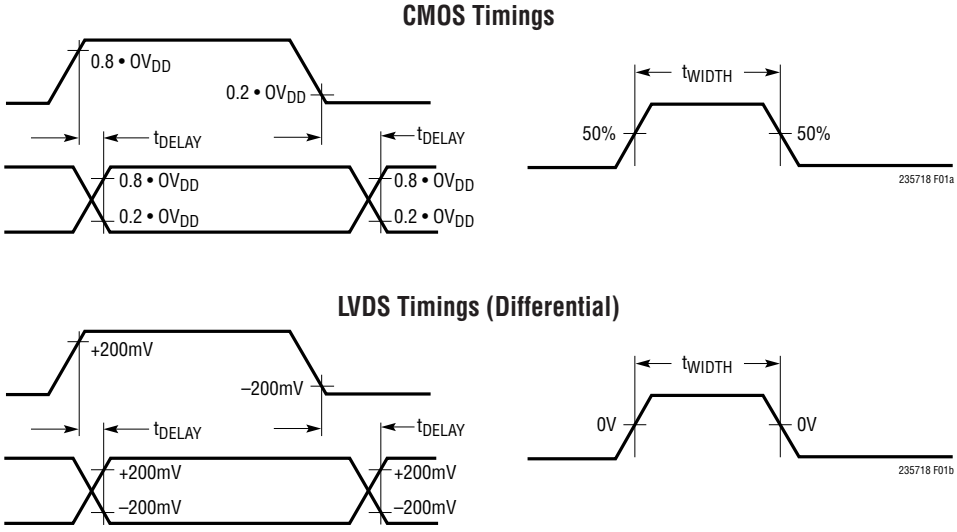
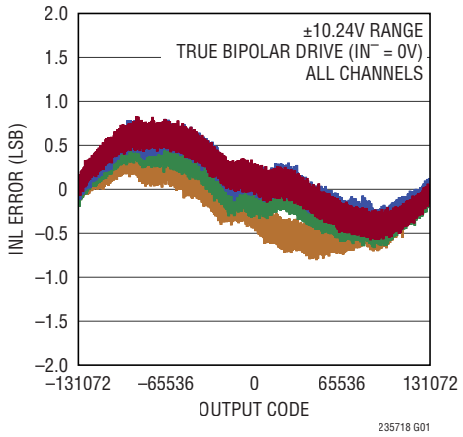


Figure 1. Voltage Levels for Timing Specifications

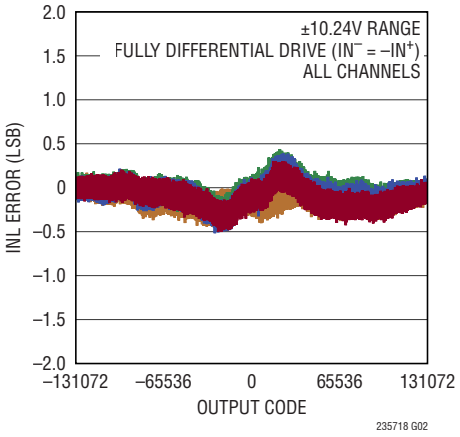
TYPICAL PERFORMANCE CHARACTERISTICS

T_A = 25°C, V_{CC} = +15V, V_{EE} = –15V, V_{DD} = 5V, OV_{DD} = 2.5V, Internal Reference and Buffer (V_{REFBUF} = 4.096V), f_{SMPL} = 350ksps, unless otherwise noted.

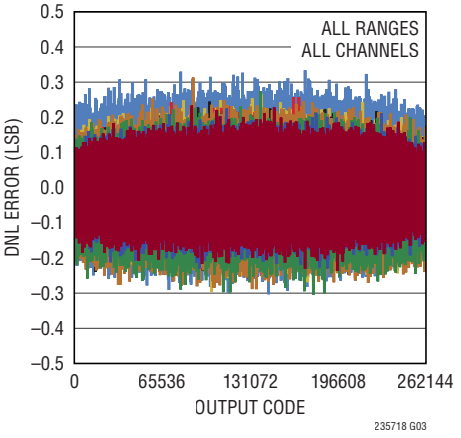
Integral Nonlinearity vs Output Code and Channel



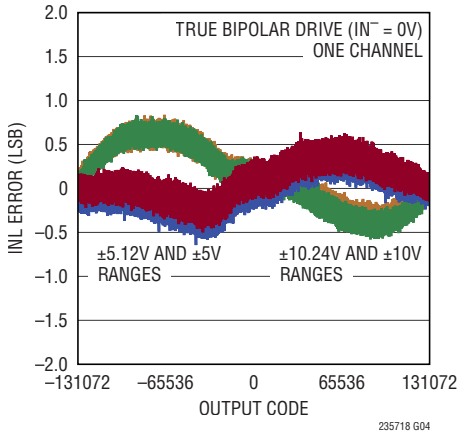
Integral Nonlinearity vs Output Code and Channel



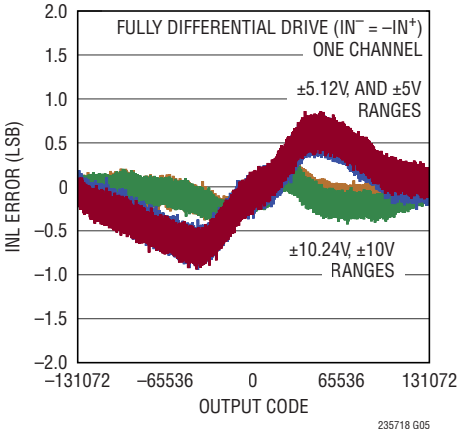
Differential Nonlinearity vs Output Code and Channel



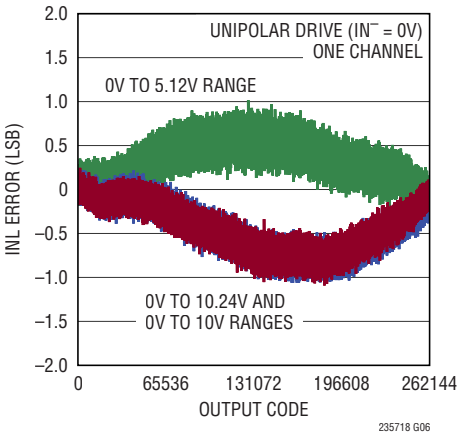
Integral Nonlinearity vs Output Code and Range



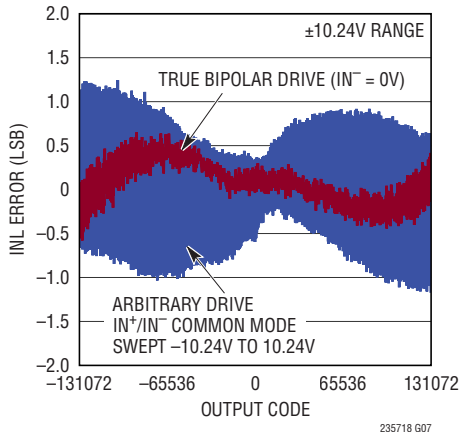
Integral Nonlinearity vs Output Code and Range



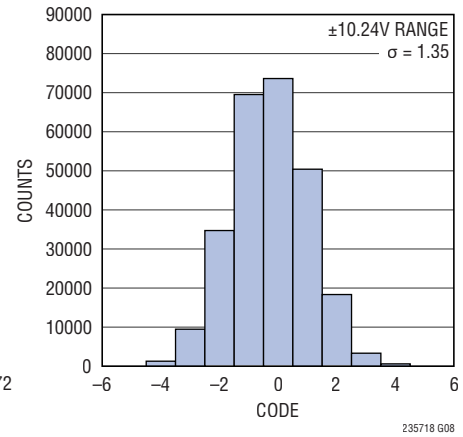
Integral Nonlinearity vs Output Code and Range



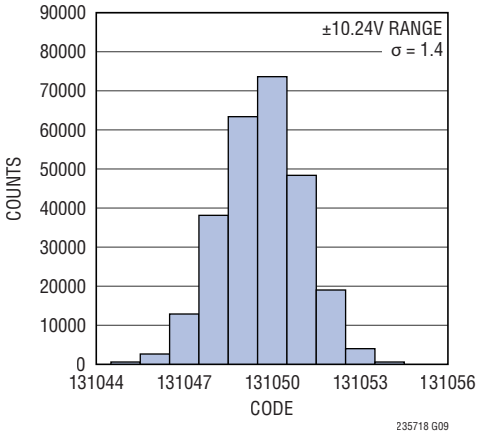
Integral Nonlinearity vs Output Code



DC Histogram (Zero-Scale)



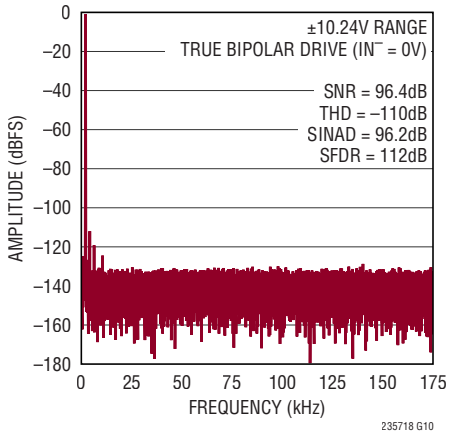
DC Histogram (Near Full-Scale)



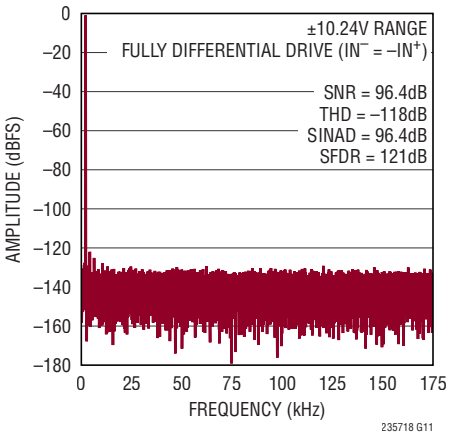
TYPICAL PERFORMANCE CHARACTERISTICS

T_A = 25°C, V_{CC} = +15V, V_{EE} = –15V, V_{DD} = 5V, OV_{DD} = 2.5V, Internal Reference and Buffer (V_{REFBUF} = 4.096V), f_{SMPL} = 350ksps, unless otherwise noted.

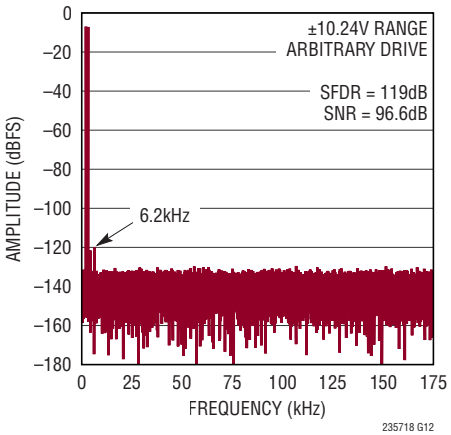
32k Point FFT f_{SMPL} = 350ksps, f_{IN} = 2kHz



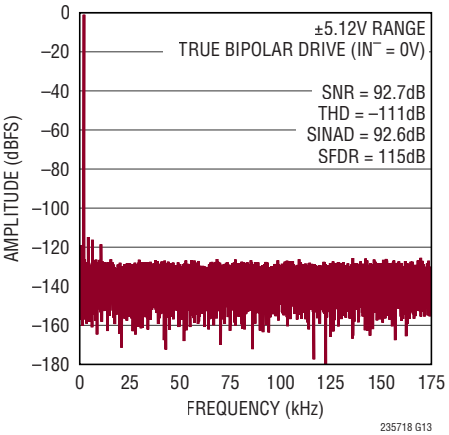
32k Point FFT f_{SMPL} = 350ksps, f_{IN} = 2kHz



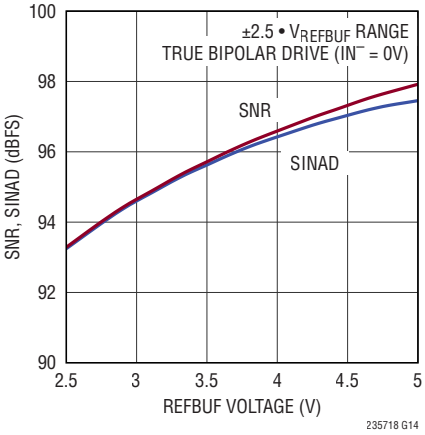
32k Point Arbitrary Two-Tone FFT f_{SMPL} = 350ksps, IN^+ = –7dBFS 2kHz Sine, IN^- = –7dBFS 3.1kHz Sine



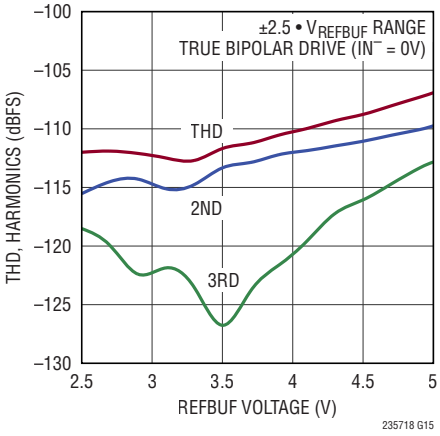
32k Point FFT f_{SMPL} = 350ksps, f_{IN} = 2kHz



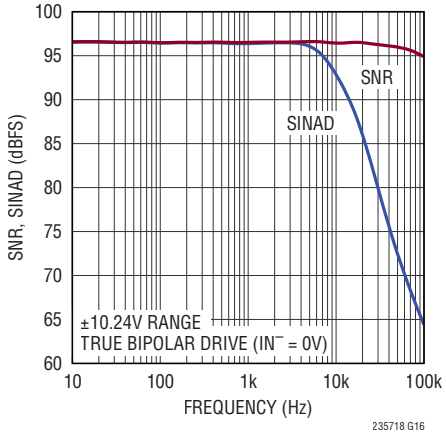
SNR, SINAD vs V_{REFBUF}, f_{IN} = 2kHz



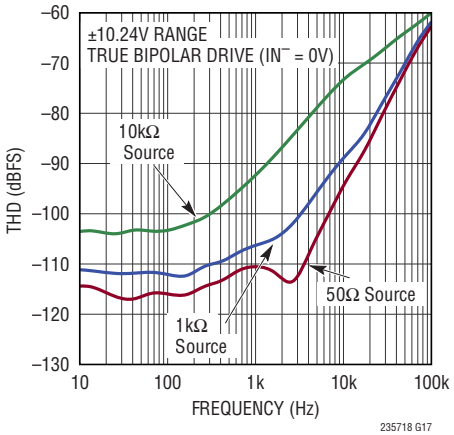
THD, Harmonics vs V_{REFBUF}, f_{IN} = 2kHz



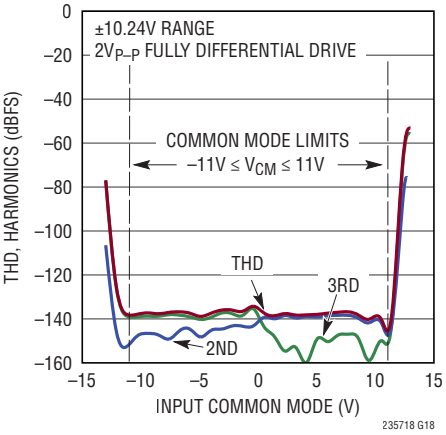
SNR, SINAD vs Input Frequency



THD vs Input Frequency and Source Resistance



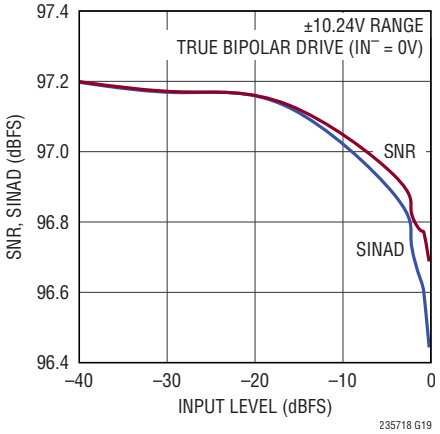
THD, Harmonics vs Input Common Mode, f_{IN} = 2kHz



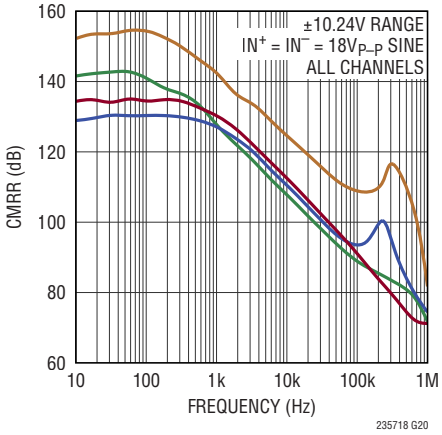
TYPICAL PERFORMANCE CHARACTERISTICS

T_A = 25°C, V_{CC} = +15V, V_{EE} = –15V, V_{DD} = 5V, OV_{DD} = 2.5V, Internal Reference and Buffer (V_{REFBUF} = 4.096V), f_{SMPL} = 350ksps, unless otherwise noted.

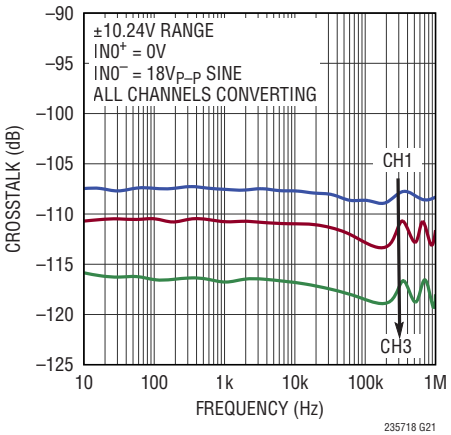
SNR, SINAD vs Input Level, f_{IN} = 2kHz



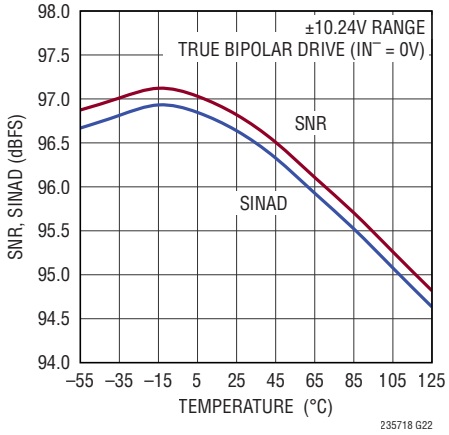
CMRR vs Input Frequency and Channel



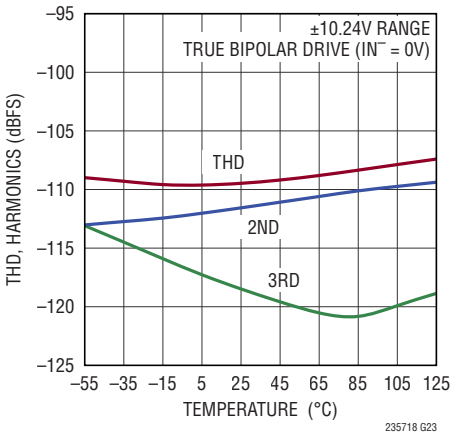
Crosstalk vs Input Frequency and Channel



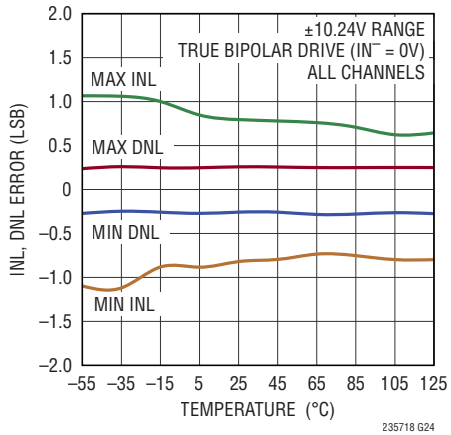
SNR, SINAD vs Temperature, f_{IN} = 2kHz



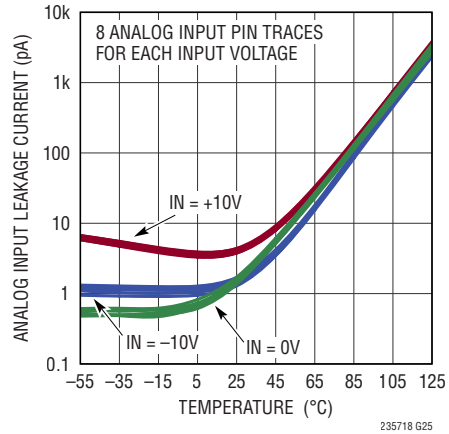
THD, Harmonics vs Temperature, f_{IN} = 2kHz



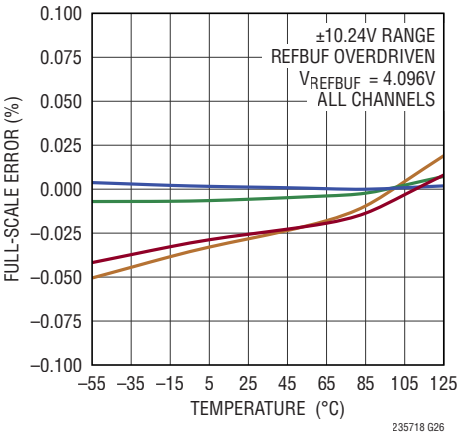
INL, DNL vs Temperature



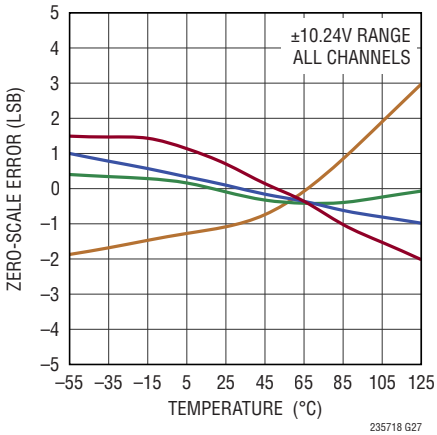
Analog Input Leakage Current vs Temperature



Positive Full-Scale Error vs Temperature and Channel



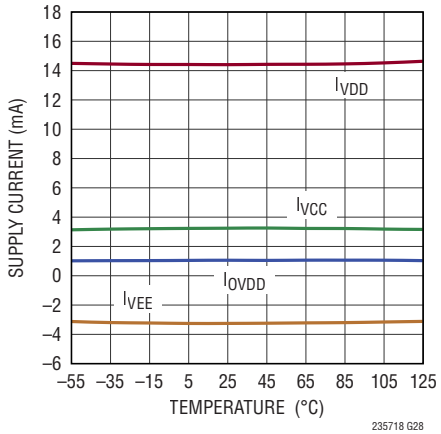
Zero-Scale Error vs Temperature and Channel



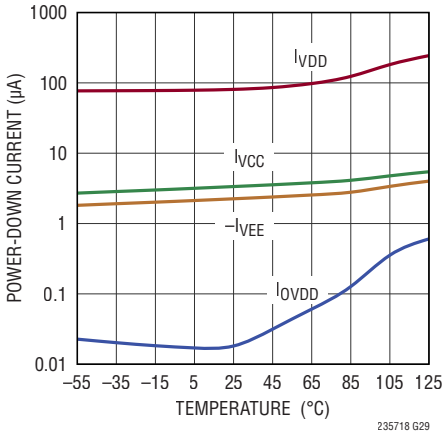
TYPICAL PERFORMANCE CHARACTERISTICS

T_A = 25°C, V_{CC} = +15V, V_{EE} = –15V, V_{DD} = 5V, OV_{DD} = 2.5V, Internal Reference and Buffer (V_{REFBUF} = 4.096V), f_{SMPL} = 350ksps, unless otherwise noted.

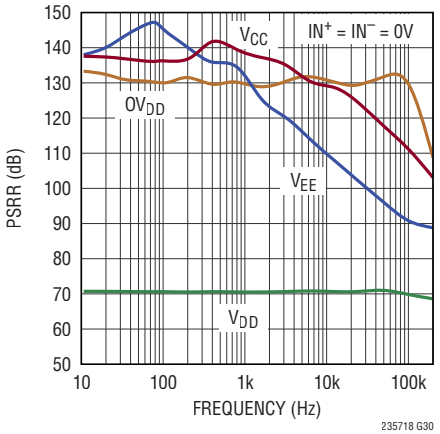
Supply Current vs Temperature



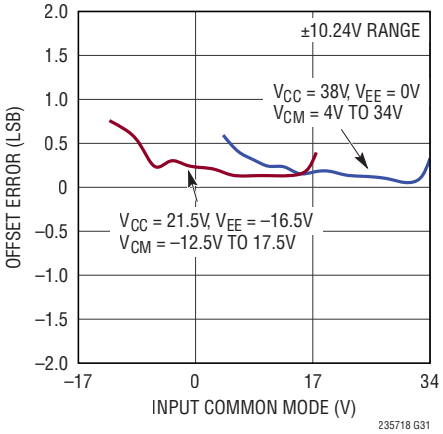
Power-Down Current vs Temperature



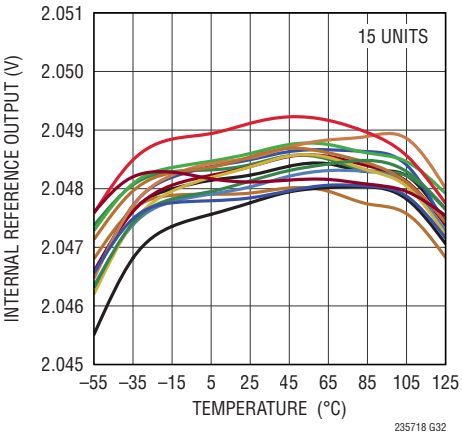
PSRR vs Frequency



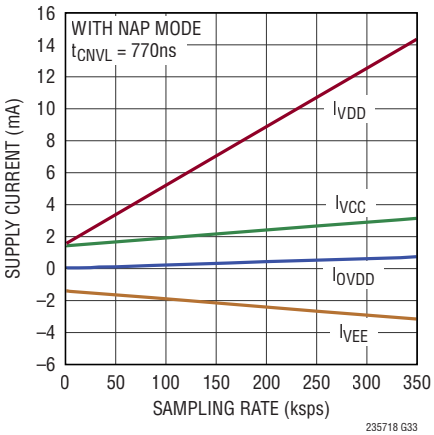
Offset Error vs Input Common Mode



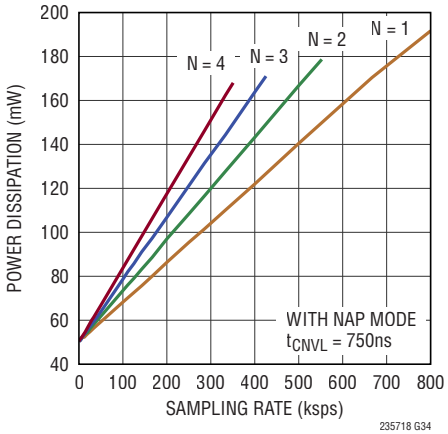
Internal Reference Output vs Temperature



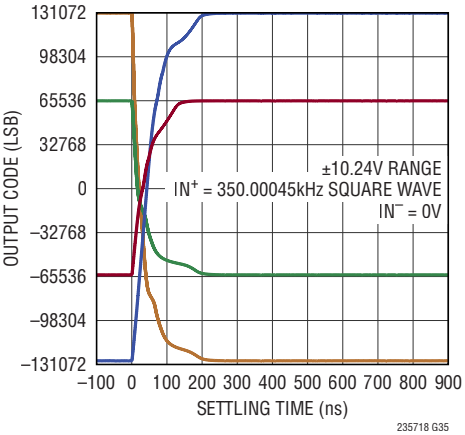
Supply Current vs Sampling Rate



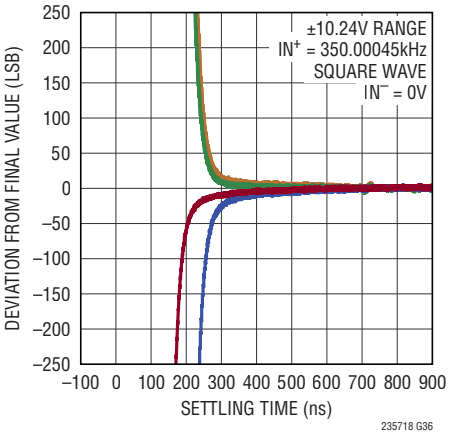
Power Dissipation vs Sampling Rate, N-Channels Enabled



Step Response (Large-Signal Settling)



Step Response (Fine Settling)



PIN FUNCTIONS

Pins that are the Same for All Digital I/O Modes

IN0+/IN0– to IN3+/IN3– (Pins 14/13, 10/9, 4/3, and 48/47): Positive and Negative Analog Inputs, Channels 0 to 3. The converter simultaneously samples and digitizes ($V_{IN}+ – V_{IN}–$) for all channels. Wide input common mode range (V_{EE} + 4V ≤ V_{CM} ≤ V_{CC} – 4V) and high common mode rejection allow the inputs to accept a wide variety of signal swings. Full-scale input range is determined by the channel's SoftSpan configuration.

GND (Pins 1, 2, 5, 6, 7, 8, 11, 12, 15, 18, 20, 25, 30, 36, 41, 44, 46): Ground. Solder all GND pins to a solid ground plane.

V_{CC} (Pin 16): Positive High Voltage Power Supply. The range of V_{CC} is 7.5V to 38V with respect to GND and 10V to 38V with respect to V_{EE}. Bypass V_{CC} to GND close to the pin with a 0.1µF ceramic capacitor.

V_{EE} (Pins 17, 45): Negative High Voltage Power Supply. The range of V_{EE} is 0V to –16.5V with respect to GND and –10V to –38V with respect to V_{CC}. Connect Pins 17 and 45 together and bypass the V_{EE} network to GND close to Pin 17 with a 0.1µF ceramic capacitor. In applications where V_{EE} is shorted to GND, this capacitor may be omitted.

REFIN (Pin 19): Bandgap Reference Output/Reference Buffer Input. An internal bandgap reference nominally outputs 2.048V on this pin. An internal reference buffer amplifies V_{REFIN} to create the converter master reference voltage V_{REFBUF} = 2 • V_{REFIN} on the REFBUF pin. When using the internal reference, bypass REFIN to GND (Pin 20) close to the pin with a 0.1µF ceramic capacitor to filter the bandgap output noise. If more accuracy is desired, overdrive REFIN with an external reference in the range of 1.25V to 2.2V. Do not load this pin when internal reference is used.

REFBUF (Pin 21): Internal Reference Buffer Output. An internal reference buffer amplifies V_{REFIN} to create the converter master reference voltage V_{REFBUF} = 2 • V_{REFIN} on this pin, nominally 4.096V when using the internal bandgap reference. Bypass REFBUF to GND (Pin 20) close to the pin with a 47µF ceramic capacitor. The internal reference buffer may be disabled by grounding its input at REFIN. With the buffer disabled, overdrive REFBUF with an external reference voltage in the range of 2.5V to 5V. When using the internal reference buffer, limit the loading of any external circuitry connected to REFBUF to less than 200µA. Using a high input impedance amplifier to buffer V_{REFBUF} to any external circuits is recommended.

PD (Pin 22): Power Down Input. When this pin is brought high, the LTC2357-18 is powered down and subsequent conversion requests are ignored. If this occurs during a conversion, the device powers down once the conversion completes. If this pin is brought high twice without an intervening conversion, an internal global reset is initiated, equivalent to a power-on-reset event. Logic levels are determined by OV_{DD}.

LVDS/$\overline{\text{CMOS}}$ (Pin 23): I/O Mode Select. Tie this pin to OV_{DD} to select LVDS I/O mode, or to ground to select CMOS I/O mode. Logic levels are determined by OV_{DD}.

CNV (Pin 24): Conversion Start Input. A rising edge on this pin puts the internal sample-and-holds into the hold mode and initiates a new conversion. CNV is not gated by $\overline{\text{CS}}$, allowing conversions to be initiated independent of the state of the serial I/O bus.

BUSY (Pin 38): Busy Output. The BUSY signal indicates that a conversion is in progress. This pin transitions low-to-high at the start of each conversion and stays high until the conversion is complete. Logic levels are determined by OV_{DD}.

V_{DDLBYP} (Pin 40): Internal 2.5V Regulator Bypass Pin. The voltage on this pin is generated via an internal regulator operating off of V_{DD}. This pin must be bypassed to GND close to the pin with a 2.2µF ceramic capacitor. Do not connect this pin to any external circuitry.

V_{DD} (Pins 42, 43): 5V Power Supply. The range of V_{DD} is 4.75V to 5.25V. Connect Pins 42 and 43 together and bypass the V_{DD} network to GND with a shared 0.1µF ceramic capacitor close to the pins.

PIN FUNCTIONS

CMOS I/O Mode

SDI+, SDO– (Pins 26 and 35): LVDS Input and Output. In CMOS I/O mode these pins are Hi-Z.

SDO0 to SDO3 (Pins 27, 28, 33, and 34): CMOS Serial Data Outputs, Channels 0 to 3. The most recent conversion result along with channel configuration information is clocked out onto the SDO pins on each rising edge of SCKI. Output data formatting is described in the Digital Interface section. Leave unused SDO outputs unconnected. Logic levels are determined by OV_{DD}.

SCKI (Pin 29): CMOS Serial Clock Input. Drive SCKI with the serial I/O clock. SCKI rising edges latch serial data in on SDI and clock serial data out on SDO0 to SDO3. For standard SPI bus operation, capture output data at the receiver on rising edges of SCKI. SCKI is allowed to idle either high or low. Logic levels are determined by OV_{DD}.

OV_{DD} (Pin 31): I/O Interface Power Supply. In CMOS I/O mode, the range of OV_{DD} is 1.71V to 5.25V. Bypass OV_{DD} to GND (Pin 30) close to the pin with a 0.1µF ceramic capacitor.

SCKO (Pin 32): CMOS Serial Clock Output. SCKI rising edges trigger transitions on SCKO that are skew-matched to the serial output data streams on SDO0 to SDO3. The resulting SCKO frequency is half that of SCKI. Rising and falling edges of SCKO may be used to capture SDO data at the receiver (FPGA) in double data rate (DDR) fashion. For standard SPI bus operation, SCKO is not used and should be left unconnected. SCKO is forced low at the falling edge of BUSY. Logic levels are determined by OV_{DD}.

SDI (Pin 37): CMOS Serial Data Input. Drive this pin with the desired 12-bit SoftSpan configuration word (see Table 1a), latched on the rising edges of SCKI. If all channels will be configured to operate only in SoftSpan 7, tie SDI to OV_{DD}. Logic levels are determined by OV_{DD}.

$\overline{CS}$ (Pin 39): Chip Select Input. The serial data I/O bus is enabled when $\overline{CS}$ is low and is disabled and Hi-Z when $\overline{CS}$ is high. $\overline{CS}$ also gates the external shift clock, SCKI. Logic levels are determined by OV_{DD}.

LVDS I/O Mode

SDI+/SDI– (Pins 26/27): LVDS Positive and Negative Serial Data Input. Differentially drive SDI+/SDI– with the desired 12-bit SoftSpan configuration word (see Table 1a), latched on both the rising and falling edges of SCKI+/SCKI–. The SDI+/SDI– input pair is internally terminated with a 100Ω differential resistor when $\overline{CS}$ is low.

SCKI+/SCKI– (Pins 28/29): LVDS Positive and Negative Serial Clock Input. Differentially drive SCKI+/SCKI– with the serial I/O clock. SCKI+/SCKI– rising and falling edges latch serial data in on SDI+/SDI– and clock serial data out on SDO+/SDO–. Idle SCKI+/SCKI– low, including when transitioning $\overline{CS}$. The SCKI+/SCKI– input pair is internally terminated with a 100Ω differential resistor when $\overline{CS}$ is low.

OV_{DD} (Pin 31): I/O Interface Power Supply. In LVDS I/O mode, the range of OV_{DD} is 2.375V to 5.25V. Bypass OV_{DD} to GND (Pin 30) close to the pin with a 0.1µF ceramic capacitor.

SCKO+/SCKO– (Pins 32/33): LVDS Positive and Negative Serial Clock Output. SCKO+/SCKO– outputs a copy of the input serial I/O clock received on SCKI+/SCKI–, skew-matched with the serial output data stream on SDO+/SDO–. Use the rising and falling edges of SCKO+/SCKO– to capture SDO+/SDO– data at the receiver (FPGA). The SCKO+/SCKO– output pair must be differentially terminated with a 100Ω resistor at the receiver (FPGA).

SDO+/SDO– (Pins 34/35): LVDS Positive and Negative Serial Data Output. The most recent conversion result along with channel configuration information is clocked out onto SDO+/SDO– on both rising and falling edges of SCKI+/SCKI–, beginning with channel 0. The SDO+/SDO– output pair must be differentially terminated with a 100Ω resistor at the receiver (FPGA).

SDI (Pin 37): CMOS Serial Data. In LVDS I/O mode, this pin is Hi-Z.

$\overline{CS}$ (Pin 39): Chip Select Input. The serial data I/O bus is enabled when $\overline{CS}$ is low, and is disabled and Hi-Z when $\overline{CS}$ is high. $\overline{CS}$ also gates the external shift clock, SCKI+/SCKI–. The internal 100Ω differential termination resistors on the SCKI+/SCKI– and SDI+/SDI– input pairs are disabled when $\overline{CS}$ is high. Logic levels are determined by OV_{DD}.

CONFIGURATION TABLES

Table 1a. SoftSpan Configuration Table. Use This Table with Table 1b to Choose Independent Binary SoftSpan Codes SS[2:0] for Each Channel Based on Desired Analog Input Range. Combine SoftSpan Codes to Form 12-Bit SoftSpan Configuration Word S[11:0]. Use Serial Interface to Write SoftSpan Configuration Word to LTC2357-18, as shown in Figure 18

BINARY SoftSpan CODE SS[2:0]	ANALOG INPUT RANGE	FULL SCALE RANGE	BINARY FORMAT OF CONVERSION RESULT
111	$\pm 2.5 \cdot V_{REFBUF}$	$5 \cdot V_{REFBUF}$	Two's Complement
110	$\pm 2.5 \cdot V_{REFBUF}/1.024$	$5 \cdot V_{REFBUF}/1.024$	Two's Complement
101	$0V$ to $2.5 \cdot V_{REFBUF}$	$2.5 \cdot V_{REFBUF}$	Straight Binary
100	$0V$ to $2.5 \cdot V_{REFBUF}/1.024$	$2.5 \cdot V_{REFBUF}/1.024$	Straight Binary
011	$\pm 1.25 \cdot V_{REFBUF}$	$2.5 \cdot V_{REFBUF}$	Two's Complement
010	$\pm 1.25 \cdot V_{REFBUF}/1.024$	$2.5 \cdot V_{REFBUF}/1.024$	Two's Complement
001	$0V$ to $1.25 \cdot V_{REFBUF}$	$1.25 \cdot V_{REFBUF}$	Straight Binary
000	Channel Disabled	Channel Disabled	All Zeros

Table 1b. Reference Configuration Table. The LTC2357-18 Supports Three Reference Configurations. Analog Input Range Scales with the Converter Master Reference Voltage, V_{REFBUF}

REFERENCE CONFIGURATION	V_{REFIN}	V_{REFBUF}	BINARY SoftSpan CODE SS[2:0]	ANALOG INPUT RANGE
Internal Reference with Internal Buffer	2.048V	4.096V	111	±10.24V
			110	±10V
			101	0V to 10.24V
			100	0V to 10V
			011	±5.12V
			010	±5V
			001	0V to 5.12V
External Reference with Internal Buffer (REFIN Pin Externally Overdriven)	1.25V (Min Value)	2.5V	111	±6.25V
			110	±6.104V
			101	0V to 6.25V
			100	0V to 6.104V
			011	±3.125V
			010	±3.052V
			001	0V to 3.125V
	2.2V (Max Value)	4.4V	111	±11V
			110	±10.742V
			101	0V to 11V
			100	0V to 10.742V
			011	±5.5V
			010	±5.371V
			001	0V to 5.5V

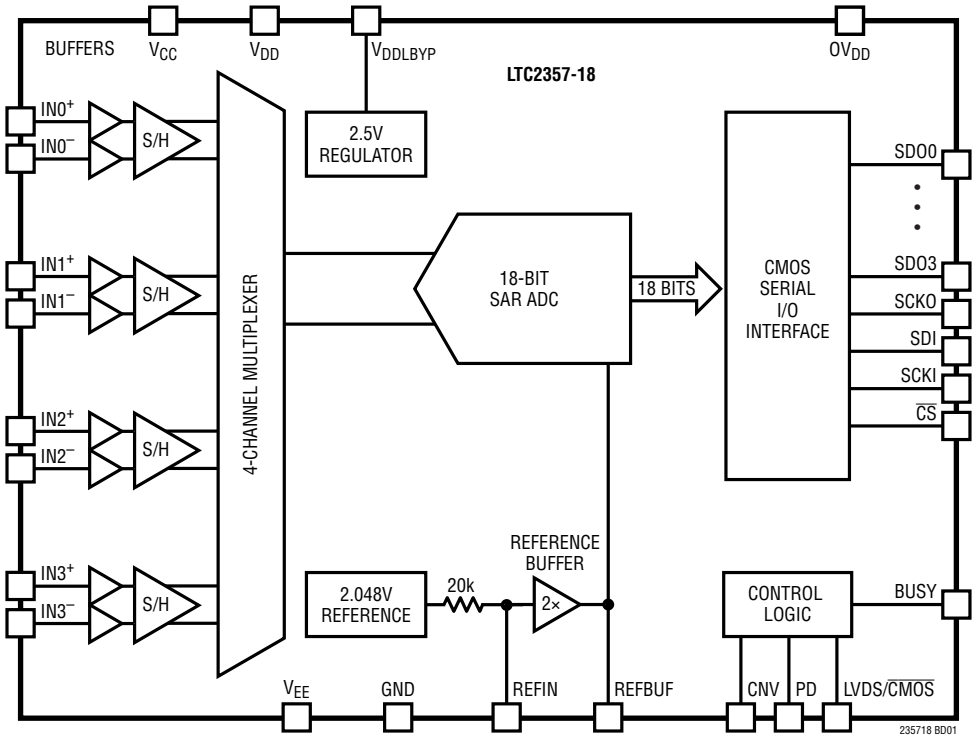
CONFIGURATION TABLES

Table 1b. Reference Configuration Table (Continued). The LTC2357-18 Supports Three Reference Configurations. Analog Input Range Scales with the Converter Master Reference Voltage, V_{REFBUF}

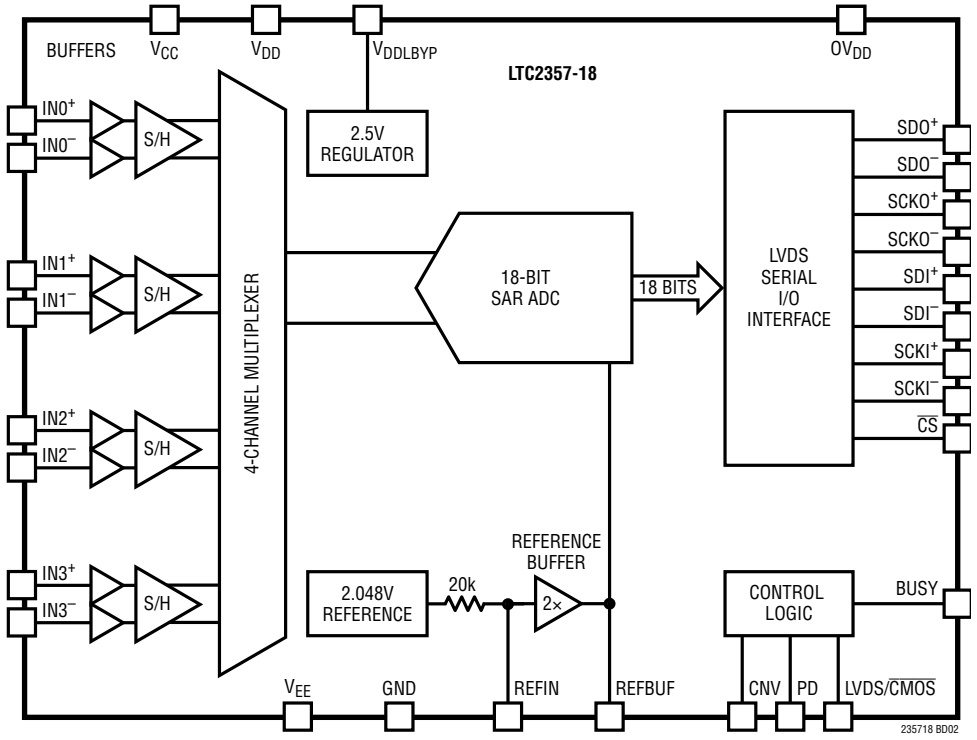
REFERENCE CONFIGURATION	V_{REFIN}	V_{REFBUF}	BINARY SoftSpan CODE SS[2:0]	ANALOG INPUT RANGE
External Reference Unbuffered (REFBUF Pin Externally Overdriven, REFIN Pin Grounded)	0V	2.5V (Min Value)	111	±6.25V
			110	±6.104V
			101	0V to 6.25V
			100	0V to 6.104V
			011	±3.125V
			010	±3.052V
			001	0V to 3.125V
	0V	5V (Max Value)	111	±12.5V
			110	±12.207V
			101	0V to 12.5V
			100	0V to 12.207V
			011	±6.25V
			010	±6.104V
			001	0V to 6.25V

FUNCTIONAL BLOCK DIAGRAM

CMOS I/O Mode

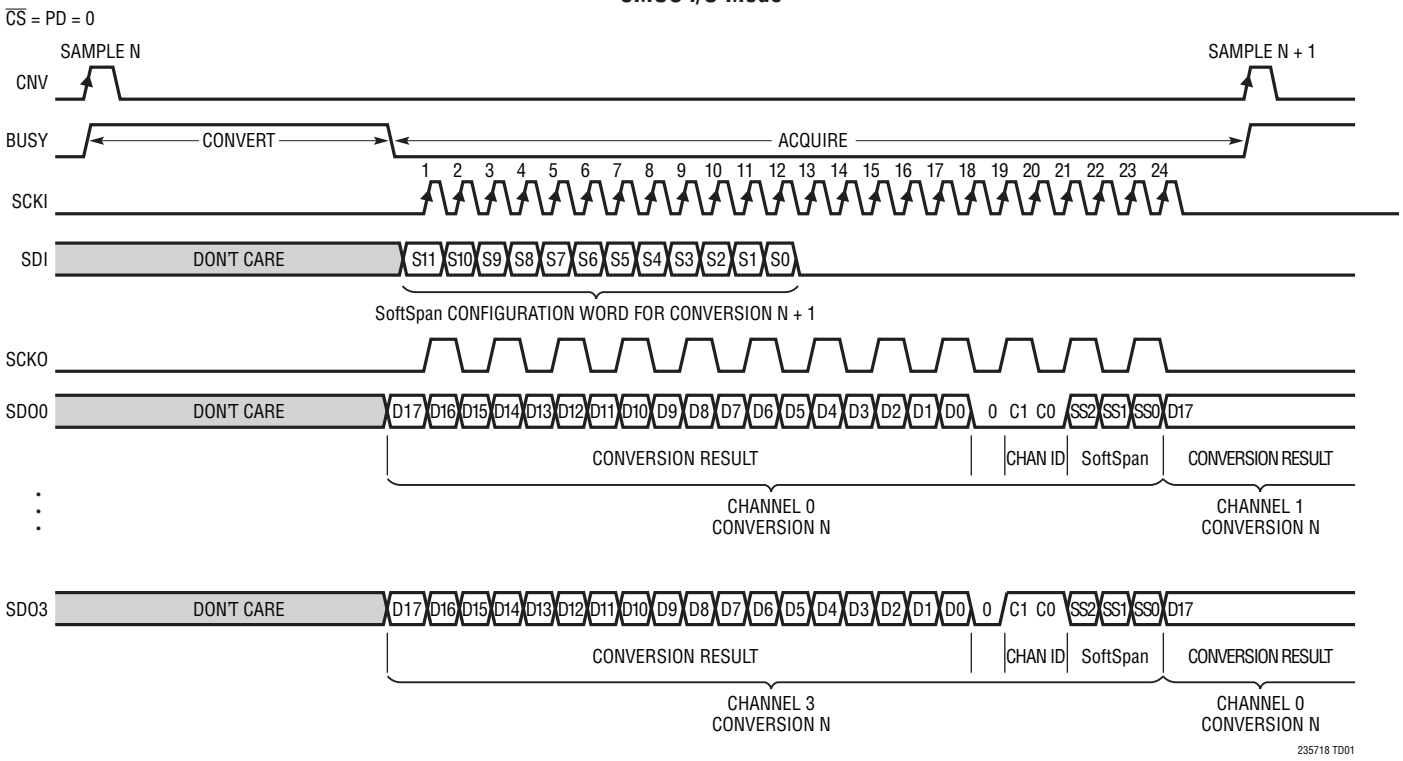


LVDS I/O Mode

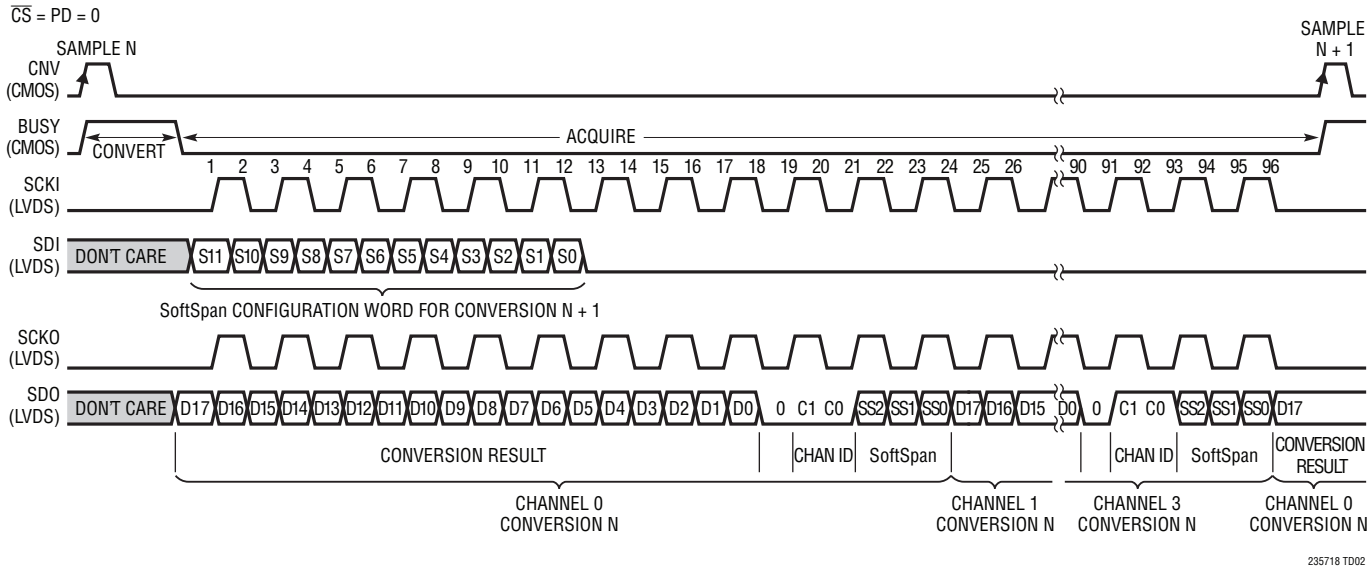


TIMING DIAGRAM

CMOS I/O Mode



LVDS I/O Mode



APPLICATIONS INFORMATION

OVERVIEW

The LTC2357-18 is an 18-bit, low noise 4-channel simultaneous sampling successive approximation register (SAR) ADC with buffered differential, wide common mode range picoamp inputs. The ADC operates from a 5V low voltage supply and flexible high voltage supplies, nominally ±15V. Using the integrated low-drift reference and buffer (V_{REFBUF} = 4.096V nominal), each channel of this SoftSpan ADC can be independently configured on a conversion-by-conversion basis to accept ±10.24V, 0V to 10.24V, ±5.12V, or 0V to 5.12V signals. The input signal range may be expanded up to ±12.5V using an external 5V reference. Individual channels may also be disabled to increase throughput on the remaining channels.

The integrated picoamp-input analog buffers, wide input common mode range, and 128dB CMRR of the LTC2357-18 allow the ADC to directly digitize a variety of signals using minimal board space and power. This input signal flexibility, combined with ±3.5LSB INL, no missing codes at 18 bits, and 96.4dB SNR, makes the LTC2357-18 an ideal choice for many high voltage applications requiring wide dynamic range.

The absolute common mode input range (V_{EE} + 4V to V_{CC} – 4V) is determined by the choice of high voltage supplies. These supplies may be biased asymmetrically around ground and include the ability for V_{EE} to be tied directly to ground.

The LTC2357-18 supports pin-selectable SPI CMOS (1.8V to 5V) and LVDS serial interfaces, enabling it to communicate equally well with legacy microcontrollers and modern FPGAs. In CMOS mode, applications may employ between one and four lanes of serial output data, allowing the user to optimize bus width and data throughput. The LTC2357-18 typically dissipates 175mW when converting four channels simultaneously at 350ksps per channel. Optional nap and power down modes may be employed to further reduce power consumption during inactive periods.

CONVERTER OPERATION

The LTC2357-18 operates in two phases. During the acquisition phase, the sampling capacitors in each channel's sample-and-hold (S/H) circuit connect to their respective analog input buffers, which track the differential analog input voltage (V_{IN}+ – V_{IN}–). A rising edge on the CNV pin transitions all channels' S/H circuits from track mode to hold mode, simultaneously sampling the input signals on all channels and initiating a conversion. During the conversion phase, each channel's sampling capacitors are connected, one channel at a time, to an 18-bit charge redistribution capacitor D/A converter (CDAC). The CDAC is sequenced through a successive approximation algorithm, effectively comparing the sampled input voltage with binary-weighted fractions of the channel's SoftSpan full-scale range (e.g., $V_{FSR}/2$, $V_{FSR}/4$ … $V_{FSR}/262144$) using a differential comparator. At the end of this process, the CDAC output approximates the channel's sampled analog input. Once all channels have been converted in this manner, the ADC control logic prepares the 18-bit digital output codes from each channel for serial transfer.

TRANSFER FUNCTION

The LTC2357-18 digitizes each channel's full-scale voltage range into 2^{18} levels. In conjunction with the ADC master reference voltage, V_{REFBUF}, a channel's SoftSpan configuration determines its input voltage range, full-scale range, LSB size, and the binary format of its conversion result, as shown in Tables 1a and 1b. For example, employing the internal reference and buffer (V_{REFBUF} = 4.096V nominal), SoftSpan 7 configures a channel to accept a ±10.24V bipolar analog input voltage range, which corresponds to a 20.48V full-scale range with a 78.125µV LSB. Other SoftSpan configurations and reference voltages may be employed to convert both larger and smaller bipolar and unipolar input ranges. Conversion results are output in two's complement binary format for all bipolar SoftSpan ranges, and in straight binary format for all unipolar

APPLICATIONS INFORMATION

SoftSpan ranges. The ideal two's complement transfer function is shown in Figure 2, while the ideal straight binary transfer function is shown in Figure 3.

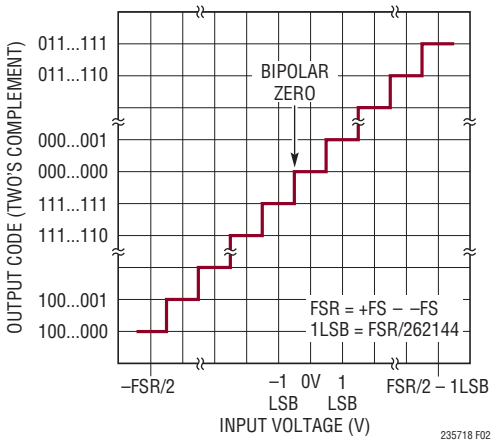


Figure 2. LTC2357-18 Two's Complement Transfer Function

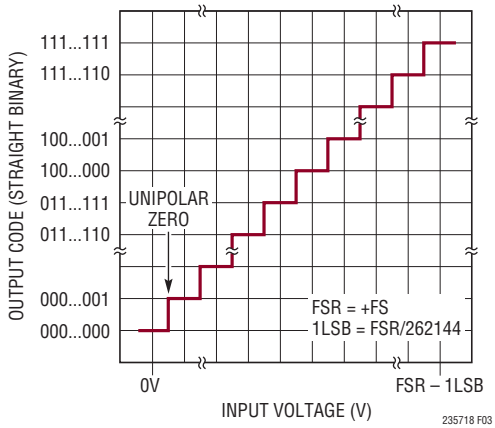


Figure 3. LTC2357-18 Straight Binary Transfer Function

BUFFERED ANALOG INPUTS

Each channel of the LTC2357-18 simultaneously samples the voltage difference ($V_{IN}+ – V_{IN}–$) between its analog input pins over a wide common mode input range while attenuating unwanted signals common to both input pins by the common-mode rejection ratio (CMRR) of the ADC. Wide common mode input range coupled with high CMRR allows the $IN^+/IN^–$ analog inputs to swing with an arbitrary relationship to each other, provided each pin remains between (V_{EE} + 4V) and (V_{CC} – 4V). This feature of the LTC2357-18 enables it to accept a wide variety of signal swings, including traditional classes of analog input signals such as pseudo-differential unipolar, pseudo-differential true bipolar, and fully differential, simplifying signal chain design. For conversion of signals extending to V_{EE}, the unbuffered LTC2348-18 ADC is recommended.

The wide operating range of the high voltage supplies offers further input common mode flexibility. As long as the voltage difference limits of 10V ≤ (V_{CC} – V_{EE}) ≤ 38V are observed, V_{CC} and V_{EE} may be independently biased anywhere within their own individually allowed operating ranges, including the ability for V_{EE} to be tied directly to ground. This feature enables the common mode input range of the LTC2357-18 to be tailored to specific application requirements.

In all SoftSpan ranges, each channel's analog inputs can be modeled by the equivalent circuit shown in Figure 4. At the start of acquisition, the sampling capacitors (C_{SAMP}) connect to the integrated buffers $BUFFER^+/BUFFER^–$ through the sampling switches. The sampled voltage is reset during the conversion process and is therefore re-acquired for each new conversion.

The diodes between the inputs and the V_{CC} and V_{EE} supplies provide input ESD protection. While within the supply voltages, the analog inputs of the LTC2357-18 draw only 5pA typical DC leakage current and the ESD protection diodes don't turn on. This offers a significant advantage over external op amp buffers, which often have diode protection that turns on during transients and corrupts the voltage on any filter capacitors at their inputs.

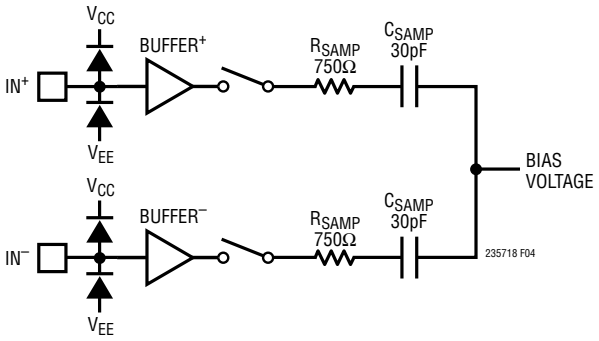


Figure 4. Equivalent Circuit for Differential Analog Inputs, Single Channel Shown

APPLICATIONS INFORMATION

Bipolar SoftSpan Input Ranges

For channels configured in SoftSpan ranges 7, 6, 3, or 2, the LTC2357-18 digitizes the differential analog input voltage ($V_{IN}+ – V_{IN}–$) over a bipolar span of ±2.5 • V_{REFBUF}, ±2.5 • V_{REFBUF}/1.024, ±1.25 • V_{REFBUF}, or ±1.25 • V_{REFBUF}/1.024, respectively, as shown in Table 1a. These SoftSpan ranges are useful for digitizing input signals where IN^+ and $IN^–$ swing above and below each other. Traditional examples include fully differential input signals, where IN^+ and $IN^–$ are driven 180 degrees out-of-phase with respect to each other centered around a common mode voltage ($V_{IN}+ + V_{IN}–$)/2, and pseudo-differential true bipolar input signals, where IN^+ swings above and below a ground reference level, driven on $IN^–$. Regardless of the chosen SoftSpan range, the wide common mode input range and high CMRR of the $IN^+/IN^–$ analog inputs allow them to swing with an arbitrary relationship to each other, provided each pin remains between (V_{CC} – 4V) and (V_{EE} + 4V). The output data format for all bipolar SoftSpan ranges is two's complement.

Unipolar SoftSpan Input Ranges

For channels configured in SoftSpan ranges 5, 4, or 1, the LTC2357-18 digitizes the differential analog input voltage ($V_{IN}+ – V_{IN}–$) over a unipolar span of 0V to 2.5 • V_{REFBUF}, 0V to 2.5 • V_{REFBUF}/1.024, or 0V to 1.25 • V_{REFBUF}, respectively, as shown in Table 1a. These SoftSpan ranges are useful for digitizing input signals where IN^+ remains above $IN^–$. A traditional example includes pseudo-differential unipolar input signals, where IN^+ swings above a ground reference level, driven on $IN^–$. Regardless of the chosen SoftSpan range, the wide common mode input range and high CMRR of the $IN^+/IN^–$ analog inputs allow them to swing with an arbitrary relationship to each other, provided each pin remains between (V_{CC} – 4V) and (V_{EE} + 4V). The output data format for all unipolar SoftSpan ranges is straight binary.

INPUT DRIVE CIRCUITS

The CMOS buffer input stage offers a very high degree of transient isolation from the sampling process. Most sensors, signal conditioning amplifiers and filter networks with less than 10kΩ of impedance can drive the passive 3pF analog input capacitance directly. For higher impedances and slow-settling circuits, add a 680pF capacitor at the pins to maintain the full DC accuracy of the LTC2357-18.

The very high input impedance of the unity gain buffers in the LTC2357-18 greatly reduces the input drive requirements and makes it possible to include optional RC filters with kΩ impedance and arbitrarily slow time constants for anti-aliasing or other purposes. Micropower op amps with limited drive capability are also well suited to drive the high impedance analog inputs directly.

The LTC2357-18 features proprietary circuitry to achieve exceptional internal crosstalk isolation between channels (–109dB typical). The PC board wiring to the analog inputs should be short and shielded to prevent external capacitive crosstalk between channels. The capacitance between adjacent package pins is 0.16pF. Low source resistance and/or high source capacitance help reduce external capacitively coupled crosstalk. Single ended input drive also enjoys additional external crosstalk isolation because every other input pin is grounded, or at a low impedance DC source, and serves as a shield between channels.

INPUT OVERDRIVE TOLERANCE

Driving an analog input above V_{CC} on any channel up to 10mA will not affect conversion results on other channels. Approximately 70% of this overdrive current will flow out of the V_{CC} pin and the remaining 30% will flow out of V_{EE}. This current flowing out of V_{EE} will produce heat across the $V_{CC} – V_{EE}$ voltage drop and must be taken into account for the total Absolute Maximum power dissipation of 500mW. Driving an analog input below V_{EE} may corrupt conversion results on other channels. This product can handle input currents of up to 100mA below V_{EE} or above V_{CC} without latch-up.

Keep in mind that driving the inputs above V_{CC} or below V_{EE} may reverse the normal current flow from the external power supplies driving these pins.

APPLICATIONS INFORMATION

Input Filtering

The true high impedance analog inputs can accommodate a very wide range of passive or active signal conditioning filters. The buffered ADC inputs have an analog bandwidth of 6MHz, and impose no particular bandwidth requirement on external filters. The external input filters can therefore be optimized independent of the ADC to reduce signal chain noise and interference. A common filter configuration is the simple anti-aliasing and noise reducing RC filter with its pole at half the sampling frequency. For example, 175kHz with R=1.33kΩ and C=680pF as shown in Figure 5.

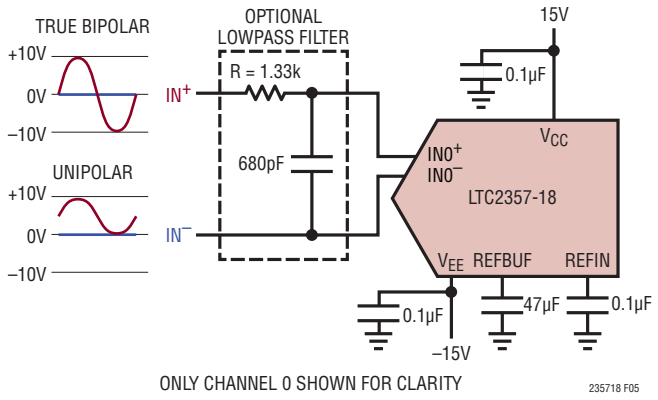


Figure 5. Filtering Single-Ended Input Signals

High quality capacitors and resistors should be used in the RC filters since these components can add distortion. NPO/COG and silver mica type dielectric capacitors have excellent linearity. Carbon surface mount resistors can generate distortion from self-heating and from damage that may occur during soldering. Metal film surface mount resistors are much less susceptible to both problems.

Arbitrary and Fully Differential Analog Input Signals

The wide common mode input range and high CMRR of the LTC2357-18 allow each channel's IN^+ and IN^- pins to swing with an arbitrary relationship to each other, provided each pin remains between (V_{CC} – 4V) and (V_{EE} + 4V). This feature of the LTC2357-18 enables it to accept a wide variety of signal swings, simplifying signal chain design.

The two-tone test shown in Figure 6b demonstrates the arbitrary input drive capability of the LTC2357-18. This test simultaneously drives IN^+ with a –7dBFS 2kHz single-ended sine wave and IN^- with a –7dBFS 3.1kHz single-ended sine wave. Together, these signals sweep the analog inputs across a wide range of common mode and differential mode voltage combinations, similar to the more general arbitrary input signal case. They also have a simple spectral representation. An ideal differential converter with no common-mode sensitivity will digitize this signal as two –7dBFS spectral tones, one at each sine wave frequency. The FFT plot in Figure 6b demonstrates the LTC2357-18 response approaches this ideal, with 121dB of SFDR limited by the converter's second harmonic distortion response to the 3.1kHz sine wave on IN^-.

The ability of the LTC2357-18 to accept arbitrary signal swings over a wide input common mode range with high CMRR can simplify application solutions. In practice, many sensors produce a differential sensor voltage riding on top of a large common mode signal. Figure 7a depicts one way of using the LTC2357-18 to digitize signals of this type. The amplifier stage provides a differential gain of approximately 10V/V to the desired sensor signal while the unwanted common mode signal is attenuated by the ADC CMRR. The circuit employs the ±5V SoftSpan range of the ADC. Figure 7b shows measured CMRR performance of this solution, which is competitive with the best commercially available instrumentation amplifiers. Figure 7c shows measured AC performance of this solution.

In Figure 8, another application circuit is shown which uses two channels of the LTC2357-18 to simultaneously sense the voltage and bidirectional current through a sense resistor over a wide common mode range.

APPLICATIONS INFORMATION

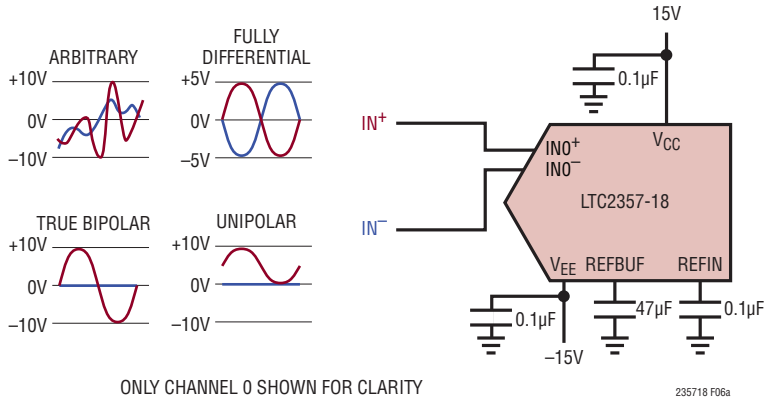


Figure 6a. Input Arbitrary, Fully Differential, True Bipolar, and Unipolar Signals

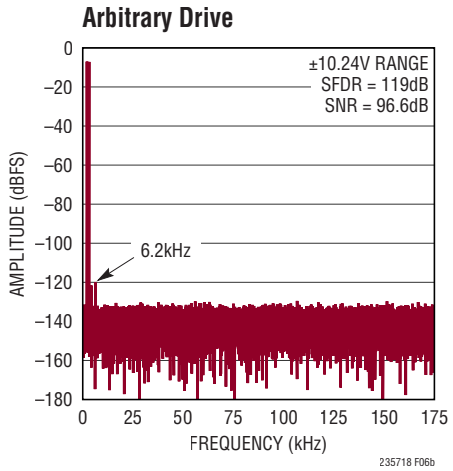


Figure 6b. Two-Tone Test. IN+ = –7dBFS 2kHz Sine, IN– = –7dBFS 3.1kHz Sine, 32k Point FFT, f_{SMPL} = 350ksps. Circuit Shown in Figure 6a

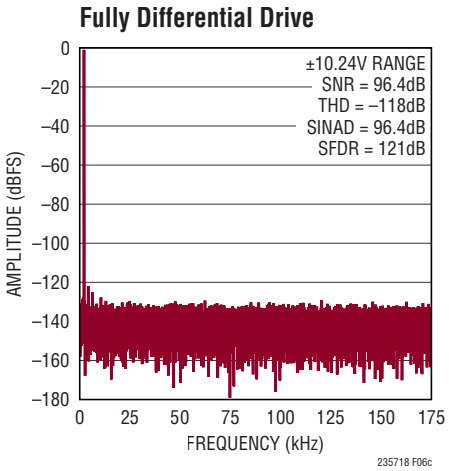


Figure 6c. IN+/IN– = –1dBFS 2kHz Fully Differential Sine, V_{CM} = 0V, 32k Point FFT, f_{SMPL} = 350ksps. Circuit Shown in Figure 6a

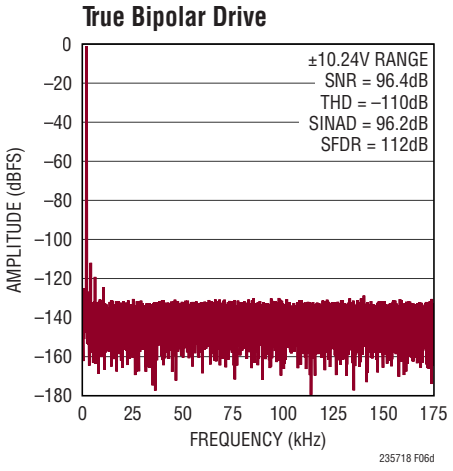


Figure 6d. IN+ = –1dBFS 2kHz True Bipolar Sine, IN– = 0V, 32k Point FFT, f_{SMPL} = 350ksps. Circuit Shown in Figure 6a

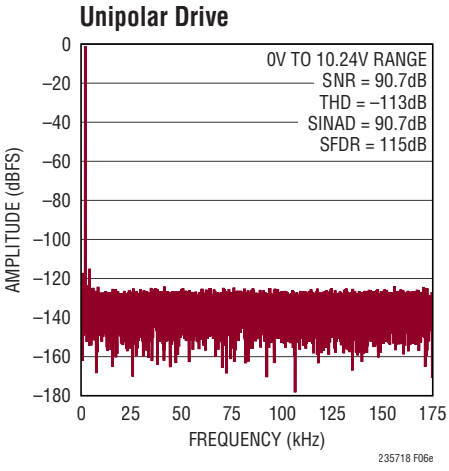


Figure 6e. IN+ = –1dBFS 2kHz Unipolar Sine, IN– = 0V, 32k Point FFT, f_{SMPL} = 350ksps. Circuit Shown in Figure 6a

APPLICATIONS INFORMATION

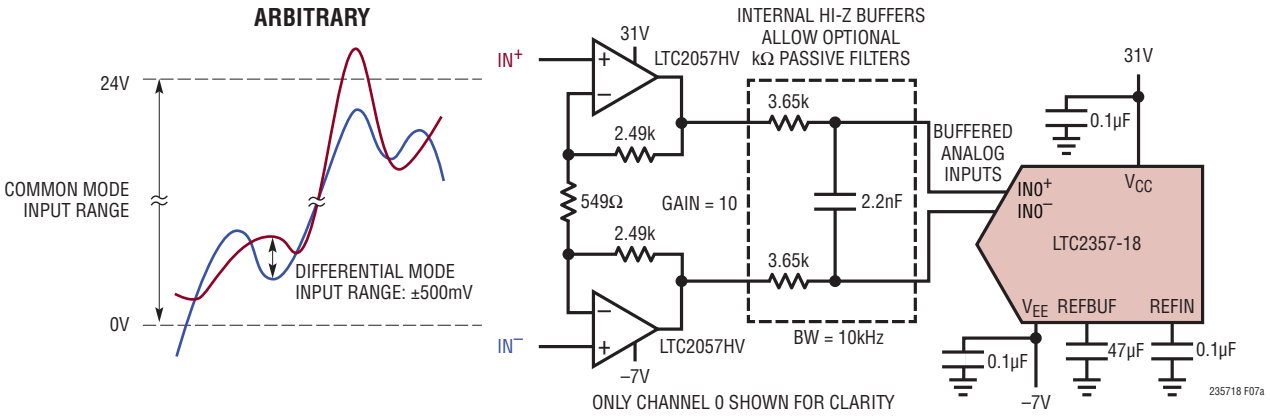


Figure 7a. Amplify Differential Signals with Gain of 10 Over a Wide Common Mode Range with Buffered Analog Inputs

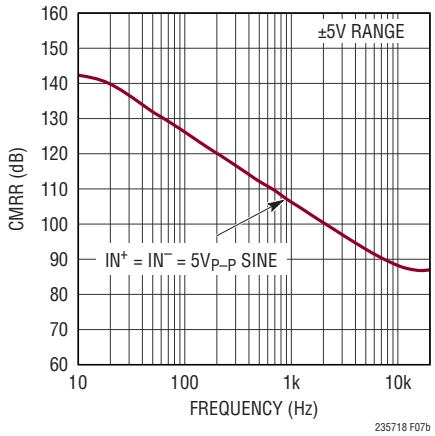


Figure 7b. CMRR vs Input Frequency. Circuit Shown in Figure 7a

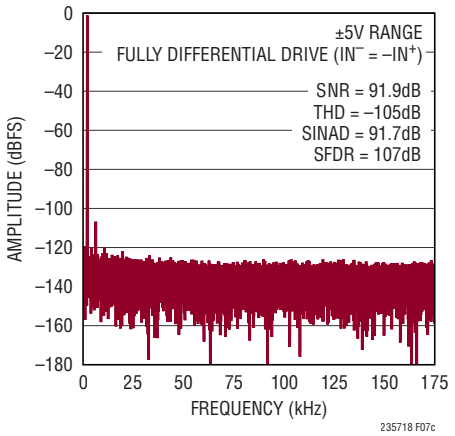
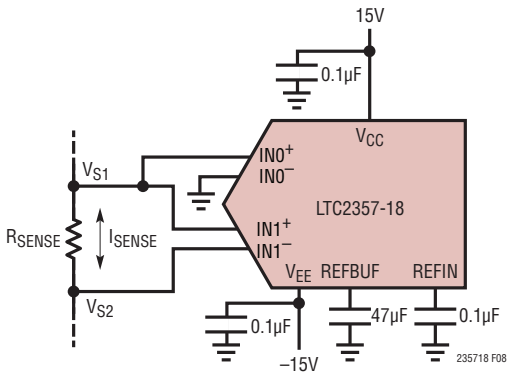


Figure 7c. IN+/IN– = 450mV 200Hz Fully Differential Sine, 0V ≤ V_{CM} ≤ 24V, 32k Point FFT, f_{SMPL} = 350ksps. Circuit Shown in Figure 7a



ONLY CHANNELS 0 AND 1 SHOWN FOR CLARITY

$$I_{SENSE} = \frac{V_{S1} - V_{S2}}{R_{SENSE}} \quad \begin{matrix} -10.24V \le V_{S1} \le 10.24V \\ -10.24V \le V_{S2} \le 10.24V \end{matrix}$$

Figure 8. Simultaneously Sense Voltage (CH0) and Current (CH1) Over a Wide Common Mode Range

APPLICATIONS INFORMATION

ADC REFERENCE

As shown previously in Table 1b, the LTC2357-18 supports three reference configurations. The first uses both the internal bandgap reference and reference buffer. The second externally overdrives the internal reference but retains the internal buffer, which isolates the external reference from ADC conversion transients. This configuration is ideal for sharing a single precision external reference across multiple ADCs. The third disables the internal buffer and overdrives the REFBUF pin externally.

Internal Reference with Internal Buffer

The LTC2357-18 has an on-chip, low noise, low drift (20ppm/°C maximum), temperature compensated bandgap reference that is factory trimmed to 2.048V. The reference output connects through a 20kΩ resistor to the REFIN pin, which serves as the input to the on-chip reference buffer, as shown in Figure 9a. When employing the internal bandgap reference, the REFIN pin should be bypassed to GND (Pin 20) close to the pin with a 0.1µF ceramic capacitor to filter wideband noise. The reference buffer amplifies V_{REFIN} to create the converter master reference voltage $V_{REFBUF} = 2 \bullet V_{REFIN}$ on the REFBUF pin, nominally 4.096V when using the internal bandgap reference. Bypass REFBUF to GND (Pin 20) close to the pin with at least a 47µF ceramic capacitor (X7R, 10V, 1210 size or X5R, 10V, 0805 size) to compensate the reference buffer, absorb transient conversion currents, and minimize noise.

External Reference with Internal Buffer

If more accuracy and/or lower drift is desired, REFIN can be easily overdriven by an external reference since 20kΩ of resistance separates the internal bandgap reference output from the REFIN pin, as shown in Figure 9b. The valid range of external reference voltage overdrive on the REFIN pin is 1.25V to 2.2V, resulting in converter master reference voltages V_{REFBUF} between 2.5V and 4.4V, respectively. Linear Technology offers a portfolio of high performance references designed to meet the needs of many applications. With its small size, low power, and high accuracy, the LTC6655-2.048 is well suited for use

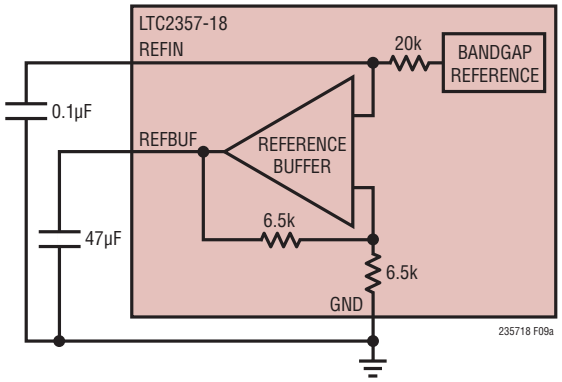


Figure 9a. Internal Reference with Internal Buffer Configuration

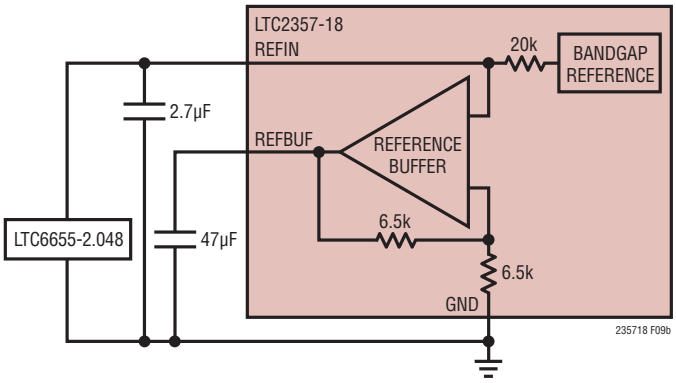


Figure 9b. External Reference with Internal Buffer Configuration

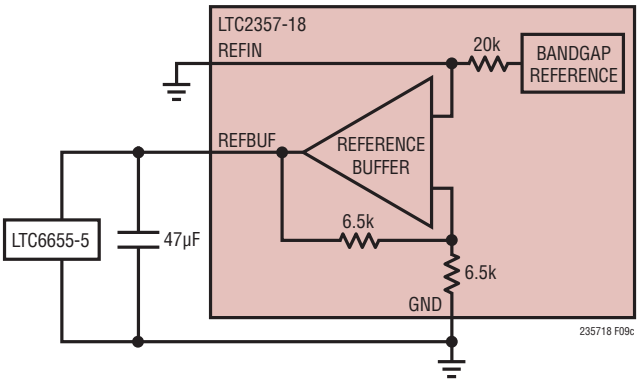


Figure 9c. External Reference with Disabled Internal Buffer Configuration