

Commercial Space
Product

5.9 GHz to 23.6 GHz, Wideband, Microwave Upconverter

FEATURES

- ▶ Wideband RF output frequency range: 5.9 GHz to 23.6 GHz
- ▶ Two upconversion modes
 - ▶ Direct conversion from baseband I/Q to RF
 - ▶ Single sideband upconversion from real IF
- ▶ LO input frequency range: 5.4 GHz to 14 GHz
- ▶ LO doubler (x2 LO) for up to 28 GHz
- ▶ Matched 100 Ω balanced RF output, LO input, and IF input
- ▶ High impedance baseband inputs
- ▶ Sideband suppression and carrier feedthrough optimization
- ▶ Variable attenuator and power detector for transmit power control
- ▶ Programmable via 4-wire SPI
- ▶ 32-lead, 5 mm $\times$ 5 mm LFCSP

COMMERCIAL SPACE FEATURES

- ▶ Support aerospace applications
- ▶ Wafer diffusion lot traceability
- ▶ Radiation monitors
 - ▶ Total ionizing dose (TID)
- ▶ Outgassing characterization

APPLICATIONS

- ▶ Low and medium Earth orbit (LEO/MEO) space payloads
- ▶ Avionics
- ▶ Point to point microwave radios
- ▶ Radar and electronic warfare systems

GENERAL DESCRIPTION

The ADRF6780S-CSL is a silicon germanium (SiGe) design, wideband, microwave upconverter optimized for point to point microwave radio designs operating in the 5.9 GHz to 23.6 GHz frequency range.

The upconverter offers two modes of frequency translation. The device is capable of direct conversion to RF from baseband in-phase quadrature (I/Q) input signals, as well as single sideband (SSB) upconversion from a real intermediate frequency (IF) input carrier frequency. The baseband inputs are high impedance and are generally terminated off chip with 100 Ω differential back terminations. The baseband I/Q input path can be disabled and a modulated real IF signal anywhere from 0.8 GHz to 3.5 GHz can be fed into the IF input path and upconverted to 5.9 GHz to 23.6 GHz while suppressing the unwanted sideband by typically better than 25 dBc. The serial port interface (SPI) allows tweaking of the quadrature phase adjustment to allow optimum sideband suppression. In addition, the SPI allows powering down the output power detector to reduce power consumption when power monitoring is not necessary.

The ADRF6780S-CSL upconverter comes in a [compact, thermally enhanced, 5 mm \$\times\$ 5 mm LFCSP](#). The ADRF6780S-CSL operates over the -40°C to $+85^{\circ}\text{C}$ temperature range.

Additional application and technical information can be found in the [Commercial Space Products Program](#) brochure and [ADRF6780](#) data sheet.

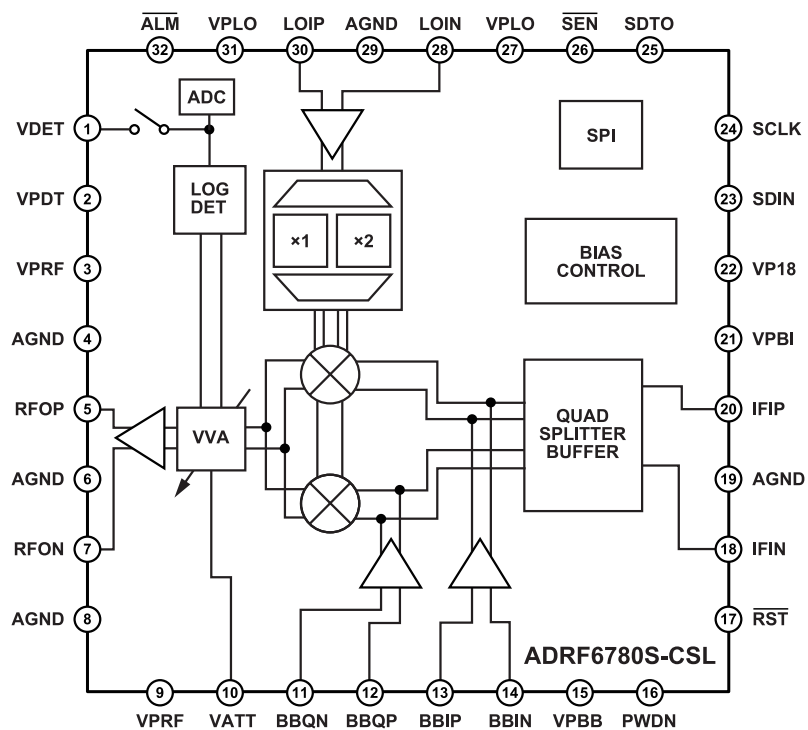
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REVISION HISTORY

11/2024—Rev. 0 to Rev. A	
Change to Table 6.....	9
11/2024—Revision 0: Initial Version	

FUNCTIONAL BLOCK DIAGRAM



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SPECIFICATIONS

VPBB = VPBI = VPLO = 3.3 V, VP18 = 1.8 V, VPDT = VPRF = 5 V, $T_A = 25^\circ\text{C}$, LO = 0 dBm differential drive, baseband I/Q amplitude = -15 dBm differential sine waves in quadrature with a 500 mV DC bias, baseband input termination with 100 Ω externally, and IF amplitude = -12 dBm differential sine waves, unless otherwise noted.

Table 1. Specifications

Parameter	Test Conditions/Comments	Min	Typ	Max	Unit
RF OUTPUT FREQUENCY RANGE		5.9		23.6	GHz
LOCAL OSCILLATOR (LO) INPUT FREQUENCY RANGE		5.4		14	GHz
LO AMPLITUDE RANGE		-6	0	+6	dBm
IF INPUT FREQUENCY RANGE		0.8		3.5	GHz
BASEBAND I/Q INPUT FREQUENCY RANGE		DC		750	MHz
I/Q MODULATOR PERFORMANCE					
Modulator Voltage Gain	Maximum gain at maximum gain setting	10	13		dB
	Minimum gain at minimum gain setting		-12		dB
Output Noise Density	Output carrier > -5 dBm		-147		dBc/Hz
	Output carrier > -14 dBm		-145		dBc/Hz
	Output carrier > -22.5 dBm		-136		dBc/Hz
Output Third-Order Intercept (OIP3)	f_1 baseband = 10 MHz, f_2 baseband = 12 MHz, baseband I/Q amplitude per tone = -15 dBm sine waves in quadrature with a 500 mV DC bias, 10 dB gain setting				
5.9 GHz to 10 GHz			24		dBm
10 GHz to 14 GHz			25		dBm
14 GHz to 20 GHz			27		dBm
20 GHz to 23.6 GHz			27		dBm
Fifth-Order Intermodulation Distortion (IMD5)	f_1 baseband = 10 MHz, f_2 baseband = 12 MHz, baseband I/Q amplitude per tone = -15 dBm sine waves in quadrature with a 500 mV DC bias, 10 dB gain setting		65		dBm
Output Second-Order Intercept (OIP2)	f_1 baseband = 10 MHz, f_2 baseband = 12 MHz, baseband I/Q amplitude per tone = -15 dBm sine waves in quadrature with a 500 mV DC bias, 10 dB gain setting				
5.9 GHz to 10 GHz			65		dBm
10 GHz to 14 GHz			65		dBm
14 GHz to 20 GHz			66		dBm
20 GHz to 23.6 GHz			50		dBm
Output 1 dB Compression Point (P1dB)					
5.9 GHz to 10 GHz	At 10 dB gain setting		10.5		dBm
	At maximum gain setting		11		dBm
10 GHz to 14 GHz	At 10 dB gain setting		11		dBm
	At maximum gain setting		12		dBm
14 GHz to 20 GHz	At 10 dB gain setting		10		dBm
	At maximum gain setting		12		dBm
20 GHz to 23.6 GHz	At 10 dB gain setting		10		dBm
	At maximum gain setting		11		dBm
LO Feedthrough	At 10 dB gain setting (can be improved by baseband DC offset adjustment)		-25		dBm
Sideband Suppression	At 10 dB gain setting		25		dBc
IF UPCONVERTER PERFORMANCE					
Upconversion Voltage Gain	Maximum gain at maximum gain setting	7	11		dB
	Minimum gain at minimum gain setting		-14		dB

SPECIFICATIONS

Table 1. Specifications (Continued)

Parameter	Test Conditions/Comments	Min	Typ	Max	Unit
Output Noise Density	Output carrier > -5 dBm		-147		dBc/Hz
	Output carrier > -14 dBm		-145		dBc/Hz
	Output carrier > -22.5 dBm		-136		dBc/Hz
OIP3	f_1 IF = 1810 MHz, f_2 IF = 1812 MHz, amplitude per tone = -15 dBm sine waves in quadrature with AC bias, 7 dB gain setting				
5.9 GHz to 10 GHz			27		dBm
10 GHz to 14 GHz			24		dBm
14 GHz to 20 GHz			22.5		dBm
20 GHz to 23.6 GHz			22.5		dBm
IMD5	f_1 IF = 1810 MHz, f_2 IF = 1812 MHz, amplitude per tone = -15 dBm sine waves in quadrature with AC bias, 7 dB gain setting		80		dBm
Output P1dB					
5.9 GHz to 10 GHz	At 7 dB gain setting		10.5		dBm
	At maximum gain setting		11.5		dBm
10 GHz to 14 GHz	At 7 dB gain setting		10		dBm
	At maximum gain setting		12		dBm
14 GHz to 20 GHz	At 7 dB gain setting		9.5		dBm
	At maximum gain setting		12		dBm
20 GHz to 23.6 GHz	At 7 dB gain setting		9.5		dBm
	At maximum gain setting		11.5		dBm
LO Feedthrough	At 7 dB gain setting (can be improved by baseband DC offset adjustment)		-35		dBm
Sideband Suppression	At 7 dB gain setting		25		dBc
Tx POWER DETECTOR PERFORMANCE					
Output Level					
Maximum			2		dBm
Minimum			-30		dBm
±1 dB Dynamic Range			34		dB
Output Voltage					
Maximum			1		V
Minimum			0.2		V
Log Slope			25		mV/dB
Time					
Rise	Input power (P_{IN}) = off to -10 dBm, 10% to 90%, C_7 = 10 pF (see ADRF6780 for more details)		134		ns
Fall	P_{IN} = -10 dBm to off, 10% to 90%, C_7 = 10 pF (see ADRF6780 for more details)		190		ns
Response	C_7 = 10 pF (see ADRF6780 for more details)		30		ns
RETURN LOSS					
RF Output	100 Ω differential		12		dB
LO Input	100 Ω differential		12		dB
IF Input	100 Ω differential		17		dB
Baseband I/Q Input Impedance			1		M Ω
LOGIC INPUTS					
Input High Voltage Range, V_{INH}		VP18 - 0.4		1.8	V
Input Low Voltage Range, V_{INL}		0		0.4	V
Input Current, I_{INH}/I_{INL}			100		μ A
Input Capacitance, C_{IN}			3		pF

SPECIFICATIONS

Table 1. Specifications (Continued)

Parameter	Test Conditions/Comments	Min	Typ	Max	Unit
LOGIC OUTPUTS					
Output High Voltage Range, V_{OH}		VP18 – 0.4		1.8	V
Output Low Voltage Range, V_{OL}		0		0.4	V
Output High Current, I_{OH}				500	μ A
POWER INTERFACE					
VPBB, VPLO, and VPBI		3.15	3.3	3.45	V
Supply Current	×1 LO path enabled, IF path disabled				
	VPBI			40	mA
	VPBB			40	mA
	VPLO			360	mA
	Total (VPBI, VPBB, and VPLO)		340	440	mA
	×2 LO path enabled, IF path disabled				
	VPBI			40	mA
	VPBB			40	mA
	VPLO			430	mA
	Total (VPBI, VPBB, and VPLO)		390	510	mA
	×1 LO path enabled, IF path enabled				
	VPBI			40	mA
	VPBB			190	mA
	VPLO			360	mA
	Total (VPBI, VPBB, and VPLO)		490	590	mA
	×2 LO path enabled, IF path enabled				
	VPBI			40	mA
	VPBB			190	mA
	VPLO			430	mA
	Total (VPBI, VPBB, and VPLO)		540	660	mA
VP18		1.7	1.8	1.9	V
VP18 Supply Current			1	2	mA
VPDT and VPRF		4.75	5	5.25	V
Supply Current	×1/×2 LO path enabled, IF path disabled				
	VPDT			6	mA
	VPRF			260	mA
	Total (VPDT and VPRF)		180	266	mA
	×1/×2 LO path enabled, IF path enabled				
	VPDT			6	mA
	VPRF			240	mA
	Total (VPDT and VPRF)		160	246	mA
Total Power Consumption	×2 LO path enabled, IF path enabled		2.58		W
	Power down		35	50	mW

SPECIFICATIONS

RADIATION TEST AND LIMIT SPECIFICATIONS

VPBB = VPBI = VPLO = 3.3 V, VP18 = 1.8 V, VPDT = VPRF = 5 V, $T_A = 25^\circ\text{C}$, LO = 0 dBm differential drive, baseband I/Q amplitude = -15 dBm differential sine waves in quadrature with a 500 mV DC bias, baseband input termination with 100 Ω externally, and IF amplitude = -12 dBm differential sine waves, unless otherwise noted.

Table 2. Radiation Test and Limit Specification

Parameter	Test Conditions/Comments ¹	Min	Typ	Max	Unit
I/Q MODULATOR PERFORMANCE					
Modulator Voltage Gain					
At 6701 MHz ²		10	13		dB
At 10001 MHz ²		10	13		dB
At 20001 MHz ³		7	13		dB
At 235001 MHz ³		7	13		dB
OIP3					
At 6002 MHz ²		14	24		dBm
IF UPCONVERTER PERFORMANCE					
Upconversion Voltage Gain					
At 6000 MHz ⁴		7	11		dB
At 11760 MHz ⁴		7	11		dB
At 20000 MHz ⁵		7	11		dB
Output P1dB					
At 6000 MHz ⁴		8	11.5		dBm
At 11750 MHz ⁴		8	12		dBm
At 20000 MHz ⁵		8	12		dBm
At 23500 MHz ⁵		6	11.5		dBm
POWER INTERFACE					
3.3 V Supply Current	×1 LO path enabled, IF path disabled, detector off				
	VPBI			40	mA
	VPBB			40	mA
	VPLO			360	mA
	Total (VPBI, VPBB, and VPLO)		340	440	mA
	×2 LO path enabled, IF path disabled, detector off				
	VPBI			40	mA
	VPBB			40	mA
	VPLO			430	mA
	Total (VPBI, VPBB, and VPLO)		390	510	mA
	×1 LO path enabled, IF path enabled, detector off				
	VPBI			40	mA
	VPBB			190	mA
	VPLO			360	mA
	Total (VPBI, VPBB, and VPLO)		490	590	mA
	×2 LO path enabled, IF path enabled, detector off				
	VPBI			40	mA
	VPBB			190	mA
	VPLO			430	mA
	Total (VPBI, VPBB, and VPLO)		540	660	mA

SPECIFICATIONS

Table 2. Radiation Test and Limit Specification (Continued)

Parameter	Test Conditions/Comments ¹	Min	Typ	Max	Unit
1.8 V Supply Current			1	2	mA
5 V Supply Current	×1/×2 LO path enabled, IF path disabled, detector off				
	VPDT			6	mA
	VPRF			260	mA
	Total (VPDT and VPRF)		180	266	mA
	×1/×2 LO path enabled, IF path enabled, detector off				
	VPDT			6	mA
	VPRF			240	mA
	Total (VPDT and VPRF)		160	246	mA

¹ The maximum gain at the maximum gain setting.

² Baseband frequency = 1 MHz, ×1 LO, detector off, and LO = 0 dBm single-ended drive.

³ Baseband frequency = 1 MHz, ×2 LO, detector off, and LO = -4 dBm single-ended drive.

⁴ IF frequency = 3500 MHz, ×1 LO, detector on, and LO = 0 dBm single-ended drive.

⁵ IF frequency = 3500 MHz, ×2 LO, detector on, and LO = -4 dBm single-ended drive.

ABSOLUTE MAXIMUM RATINGS

Table 3. Absolute Maximum Ratings

Parameter	Rating
Supply Voltage	
VPDT and VPRF	6.5 V
VPBB, VPLO, and VPBI	4.3 V
VP18	2.0 V
Temperature	
Maximum Junction	125°C
Operating Range	–40°C to +85°C
Storage Range	–55°C to +125°C
Lead Range (Soldering 60 sec)	–65°C to +150°C

Stresses at or above those listed under Absolute Maximum Ratings may cause permanent damage to the product. This is a stress rating only; functional operation of the product at these or any other conditions above those indicated in the operational section of this specification is not implied. Operation beyond the maximum operating conditions for extended periods may affect product reliability.

THERMAL RESISTANCE

Thermal performance is directly linked to PCB design and operating environment. Careful attention to PCB thermal design is required.

θ_{JA} is thermal resistance, junction to ambient (°C/W), and $\theta_{JC, TOP}$ and $\theta_{JC, BOT}$ are the top and bottom thermal resistance, junction to case (°C/W).

Table 4. Thermal Resistance

Package Type ¹	θ_{JA}	$\theta_{JC, TOP}$	$\theta_{JC, BOT}$	Unit
CP-32-20	32.5	23.0	1.7	°C/W

¹ See JEDEC Standard JESD51-2 for additional information on optimizing the thermal impedance (printed circuit board (PCB) with 3 × 3 vias).

OUTGAS TESTING

The criteria used for the acceptance and rejection of materials must be determined by the user and based upon specific component and system requirements. Historically, a total mass loss (TML) of 1.00% and collected volatile condensable material (CVCM) of 0.10% have been used as screening levels for rejection of spacecraft materials.

Table 5. Outgas Testing

Specification (Tested per ASTM E595-15)	Value	Unit
Total Mass Lost	0.03	%
Collected Volatile Condensable Material	0.01	%
Water Vapor Recovered	0.03	%

RADIATION FEATURES

Table 6. Radiation Features

Specifications	Value	Unit
Maximum Total Dose Available (Dose Rate = 50 rad (Si)/sec to 300 rad (Si)/sec) ¹	100	krad (Si)

¹ Guaranteed by device and process characterization. Contact Analog Devices, Inc, [Technical Support](#) for data available up to 100 krad.

ELECTROSTATIC DISCHARGE (ESD) RATINGS

The following ESD information is provided for handling of ESD-sensitive devices in an ESD protected area only.

Human body model (HBM) per ANSI/ESDA/JEDEC JS-001.

Charged device model (CDM) per ANSI/ESDA/JEDEC JS-002.

ESD Ratings for ADRF6780S-CSL

Table 7. ADRF6780S-CSL, 32-Lead LFCSP

ESD Model	Withstand Threshold (V)	Class
HBM	±500	1B
CDM	±1250 ¹	C3
	±500 ²	C2a

¹ For all pins except the RF pins (RFOP, RFON, BBQN, BBQP, BBIP, BBIN, IFIN, IFIP, LOIN, and LOIP).

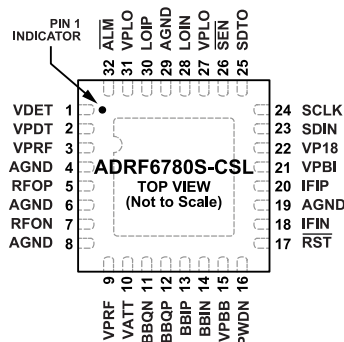
² For all pins.

ESD CAUTION



ESD (electrostatic discharge) sensitive device. Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

PIN CONFIGURATION AND FUNCTION DESCRIPTIONS



- NOTES
1. SOLDER THE EXPOSED PAD TO A LOW IMPEDANCE GROUND PLANE.
 2. THE DEVICE NUMBER ON THE FIGURE DOES NOT INDICATE THE LABEL ON THE PACKAGE. PLEASE REFER TO PIN 1 INDICATOR FOR PIN LOCATIONS.

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Figure 2. Pin Configuration

Table 8. Pin Function Descriptions

Pin No.	Mnemonic	Description
1	VDET	RF Detector Output. The voltage output is proportional to the decibel RF output power. The detector slope is nominally 50 mV/dB.
2	VPDT	Power Supply Connection for the RF Detector. Decouple the VPDT pin with 100 pF and 0.1 μ F capacitors as close as possible to the pin. Note that this pin must always be supplied with 5 V.
3, 9	VPRF	Power Supply Connections for the RF Path. Decouple the VPRF pins with 100 pF and 0.1 μ F capacitors as close as possible to the pins.
4, 6, 8, 19, 29	AGND	Analog Grounds. Connect these pins to a low impedance ground plane.
5, 7	RFOP, RFON	RF Outputs. These outputs are 100 Ω differential outputs for the RF path. Frequency range is 5.9 GHz to 23.6 GHz.
10	VATT	Modulator Output Attenuator Control Input. The RF voltage variable attenuator is controlled by applying a 0 V to 2.6 V control voltage to the VATT pin. Increase the gain when the VATT voltage increases. This pin is linear in dB over the central gain range.
11 to 14	BBQN, BBQP, BBIP, BBIN	I Channel and Q Channel Baseband Inputs. These inputs are high input impedance and are typically differentially terminated to a 100 Ω resistor using an off chip termination. The nominal common-mode bias level on these pins must be 0.5 V.
15	VPBB	Power Supply Connection for Baseband Path. Decouple the VPBB pin with 100 pF and 0.1 μ F capacitors as close as possible to the pin.
16	PWDN	Power Down. The ADRF6780S-CSL powers up when the PWDN pin is at a low logic level (<0.5 V). To power down the ADRF6780S-CSL, apply a logic high level (>1.2 V). When the ADRF6780S-CSL is powered up, the SPI can also be used as a power-down capability. The PWDN pin has an internal 18 k Ω pull-down resistor.
17	$\overline{\text{RST}}$	Reset. This pin provides the ability to reset the SPI to the default register settings. Pull the $\overline{\text{RST}}$ pin to a logic high level in normal operation. Driving the $\overline{\text{RST}}$ pin to a logic low level loads the default SPI register settings. The $\overline{\text{RST}}$ pin has an internal 7.75 k Ω pull-up resistor.
18, 20	IFIN, IFIP	IF Inputs. These inputs are 100 Ω differential inputs for IF upconversion, and these pins must be AC-coupled. When the IF mode is set, remove the 0 Ω R10 to R13 resistors from the I/Q lines.
21	VPBI	Power Supply Connection. Decouple the VPBI pin with 100 pF and 0.1 μ F capacitors as close as possible to the pin.
22	VP18	1.8 V Power Supply. Decouple the VP18 pin with 100 pF and 0.1 μ F capacitors as close as possible to the pin.
23	SDIN	Serial Data Input. Serial data applied to the SDIN pin is loaded into the SPI register upon a successful write command as indicated in the timing diagrams (see the ADRF6780 data sheet for more details). The first MSB is a control bit, and this bit determines whether data is written to the register (logic low) or read from the serial data output pin (logic high). The SDIN pin has an internal 18 k Ω pull-down resistor.
24	SCLK	Serial Clock. This pin is the clock input for the SPI. The SCLK pin has an internal 18 k Ω pull-down resistor.
25	SDTO	Serial Data Output. The SDTO pin provides a SPI readback capability. See the timing diagrams for normal operation (see the ADRF6780 data sheet for more details). The SDTO pin has an internal 18 k Ω pull-down resistor.
26	$\overline{\text{SEN}}$	Serial Enable. When the $\overline{\text{SEN}}$ input pin goes high, the data stored in the shift registers is loaded into the register. The pin has an internal 7.75 k Ω pull-up resistor.
27, 31	VPLO	Power Supply Connections for the LO Path. Decouple the VPLO pin with 100 pF and 0.1 μ F capacitors as close as possible to the pins.

PIN CONFIGURATION AND FUNCTION DESCRIPTIONS**Table 8. Pin Function Descriptions (Continued)**

Pin No.	Mnemonic	Description
28, 30	LOIN, LOIP	LO Inputs. These inputs are 100 Ω differential inputs for the LO path. The LO input frequency range is 5.4 GHz to 14 GHz. The on-chip LO frequency doubler can be enabled via a SPI command.
32	$\overline{\text{ALM}}$	Alarm. The $\overline{\text{ALM}}$ pin indicates the internal alarm conditions. The $\overline{\text{ALM}}$ pin is logic low when an alarm condition is detected.
	EP	Exposed Pad. Solder the exposed pad to a low impedance ground plane.

TYPICAL PERFORMANCE CHARACTERISTICS

See the [ADRF6780](#) data sheet for a full set of typical performance characteristics plots.

OUTLINE DIMENSIONS

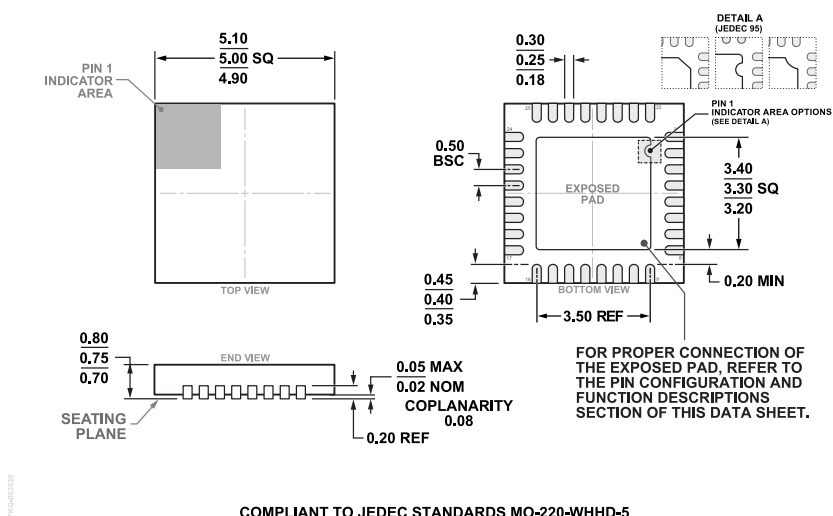


Figure 3. 32-Lead Lead Frame Chip Scale Package [LFCSP]
5 mm × 5 mm Body and 0.75 mm Package Height
(CP-32-20)
Dimensions shown in millimeters

ORDERING GUIDE

Model ¹	Temperature Range	Package Description	Package Quantity	Package Option
ADRF6780ACPZN-CSL	-40°C to +85°C	32-Lead LFCSP (5 mm × 5 mm × 0.75 mm)	Tray, 490	CP-32-20
ADRF6780ACPZN-CSL-R7	-40°C to +85°C	32-Lead LFCSP (5 mm × 5 mm × 0.75 mm)	Reel, 500	CP-32-20

¹ Z = RoHS Compliant Part.