

Synthetic Instruments Working Group on Frequency Translation Devices (FTDs):

Down Converter Parameter Definitions & Specifications

Version: Rev 2.2a

Revision History:

DATE	REVISION #	TYPE	COMMENTS
4/30/25	Draft	Draft update	Santa Rosa meeting comments
6/30/05	Draft	Draft Update	Added SI Block Diagrams, Attenuator Model, Attenuator Switching Speed ,Third Order Intercept Diagrams
7/26/05	Rev 1.0	Baseline Release	Incorporated inputs from 6/30/05 Draft comments
01/19/06	Rev 2.0	Major Update: Implements baseline comments/discussion	Incorporated Inputs from SIWG Nov. 2005 meeting
02/24/06	Rev 2.1	Incremental update	Per written responses received on Rev 2.0; eliminated M/O classes.
03/15/06	Rev 2.2	First release version to be voted on	Per SIWG Meeting of Feb.28-March 2; added Appendix A (External LO Specifications)
10/10/06	Rev 2.2a	Cosmetic cleanup after approval for release to NDIA & NAEC (Navy)	Minor typos/edits

PREFACE

The emerging technology of Synthetic Instrumentation (SI) holds great promise in reducing the ATS logistics footprint and mitigating ATS obsolescence from a test and measurement perspective. A critical synthetic instrument component is the “Down Converter.” The primary function of a down converter is to translate a frequency or group of frequencies from a higher frequency, usually in the GHz range, to a lower or intermediate frequency where the signal may be more readily digitized and processed.

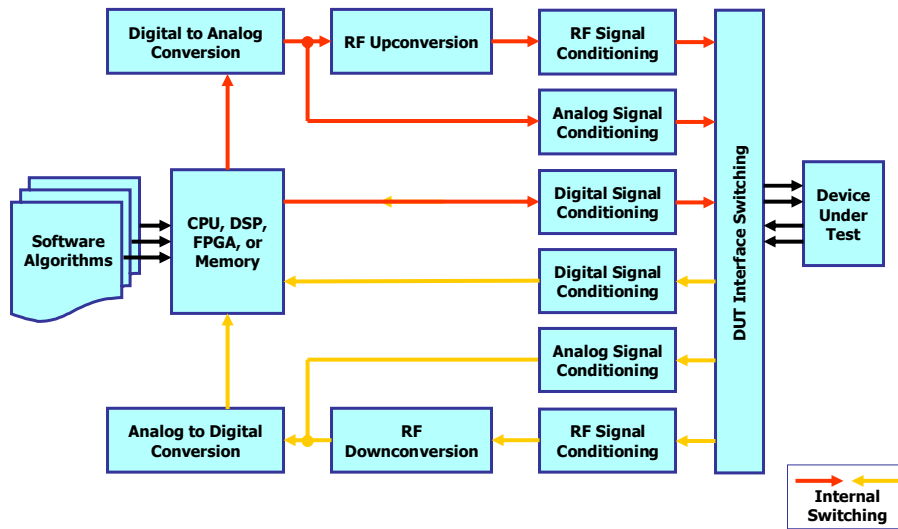
Down converters come in many different types of instantiations which may employ similar or different circuit topologies/interconnection schemes, form factors, and specification behaviors. When contemplating the replacement of a down converter in a SI context, it is important for the SI user to consider the selection/design of a replacement unit based on satisfying the triad of requirements of the existing down converter.

The intent of this document is to provide “best specification practices” and guidance to the DOD and Prime System user in specifying /characterizing Down Converters (DCONV) parameters, for use in a SI context, for new development and/or replacement purposes. It should be noted that an exact match / direct replacement may, in certain instances, not be possible and the user must evaluate the potential risk against his target application(s) when making a selection. Each specification parameter or group of specification parameters specified in this document may or not be applicable in support of a particular application. Also, different Down Converter artifacts available in the marketplace may or not possess all of the features or functionalities specified and described in this document.

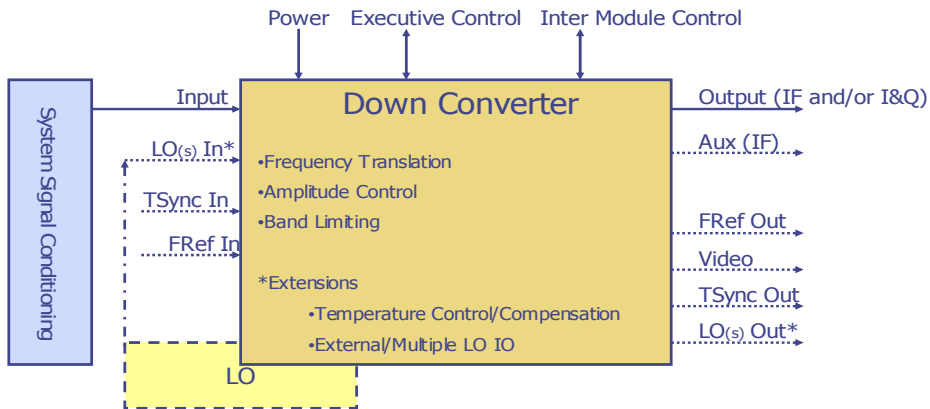
This document is in concert with the High level Synthetic Instrument (SI) system model (Fig. A) and Down Converter High Level I/O model (Fig. B) depicted on the ensuing page, as well as Appendix A (External Local Oscillator Specifications) of this Document. The Down Converter High Level Model depicted in Fig. B depicts a core Down Converter (RF/MW Input and an IF Output) with auxiliary I/O Functionality which may or may not be required based on the use case or application for which a Down Converter is intended. It should be noted that two distinct flavors or variants of a Down Converter are addressed within the context of this document: a Down Converter employing an Embedded Local Oscillator (DCELO) and a Down Converter employing an External LO (DCXLO). Various pros and cons (i.e., flexibility of use, performance, space constraints, etc.) are associated with employing any of these two Down Converter variants. It is the responsibility and purview of the user to determine which variant to employ in a new development or replacement situation based on a particular use case/application.

It is anticipated that portions of this document will be utilized to establish DCONV requirements in support of future SI related DOD procurements. It is also anticipated that each responding manufacturer /supplier would respond to a Request for Quotation per the normalized specification requirements specified herein. Each manufacturer/supplier shall be responsible for the validation of each specified parameter per RFQ specification requirements.

High Level Synthetic Instrument System Model:



Down Converter High Level I/O Model:



Notes: 1. Solid lines depict core or minimum capability – dotted lines reflect extensions to core capability. 2. If a DCXLO capability is required the LO must be included in the core capability.

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1.0 RF/UW INPUT RELATED PARAMETERS

1.1. Frequency Range:

Frequency range is a continuous range of frequencies that extends from one limiting frequency (FL) to another (FH). The frequency range of a Down Converter specifies the frequencies at which it is operable and satisfies its stated specifications.

Frequency range for a Down Converter is typically expressed in GHz (billions of cycles per second).

Recommended Specification:

Parameter	Test /Validation Conditions	Units of Measure
Frequency Low (FL)	TBP BY SUPPLIER	Hertz (e.g., 100 MHz, 1 GHz)
Frequency High (FH)	TBP BY SUPPLIER	Hertz (e.g., 6 GHz, 26.5 GHz)

Note: (1) If a Down Converter accommodates various bands specify FL & FH for each band.

1.2 Return Loss (RL):

Return Loss (RL) is a measure in dB of the ratio of power reflected back into the source. The greater the return loss the better the impedance matching and performance since most of the power is being absorbed into the load/receiver and very little is being reflected back to the source. Return loss may be mathematically expressed as:

$RL = -20 \text{ Log } (V_r/V_i)$; where V_r is the reflected power and V_i represents the transmitted or incident power.

The greater the return loss the better the impedance matching and performance since most of the power is being absorbed into the load/receiver and very little is being reflected back to the source.

Recommended Specifications:

Parameter	Test/Validation Conditions	Units of Measure
Return Loss	TBP BY SUPPLIER	$-20 \text{ Log}(V_r/V_i)$

Note: A Related Parameter is Voltage Standing Ratio (VSWR). VSWR is the ratio between the sum and difference of an incident and its associated reflected voltage wave. VSWR ratios may range from 1 to infinity.

1.3 Input Attenuator

An attenuator is an electrical network that reduces the amplitude of a signal without appreciably distorting its waveform. Electrical attenuators are usually passive devices and the degree of attenuation provided may be fixed, continuously variable/adjustable (mechanical or electronic), or incrementally adjustable in specific step sizes (Digital Step Attenuators). The input and output impedances of an attenuator are usually matched to the impedances of the signal source (i.e., Unit Under Test (UUT) RF/MW output) and receiver/load (i.e. Down Converter). Some of the typical specifications associated with Down Converter Input attenuators are:

- **Type** – Fixed, variable/adjustable, Step (Fig. 1), Mechanical, Electrical.
- **Range** – A continuous range of attenuation values that extends from one limiting attenuation setting (0 dB) to another (70dB). The input attenuator range of a Down Converter specifies the attenuator settings at which it is operable and satisfies its stated specifications.
- **Attenuator Step Size** – This specification attribute defines the value (dB) that the input attenuator may be incremented (i.e., 10 dB) or decremented over its stated range. In Down converters, the manufacture will often suggest step attenuator settings for a range of RF/MW RF input signal levels to ensure linear Down Converter operation. See **Fig. 1**.
- **Attenuator Step Accuracy** – This specification attribute is the deviation of the actual attenuation step from the specified value over the specified frequency range.
- **Switching Speed** – This is the delay time or time difference (typically in msec) from the time (50% pt. of the control pulse amplitude) a binary command is applied to the input control connector pins of a Down Converter to the time it takes the attenuated RF Signal to reach 90% of the final attenuation step value when the attenuator is turned on, or 10% value when it is turned off. See **Fig. 2**.

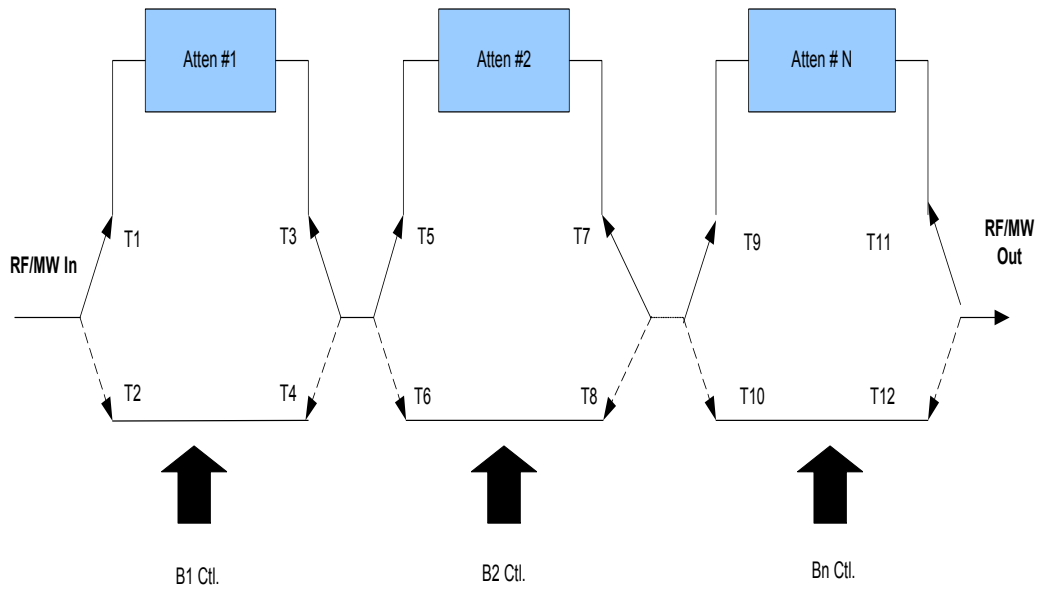


Fig. 1 –Input Step Attenuator Switching Model

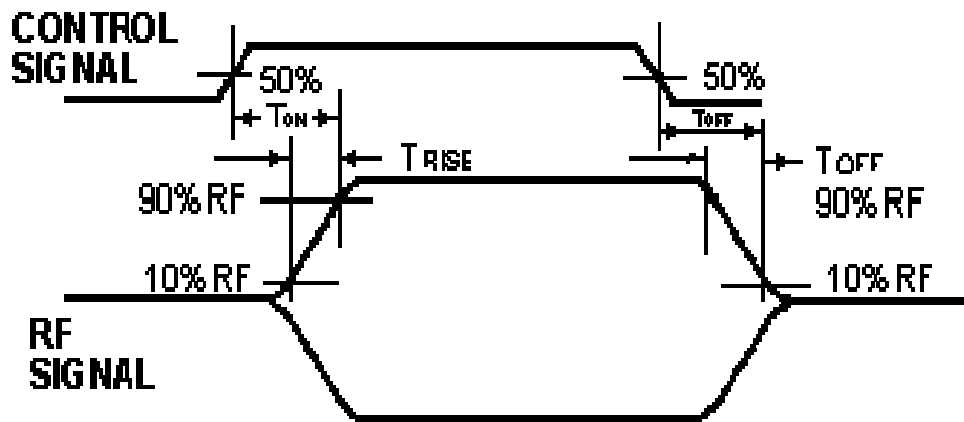


Fig. 2 Input Attenuator Switching Speed

Recommended Specifications:

Parameter	Test/Validation Conditions	Unit of Measure
Type	Inspection	Fixed, Variable/Adjustable, Step, Mechanical, Electrical
Range	TBP BY SUPPLIER	dB
Attenuator Step Size	TBP BY SUPPLIER	dB
Attenuator Step Accuracy(Accuracy as a % of attenuation value)	TBP BY SUPPLIER	dB
Switching Speed	TBP BY SUPPLIER	msec

1.4. RF Input 1 dB Input Compression Point:

Compression is a measure of the linearity of a device such as a Down Converter. The 1 dB compression pt. is usually used as a standard of this measure. From a Down Converter perspective, the 1 dB compression point may be defined as the RF input level at which the Down Converter's gain decreases by 1dB from its small signal gain.

Note: When working with a gain cascade such as employed in Down Converters, it is necessary to consider level of signal being applied to each module because components such as mixers and amplifiers can only output a finite amount of signal power. A useful measure of the amount of power that a device can produce is the "1 dB compression point. "At low signal levels, an ideal Down Converter may be considered to be a linear device but as the input signal increases, the amount of signal at the device's output will begin to tail off. When the gain reduction between the input and output reaches 1 dB, the input power is measured and referred to as the "1 dB Input Compression Point."

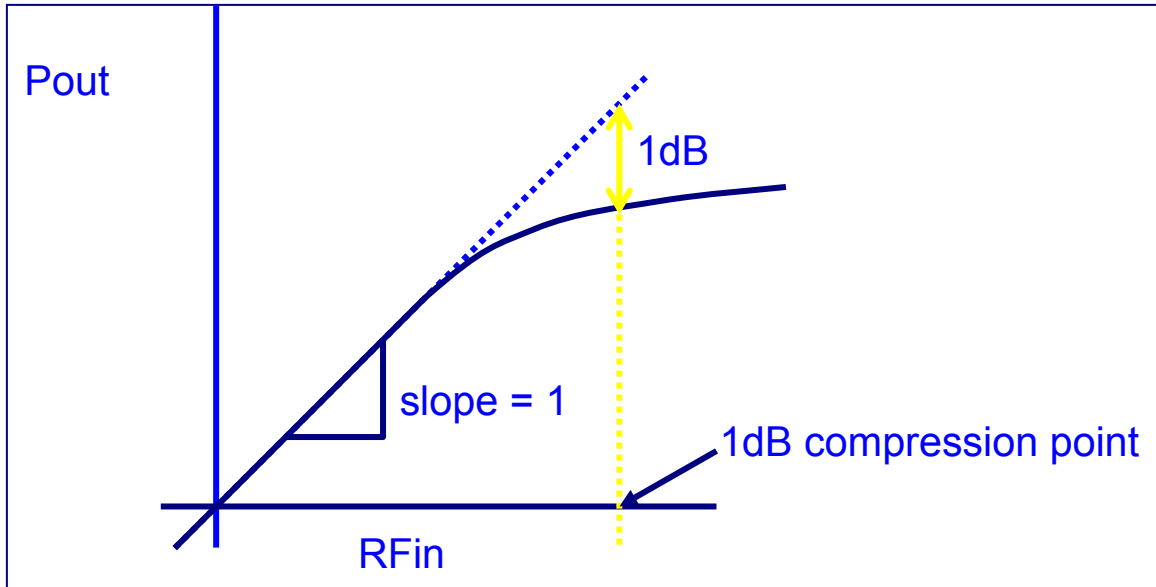


Fig.3 – RF Input 1dB Compression Point

Recommended Specification:

Parameter	Test/Validation Conditions	Units of Measure
RF Input 1 dB compression Point	TBP BY SUPPLIER	xx dBm

Related parameters: 2nd order intercept, 3rd order intercept.

1.5 Maximum Continuous input Signal Level:

This is the maximum signal level (Pin MAX) that may safely be applied to a Down Converter’s input over an extended period of time (i.e., > xx hours) without causing any damage to a Frequency Translation Device such as a Down Converter.

Related specs: Maximum Peak Input Signal Amplitude

Recommended Specifications:

Parameter	Test /Validation Conditions	Units of Measure
Max Continuous Input Signal Level (see note)	TBP BY SUPPLIER	xx dBm
Signal Application Time	TBP BY SUPPLIER	> xx hours

Note: Destructive testing not condoned here, extrapolation or analysis preferred method.

1.6 Maximum Peak Input Signal Amplitude:

This is the maximum peak signal level (Vin MAX) that may safely be applied to a Down Converter's input over a defined duty cycle without causing any damage.

Related specs: Maximum Continuous Input Signal Level

Recommended Specifications:

Parameter	Test/Validation Conditions	Units of Measure
Max Peak Input Signal Amplitude (see note)	TBP BY SUPPLIER	xx Volts Peak
Duty Cycle (see note)	TBP BY SUPPLIER	xx %

Note: Destructive testing not condoned here, extrapolation or analysis preferred method.

1.7 Maximum DC Voltage Input:

This specification attribute is the maximum DC voltage or bias that can be applied along with the RF/MW signal to be down converted.

Recommended Specifications:

Parameter	Test/Validation Conditions	Units of Measure
Max DC Input Voltage	TBP BY SUPPLIER	xx VDC

1.8 Input (Pre-selection) Filtering:

Pre-selection filtering may be defined as filtering of the RF/MW signal input to a Down Converter prior to the mixing process. A pre-selection filter is typically a tunable bandpass filter that eliminates spurious signals and image frequencies from being part of the Down Converter's mixing process.

Note: An "image" frequency is located at the same frequency difference (f) to one side of the local oscillator as the tuned (desired) frequency is to the other side. An undesired signal received at the image frequency by a Down Converter not having pre-selection would therefore mix (beat) with the local oscillator and produce the proper receiver IF, and be processed in the same manner as a signal at the desired frequency (i.e., LO = 9GHz, IF = 1 GHz, RF Input = 8GHz, & undesired image frequency of 10 GHz)

Recommended Specifications:

Parameter	Test /Validation Conditions	Units of Measure
Pre-selection Available	Inspection	Yes/ No
Switchable: on/off	Inspection	Yes/No
Pre-selector Frequency range	TBP BY SUPPLIER	GHz
1 dB Bandwidth	TBP BY SUPPLIER	MHz
Topology/roll off	TBP BY SUPPLIER	# of Poles; dB/octave
Tuning Speed	TBP BY SUPPLIER	msec
Tuning Accuracy	TBP BY SUPPLIER	+/- MHz

1.9 Noise Figure (NF):

Noise Figure is usually expressed in decibels (dB), and is with respect to thermal noise power at the system impedance, at a standard noise temperature (usually 20° C, 293 K) over the bandwidth of interest. It is determined by (a) measuring (determining) the ratio, usually expressed in dB, of the thermal noise power at the output, to that at the input, and (b) subtracting from that result, the gain, in dB, of the system. Typical noise figures range from 0.5 dB for very low noise devices, to 4 to 8 dB. In some systems, *e.g.*, heterodyne systems, total output noise power includes noise from other than thermal sources, such as spurious contributions from image-frequency transformation, but noise from these sources is not considered in determining the noise figure. In this definition, the noise figure is determined only with respect to that noise that appears in the output via the principal frequency transformation of the system, and excludes noise that appears via the image frequency transformation.

Noise Figure (NF) is sometimes referred to as Noise Factor (F). The relationship may be defined as:

NF = 10 Log 10 (F); where

Noise Factor (F) = Total Output Noise Power/Output Noise due to input Source Only

In this definition, "Noise" is defined as random fluctuations due to thermal noise power in an electronic device and does not include Electromagnetic Interference (EMI) or spurious signals. In this context, thermal noise power may be defined as follows: $P_{na} = KT (\Delta F)$. Where:

- K= Boltzmann`s Constant ($1.38 \cdot 10^{-23}$ Joules/Delta K)
- T= Temperature in Kelvin
- Delta F = Noise Bandwidth (Hz)

At room temperature (290 Delta K), the noise power density $P_{nad} = -174$ dBm/Hz. Thus we have the equation:

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NF = Pnout - (-174dBm/Hz +20*Log (BW) +Gain), where:

- NF = Noise Figure of the Unit Under Test (UUT) in dB
- Pnout = measured output noise power
- -174dBm/Hz = noise density of 290 degrees Kelvin
- BW= bandwidth of the frequency range of interest
- Gain = Device (i.e., Down Converter) Gain

To simplify, we can directly measure the output power density (in dBm/Hz) and the equation becomes: **NF = Pnoutdensity+174dBm/Hz-Gain.**

Note: Noise Figure is typically measured directly using a Noise Figure Meter or via employing the Gain Method via the utilization of a Spectrum Analyzer. The Gain Method involves more measurements and calculations than using a NF meter but under certain conditions may be more accurate. This method employs the Noise Factor (NF) definition given earlier in this section. To use the “Gain Method to measure Noise Figure, the gain of the UUT needs to be predetermined. Then the input of the UUT is terminated with the characteristic impedance (50 ohms for most RF applications). The output noise power density is then measured with a spectrum analyzer and the NF calculation is then performed per the equation: $NF = Pnoutdensity + 174dBm/Hz - Gain$. The noise BW to be used in the calculation is the smaller of the Down Converter’s bandwidth or the measurement device’s bandwidth. For example, if a Spectrum Analyzer or Noise Figure Meter is used to affect a measurement, its bandwidth may be less than that of a Microwave Down Converter; in this case the measurement device bandwidth is the limiting factor in the Noise Figure calculation. In the case of a wide band down converter, this is a “spot” noise figure and multiple measurements across the full down converter bandwidth are required to determine the worst case. If a power meter is utilized to measure Noise Power, the Down Converter’s bandwidth may be the limiting bandwidth in the calculation. The noise bandwidth of a device is generally not entirely coincident with its 3 dB bandwidth; the output filter type employed and its shape factor are also contributing factors.

Recommended Specifications:

Parameter	Test /Validation Conditions	Units of Measure
Noise Figure Bandwidth (Hz)	• Input attenuator (if any) set to 0dB	xx dB
	• IF attenuator set to 0-dB or variable gain amplifiers set to maximum gain	xx dB
	• Pre –selection on	xx dB
	• Pre-selection off	xx dB

Note: Test/Validation Conditions TBP by supplier; recommended conditions provided here.

1.10 Third Order Intercept (IP3):

The generation of spurious output frequencies in a down converter's mixer is the result of using non-linear switching elements. Even for a single input frequency the number of such products that is generated as discernible power levels is quite large. These products have even higher power when the input contains multi-tone components. A figure of merit indicative of the ability of a down converter's mixer to suppress such intermodulation products is the two tone third order intercept point (usually measured in dBm); see Fig.4 below. The Third Order interception point is the intercept of the fundamental P_{out} vs. P_{in} extrapolated line and the third order intermodulation products extrapolated line. IP3 is highly dependent on the LO and RF frequency, the LO drive level, and the impedance characteristics of all terminations. The hypothetical intercept point is derived by extrapolating measured data to derive an input RF power level at which IF power and intermodulation products would be equal. To be more correct, the intercept point should be named the two tone intercept point because two tones are used as the signal source. The two tones (F_1 & F_2) in turn generate third order distortion products ($2F_1-F_2$ & $2F_2-F_1$) which are measured and compared against one of the signals (Fig.5). Mixers with high intercept points generate low intermodulation distortion products.

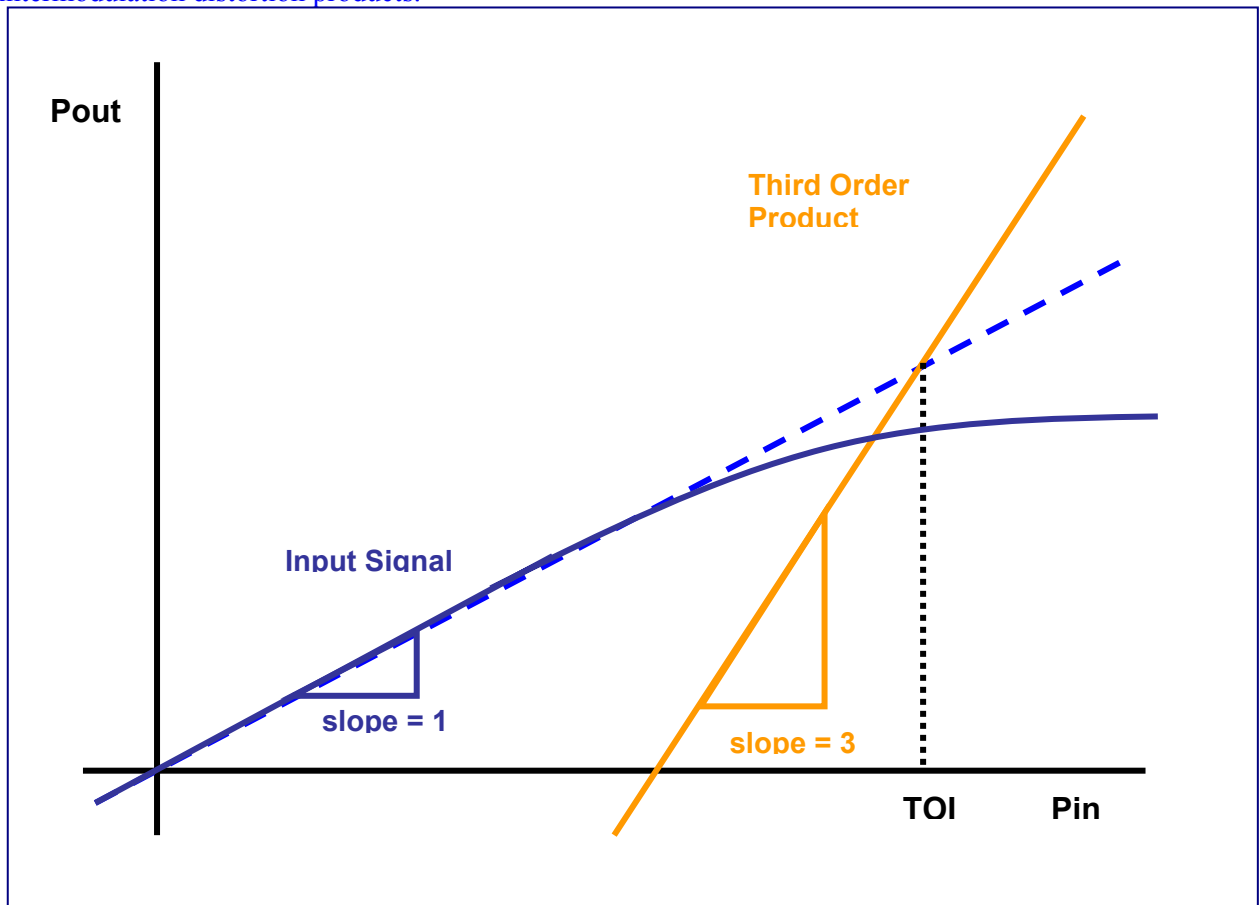


Fig.4 Third Order Intercept Point (IP3)

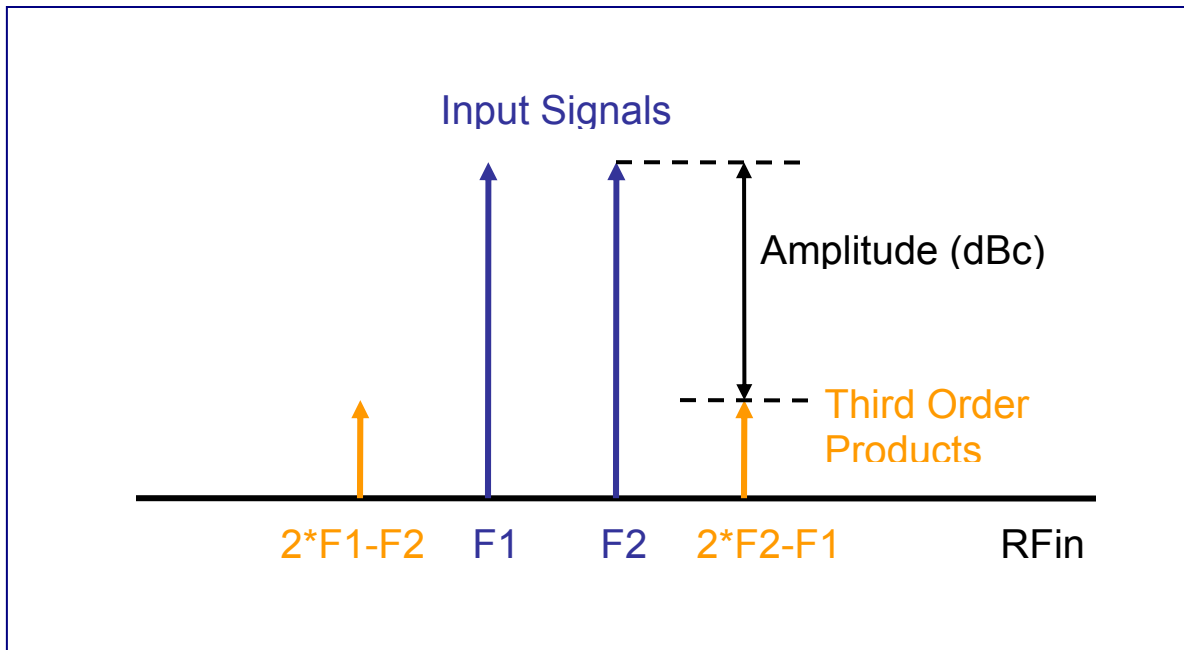


Fig. 5 Two Tone Testing

Note: All of these specifications except residual responses require definition of an input signal level at which the performance is measured. For spectrum analyzers, some manufacturers typically define these in terms of a signal level present at the first mixer when a specific value of input attenuation is chosen. This can be a bit misleading as it depends on the insertion loss or gain ahead of the first mixer but it seems to be a common practice among other manufacturers..

Some manufacturers rate harmonic distortion in terms of second harmonic intercept rather than as a specific level. 1 dB gain compression level is also frequently specified but is not included here. Also, tone spacing shall be specified in small, medium, and/or large offsets (i.e., 100 KHz, 1 MHz, and/or 10MHz) to enable a normalized comparison among various DCONV artifacts.

Recommended Specification Elements:

Parameter	Test /Validation Conditions	Units of Measure
Third Order Intercept	Input attenuation – 0 dB Input signal level (each tone) Tone Spacing (KHz or MHz)	dBm

Note: Test/Validation conditions TBP by supplier; recommended conditions provided here.

1.11 Max Input Phase Noise Contribution to LO Input:

Maximum Input Phase Noise Contribution pertains to the maximum Phase Noise that can be imparted to the LO input of a Down Converter and have it still achieve its stated performance specifications. This specification parameter applies only to Down Converters containing one or more Local Oscillator (LO) inputs. Phase Noise limits the instantaneous dynamic range of a measurement device. The noise spectrum surrounding a strong signal can mask a low level signal on a nearby signal (See also section 3.2). Ideally, Phase Noise performance should be specified at one or more frequency offsets from a carrier signal (i.e., 30Hz, 100Hz, 1 KHz, 10KHz, 100KHz).

Recommended Specifications:

Parameter	Test /Validation Conditions	Units of Measure
Maximum Input Phase Noise Contribution (see Notes below)	TBP BY SUPPLIER	dBc/Hz

Notes:

Phase Noise is a measure of the short term / random fluctuations in the phase of a wave caused by time –domain instabilities in an internal signal source/local oscillator. It is measured as the single sideband noise (**P_{ss}**), resulting from changes in frequency, in decibels below the amplitude at the operating frequency of a signal source/oscillator (**P_s**) using a 1Hz bandwidth (dBc/Hz) at two or more frequency displacements from the operating frequency of the signal source/oscillator. This measurement has particular application to the analog communications industry. Three primary sources of this instability are: a. Steady State (MIL –PRF-55310D, par 4.8.17.1) b. Random Vibration (MIL –PRF 55310D, par 4.8.17.2), and acoustic (MIL-PRF 55310D, par 4.18.17.3). Mathematically, Phase Noise may be expressed as follows:

Sc (f) = 10 Log (P_s/P_{ss}), where:

- Sc (f) is the phase noise power in dB relative to the carrier (dBc/Hz) at a given frequency offset (f) from the carrier.
- P_s is the carrier or test signal.
- P_{ss} is the single sideband phase noise per unit bandwidth at a frequency offset (f).

It is customary to separate electrically generated from mechanically generated phase noise, the latter falls under the description of microphonics and is generally measured in degrees of phase offset induced by a specific mechanical stimulus.

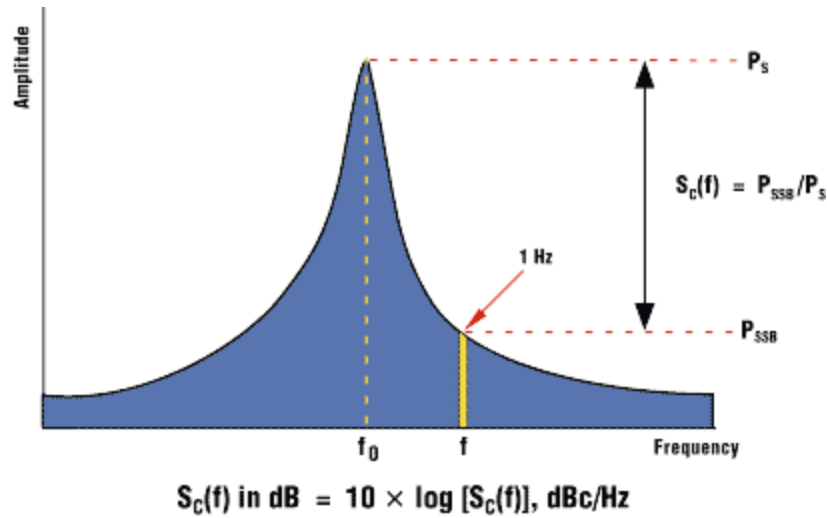


Fig. 6 Phase Noise Definition

2.0 IF OUTPUT PARAMETERS:

2.1 IF Frequency - 1dB or 3 dB Bandwidth:

This specification parameter is applicable to both Tuned Down Converters and Block Down Converters. This specification parameter pertains to the frequency or band of frequencies resulting from mixing the RF input signal to a down converter with an external or internal local oscillator. Usually the IF is lower than the RF in frequency, which facilitates further amplification and processing/filtering by the down converter. The IF Center Frequency is typically measured in MHz (millions of cycles per second).

Recommended Specifications:

Parameter	Test /Validation Conditions	Units of Measure
IF Center Frequency (Fixed)	TBP BY SUPPLIER	xxx MHz
IF Center Frequency/Frequencies (Tunable)> Note (5)	TBP BY SUPPLIER	xxx MHz,...., yyy MHz
LO "1"...LO "N" (If IF CF is tunable) > Note (5)	TBP BY SUPPLIER	LO (N) = xxx GHz – yyy GHz; zzz GHz setting.
3 dB Bandwidth (Note 1)	TBP BY SUPPLIER	xxx MHz
1 dB Bandwidth (Note 2)	TBP BY SUPPLIER	xxx MHz

Notes:

(1) **3-dB Bandwidth:** This is the maximum effective IF signal bandwidth that the down converter can present to the digitizer. It represents the informational bandwidth of the converter. The signal bandwidth may vary considerably at various stages in the down converter. The specified 3-dB bandwidth represents the minimum value. It is a measure of the spectral width between 2 points for which the amplitude profile is 3 dB below a peak close to mid band.

Related Parameters: 1-dB bandwidth, Noise bandwidth, delay between output and input, variation in delay over the full frequency range, IF amplitude and phase response.

(2) **1- dB Bandwidth:** Similar to Note (1) above. This parameter should be specified if the target application warrants it. The 3-dB bandwidth is an indication of the maximum informational bandwidth supported by the device. The 1-dB bandwidth is more realistic in conveying the capability of the receiver in handling the information rate required for applications such as digital communications.

(3) A thorough characterization of the IF pass band encompasses its amplitude and phase profile over its specified frequency bandwidth as well as its absolute group delay and distortion, which may be captured/characterized by its 2-tone intermodulation distortion characteristics (see Section 1.10, Fig.5) and/or IF filter Phase Linearity plot (see Section 2.6).

(4) **Filter Type and Flatness:**

The primary bandwidth limiting element in a frequency converter is the IF Output filter. It may be either a low pass, band pass, or a series combination of low and high pass units depending on the desired output center frequency and bandwidth required.

Filters are typically designed to meet generic classes such as Bessel, Gaussian, Butterworth, Chebychev, or elliptical. The class determines the amplitude and phase characteristics across the filter pass band, the attenuation characteristics in the transition from pass to stop band, and the performance in the stop band. Depending on the class, certain of the parameters in the table below are not applicable. For measurement applications, Bessel or Gaussian characteristic filters are usually preferred to minimize signal distortion. The class type is noted as optional as there are more classes than mentioned, and some designs that are considered as “almost” a class type. While it is possible to deduce the class in some cases from the stated parameters, it’s sometimes useful for the user to know and not have to guess.

Flatness refers to variations in amplitude response across the pass band of the filter relative to amplitude at the filter center frequency.

At this time we will not require the Down Converter’s IF filter to be characterized, unless the Test/Validation process deems that this is important specification parameter needed to ensure the specification of interchangeable Down Converters. The table below is provided for informational purposes at this time.

Various Filter Characterizations:

Type	Class (Optional)	Parameters	Spec
Low Pass	Bessel Gaussian	3 dB bandwidth	F_{lo} and F_{hi} or $F_c \pm BW/2$
Bandpass	Butterworth Chebychev	Shape factor (3/60 dB BW ratio) (Sometimes 6/60 dB ratio)	N:1
Low / High pass	Elliptic	Pass band ripple (flatness) Minimum stop band attenuation	X(dB) S(dB)

(5) When a tunable rather than fixed IF is employed, it is recommended that specification of external local oscillator ranges and fixed values/settings employed be provided which result in the variable IF frequency/frequencies specified (see Appendix A).

2.2 Maximum Output Linear Power:

This specification parameter pertains to the maximum output signal power that the Down Converter can generate while still meeting its harmonic and intermodulation distortion specifications.

Recommended Specifications:

Parameter	Test/Validation Conditions	Units of Measure
Maximum Output Linear Power	TBP BY SUPPLIER	x dBm

2.3 IF Output Gain Control: This specification parameter pertains to the range of Down Converter gain (dB) available in the IF Output stage which may be adjusted/programmed by the user to match the input signal requirements of a companion digitizer, such as in a synthetic instrument environment.

Recommended Specifications:

Parameter	Test/Validation Conditions	Units of Measure
Range	TBP BY SUPPLIER	x dB
Step Size	TBP BY SUPPLIER	y dB
Step Accuracy	TBP BY SUPPLIER	+/- dB
Settling Time (Note 1)	TBP BY SUPPLIER	nsec, usec, or msec

Note:

(1) **Settling Time** for a Down Converter's gain control circuitry is defined as the time it takes for its main or auxiliary IF output to settle to a new signal amplitude value when a change in the IF gain control is programmed at a fixed IF signal frequency.

2.4. Maximum IF Signal Output:

This specification parameter pertains to the maximum IF signal output in V_{pp} that can be applied to the input of a digitizer with 0 dB of input attenuation and the IF gain control set to its maximum level.

Note: This is primarily a safety specification.

Recommended Specifications:

Parameter	Test/Validation Conditions	Units of Measure
Maximum IF Signal Output	TBP BY SUPPLIER	V_{pp}

2.5 Conversion Gain/Loss:

The Conversion gain, CG, is one of the standard parameters which tend to be specified in down converters specifications to indicate some measure of performance of the heterodyne process. G is the ratio of an output power to an input power. In some cases, the actual output power is smaller than the input and in those cases G is a negative value, or a loss. G is called a "conversion" gain because it indicates the relative level of an output which has been converted to a frequency which differs from that of the input.

Conversion Gain may be defined as follows:

$CG = P_{if} / P_s$, where P_s represents the power of the RF/UW signal applied to a down converter's input and P_{if} represents the mean IF power the Down Converter's mixer output port supplies to a matched load R. This expression is similar to the gain of a power amplifier except in a Down Converter measurement context the input and output frequencies are different. This measurement should be performed at the IF center frequency with any input attenuator set to 0 dB.

Mathematically CG may also be expressed from a RF to IF voltages gain perspective as follows:

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$$CG = 20 \log \{A_{ifout}(F_{out})/A_{ifin}(F_{in})\} \text{ dB}$$

Recommended Specification:

Parameter	Test /Validation Conditions	Units of Measure
Nominal Conversion Gain Input frequency F ₁	Input attenuator set to 0, IF gain set to maximum	xx dB
Conversion Gain fluctuation over the full frequency range (see note)	See above	± yy dB
Conversion Gain range	See above	xx to yy dB
Conversion Gain accuracy	See above	± zz dB

Notes: 1. Test/Validation conditions TBP by supplier, recommended conditions provided here. 2. Some Down Converter manufacturers have internal calibration tables that may preclude specifying all or some of the above parameters. In these cases, best practices often dictate that manufacturers should specify gain variations/fluctuations with and without correction, if applicable to the target application.

2.6 Absolute Group Delay:

This is a measure of the time it takes information to travel from the input to output of the down converter. It usually varies as a function of the frequency range (i.e., Frequency A... Frequency Z). It is important in applications using pulsed signals such as radar warning receivers or TDMA formats. This parameter is focused on characterizing the latency of a down converter.

Recommended Specification:

Parameter	Test/Validation Conditions	Units of Measure
Absolute Group delay	TBP BY SUPPLIER	nsec
Frequency A	Input attenuator & IF attenuator set to 0 dB	X(A)+/-Y(A)ns
Frequency Z	Input attenuator & IF attenuator set to 0 dB	X(Z)+/-Y(Z)ns

NOTES: 1. Specify contribution to delay of Input and output IF attenuators if significant.

2.7 Phase Deviation from Linear (Phase Linearity):

A Down Converter must pass modulated signals while introducing minimal or no distortion; all of the frequency components of signals passing through the Down Converter must experience the same amount of time delay. In order to achieve this ideal goal, the Down Converter needs a flat amplitude response and linear (constant slope) phase response over the bandwidth of the complex signal being down converted; therefore, a flat Group Delay response is needed.

In order to affect flat Group Delay, the Down Converter's IF Output filter must exhibit Phase Linearity over the complete or a specified portion of the IF pass-band. Phase Linearity is defined as the linearity of a plot of phase shift vs. frequency for a Down Converter's IF output (see fig below).

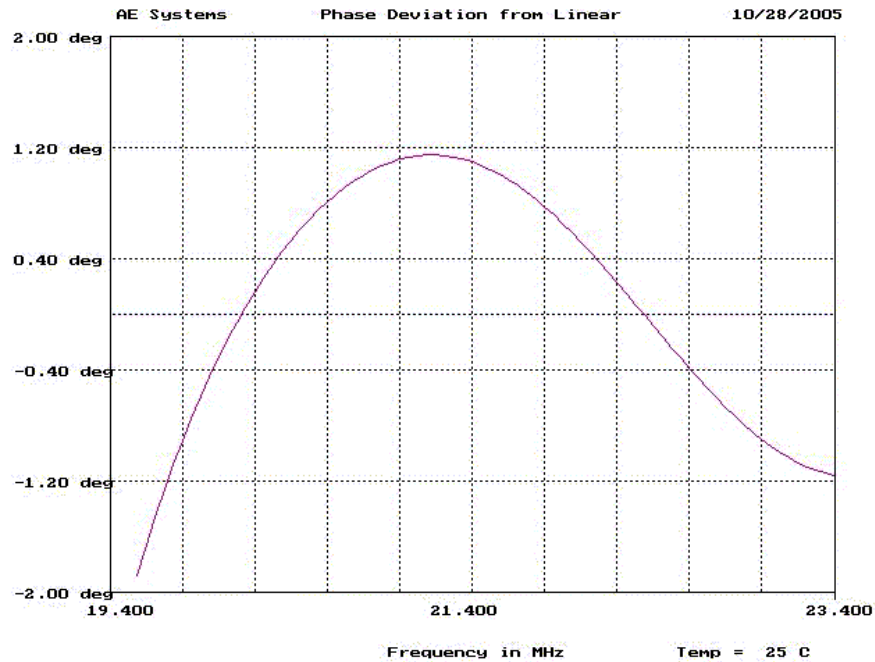


Fig.7 – Phase Linearity Plot: Phase Shift vs. Frequency

The slope at any linear segment of the curve represents the rate of change of the total signal phase shift with respect to angular frequency, or Group Delay. Even a filter that has moderately sharp phase changes at its edges still can have good phase linearity over a portion of its passband. The user of a system or instrumentation developer often need to know this information in order to develop test programs or develop a replacement instrument for an obsolete Down Converter.

Recommended Specifications:

Parameter	Test /Validation Conditions	Units of Measure
Filter Type	Inspection	Bessel, Gaussian, Butterworth, Chebychev, Elliptic
Linear Segment #	Inspection of Phase vs. Frequency Plot	1 to N
Linear Segment # Phase Deviation	Phase vs. Frequency Plot extracted from Group Delay measurements or simulations	+/- x degrees over IF BW or segment #

Note: Consider the time delay through a filter for a pulse train consisting of sine waves (Fourier Analysis/Theory). If the Group Delay is non uniform and varies with sine wave frequency, the time domain response to a sharp input signal change may show overshoot or ringing. At any sine wave frequency, the filter group delay is the derivative of the filter phase shift with respect to frequency: Delay = d (phase shift)/d (frequency). Thus a perfectly uniform group delay is equivalent to a perfectly linear phase response. That is, a linear phase response (relative to frequency) results in an output waveform that's merely a time shifted version of its input signal. The amount of the time shift is the Group Delay in seconds.

Example: To be provided (TBP) on a future specification update.

2.8 Output Return Loss:

The Return Loss (RL) looking into the IF output terminals of a Down Converter. The Return Loss is a measure of the deviation from 50 ohms or 75 ohms of the input or output impedance of a down converter's I/O (See Return Loss definition in Down Converter input Section 1.2).

Recommended Specifications:

Parameter	Test/Validation Conditions	Units of Measure
Return Loss	TBP BY SUPPLIER	-20 Log(Vr/Vi)

2.9 Spurious Responses:

This term pertains to undesired signals produced by an active microwave component, such as a down converter, usually at a frequency unrelated to the desired signal or its harmonics. Their content is specified in dBc.

Summarized below are several types of spurious responses that should be specified to properly characterize a Down Converter:

2.9.1 Residual Responses/Leakage or Isolation (Unrelated to RF input signal)

These are output signals that result from internally generated signals such as harmonics of reference clocks or local oscillator signals that leak into the signal path and appear as output signals when the down converter is tuned to specific frequencies. These signals are present at the converter output even if the input is terminated. These are typically specified as equivalent to some input signal level at a specified (usually zero dB) input attenuation setting. Examples of leakage signals are:

- Local Oscillator to RF/MW Input
- Local Oscillator to IF Output
- RF/MW Input to IF Output

Recommended Specifications:

Parameter	Test/Validation Conditions	Units of Measure
Local Oscillator Leakage @ RF Input	TBP BY SUPPLIER	dBm max
Local Oscillator Leakage @ IF Output(s)	TBP BY SUPPLIER	dBm max
RF/MW Input Leakage @ IF Output(s)	TBP BY SUPPLIER	dBm max

2.9.2 Non Harmonic Spurious

These are undesired mixing products resulting from the heterodyne process. If the input frequency is F_i and the LO frequency is F_{lo} , then undesired mixing products can occur at $(nF_i \pm mF_{lo})$ where n and m are non zero integers. If more than one heterodyne step is employed, there can be additional products resulting from any combination of input, IF, and oscillator signals present in the unit. These are usually specified at a particular combination of input signal level and attenuation setting.

Recommended Specifications:

Parameter	Test/Validation Conditions	Units of Measure
Non Harmonic Spurious @ IF Output(s)	TBP BY SUPPLIER	dBm max

2.9.3 Harmonic Spurious

High signal input levels at the front end of the down converter can result in harmonics of the input being generated in the input mixer. These are usually specified at some input attenuation setting and input signal level.

Recommended Specifications:

Parameter	Test/Validation Conditions	Units of Measure
Harmonic Spurious @ RF Input	TBP BY SUPPLIER	dBm max

Note: All of these specifications except residual responses require definition of an input signal level at which the performance is measured. For spectrum analyzers, some manufacturers typically define these in terms of a signal level present at the first mixer when a specific value of input attenuation is chosen. This can be a bit misleading as it depends on the insertion loss or gain ahead of the first mixer but it seems to be a common practice among other manufacturers. Some manufacturers rate harmonic distortion in terms of second harmonic intercept rather than as a specific level. 1 dB gain compression level is also frequently specified but is not included here.

2.10 IF Phase Noise Output:

This specification parameter pertains to the noise that can be imparted by the IF output of a Down Converter into a sensor device such as a digitizer. Phase Noise (see **Notes** in Section 1.11) limits the instantaneous dynamic range of a measurement device. The noise spectrum surrounding a strong IF Output signal frequency can mask an adjacent low level IF signal frequency. Ideally, IF Output Phase Noise performance should be specified at one or more frequency offsets from a specified IF carrier signal frequency (i.e., 30 Hz, 100 Hz, 1 KHz, 10 KHz, 100 KHz).

Recommended Specifications:

Parameter	Test /Validation Conditions	Units of Measure
Phase Noise	TBP BY SUPPLIER	dBc/Hz

3.0 LOCAL OSCILLATOR RELATED PARAMETERS:

3.1 Reference Signal Inputs/Outputs

3.1.1 Reference Frequency Input (RFI)

These specification parameters pertain to the external time base input signal port of a Down Converter (i.e. Reference In) that is used to control the frequency of a down converter's local oscillator(s). The most commonly used Reference Inputs accommodate signal frequencies of 1, 2, 5, or 10 MHz. Recommended specifications associated with this input signal port of a Down

Converter, whether it employs an external or internal Local Oscillator, are summarized in the table below:

Recommended Specifications:

Parameter	Test/Validation Conditions	Units of Measure
Ref Frequency Input (RFI)Frequency	TBP BY SUPPLIER	MHz
RFI Lock Frequency Range	TBP BY SUPPLIER	X to Y MHz
RFI Signal Input Level Range	TBP BY SUPPLIER	X to Y dBm
RFI Input Impedance	TBP BY SUPPLIER	Nominal Ohms (i.e.,50 or 75 ohms)

3.1.2 Reference Frequency Output (RFO)

Recommended specifications associated with this Down Converter output signal are summarized in the table below for Down Converters employing either internal or external LOs:

Parameter	Test/Validation Conditions	Units of Measure
Ref Frequency Output (RFO) Frequency	TBP BY SUPPLIER	MHz
RFO Signal Amplitude	TBP BY SUPPLIER	dBm
RFO Output Impedance	TBP BY SUPPLIER	Nominal Ohms (i.e.,50 or 75 ohms)
RFO Frequency stability	TBP BY SUPPLIER	Aging rate/day, absolute accuracy over a 1 year period, & environmental effects on frequency.

3.2 External/Internal Local Oscillator Parameters:

These specification parameters pertain to the attributes of a device that generates a stable RF frequency that is mixed with the received RF signal to obtain an IF output signal. A Local Oscillator may operate at a frequency above (or below) the desired RF frequency by an amount equal to the IF frequency of the receiver/down converter. Local Oscillator functionality may be provided either internal to a Down Converter (DCONV) or via an external LO. In those instances where a Down Converter requires an External LO capability, the specification parameters for the LO must be specified from a Down Converter Input perspective. Appendix A of this document provides a summary of the minimum but essential specification parameters needed to characterize an external Local Oscillator in the context of a Down Converter application.

Recommended Specifications:

Parameter	Test /Validation Conditions	Units of Measure
DCONV External LO Inputs:		
Number of LO Inputs	Visual	1 to N
Frequency Input Range	TBP BY SUPPLIER	X to Y GHz; for 1 to N
Frequency Step Size	TBP BY SUPPLIER	Hz; for 1 to N
Frequency Switching Speed	TBP BY SUPPLIER	msec; for 1 to N
LO Input Power range	TBP BY SUPPLIER	X to Y dBm; for 1 to N
LO Input Impedance	TBP BY SUPPLIER	Ohms (nominal); for 1 to N
Maximum Input Phase Noise Contribution (see Notes p.17)	TBP BY SUPPLIER	dBc/Hz; for 1 to N
Internal LO:		
Tuning Resolution/Step Size	TBP BY SUPPLIER	Hz
Tuning Speed	TBP BY SUPPLIER	nsec or msec
Frequency Stability	TBP BY SUPPLIER	Aging rate/day, absolute accuracy over a 1 year period, & environmental effects on frequency.

4.0 Power Related Parameters:

Recommended Specifications:

Parameter	Test/Validation Conditions	Units of Measure
AC Voltage	TBP BY SUPPLIER	VAC
AC Current	TBP BY SUPPLIER	Amps
Phase	TBP BY SUPPLIER	Phase
DC Voltage (s)	TBP BY SUPPLIER	VDC
DC Current	TBP BY SUPPLIER	Amps
Power	TBP BY SUPPLIER	Watts

5.0 Related Physical Parameters:

Recommended Specifications:

Parameter	Test/Validation Conditions	Units of Measure/Description
Connector Type	Inspection	TBP BY SUPPLIER
Dimensions/Form Factor	Inspection	Rack/VXI/PXI/LXI
Weight	TBP BY SUPPLIER	lbs
Environmental Class Standard	TBP BY SUPPLIER	TBP BY SUPPLIER
EMI/EMC Class Standard	TBP BY SUPPLIER	TBP BY SUPPLIER

6.0 COMMUNICATIONS & CONTROL:

6.1 Controllability/Software Driver

Each Down Converter artifact shall be controlled by an IVI compliant driver. At the present time it is envisioned that different DCONV artifacts may have similar but different hardware controllable attributes/functions thus precluding the possible use of a common IVI Application Programming Interface (API). In this instance, a base class driver for Down Converters encompassing a minimum but essential set of DCONV hardware attributes/functions (i.e.; RF Input and IF Output) shall be required. Suppliers are encouraged to provide extensions to the base class (TBP) DCONV driver which makes full utility of their Down Converter's functionality.

Parameter	Test /Validation Conditions	Units of Measure
IVI SW Driver	TBP BY SUPPLIER	N/A

6.2 Internal/External Control:

Define whether the subject Down Converter can be controlled via an external or internal controller, or both.

Parameter	Test /Validation Conditions	Units of Measure
Internal/External Control	TBP BY SUPPLIER	N/A

6.3 Synch/Trigger Inputs and Outputs:

Specify whether the subject down converter can be synched / triggered via an external signal in order to launch its frequency translation process and, if so, define its associated signal characteristics. Similarly, if the subject Down Converter employs a Synch Out capability specify

its synch/trigger output signal characteristics; a Synch Out capability signifies that the Down Converter's frequency translation process has stabilized and the signal is ready to be digitized.

Recommended Specifications:

Parameter	Test/Validation Conditions	Units of Measure/Description
Synch Input	TBP BY SUPPLIER	Input synch signal characteristics (voltage vs. time)
Synch Input Impedance	TBP BY SUPPLIER	Nominal (i.e., 50 or 75 ohms)
Synch Output	TBP BY SUPPLIER	Output synch signal characteristics (voltage vs. time)
Synch Output Impedance	TBP BY SUPPLIER	Nominal (i.e., 50 or 75 ohms)

6.4 Video Detector Output:

Ascertain whether the subject Down Converter employs a video detection capability of its IF Output signal and, if so, specify its associated signal characteristics as defined in the table below.

Recommended Specifications:

Parameter	Test/Validation Conditions	Units of Measure/Description
Input Frequency Bandwidth	TBP BY SUPPLIER	MHz
Output Bandwidth	TBP BY SUPPLIER –No pre-selection	nsec rise time @ X MHz input to detector
Output IF Level	TBP BY SUPPLIER – (i.e., Detector Sensitivity to x dBm)	dBm
D/C Output Level	TBP BY SUPPLIER -(i.e., Spec at x dBm @IF Out.)	Volts & +/-Polarity

Note: A Video Detector Output capability may be used in lieu of or in conjunction with a synch/trigger capability (see Section 6.3 above).

6.5 Supported Busses:

Define which, if any, of the following busses can be used to provide external control:

Recommended Specifications:

Parameter	Test/Validation Conditions	Units of Measure/Description
External Control	Inspection	GPIB,VXI,PXI, LXI, other

7.0 Validation:

Each manufacturer/supplier of a Down Converter artifact will be responsible for independently validating per best commercial practices each of the specification parameters, as applicable to a manufacturer`s/supplier`s particular product, described in this document. From time to time it is anticipated that Best Commercial Practice validation methodologies will be provided as an addendum to this document addressing some of the more problematic and misunderstood Down Converter specification parameters.

APPENDIX A

External Local Oscillator (LO) Specifications

The primary function of a Local Oscillator is to generate a stable and spectrally pure RF frequency that is subsequently mixed with a Down Converter's RF/MW signal input in order to obtain an IF output signal frequency or frequencies that are more easily processed by a companion digitizing device. Local Oscillator functionality may be provided either internal to a Down Converter (DCONV) or via an external LO. Determination of which type of LO to employ in the context of a Down Converter application is driven by a number of factors such as: size, performance, development risk, & design/upgrade flexibility.

1.0 Primary Performance Specifications - The table depicted below provides a summary of the minimum but essential primary performance specification parameters needed to characterize an external Local Oscillator in the context of a SI Down Converter application.

Recommended Specifications:

Parameter	Test /Validation Conditions	Units of Measure
External LO Outputs:		
Number of LO Outputs	Visual	1 to N
Frequency Output Range	TBP BY SUPPLIER	X to Y GHz; for 1 to N
Frequency Output Step Size	TBP BY SUPPLIER	Hz; for 1 to N
Frequency Switching Speed	TBP BY SUPPLIER	msec; for 1 to N
LO Output Power range	TBP BY SUPPLIER	X to Y dBm; for 1 to N
LO Output Impedance	TBP BY SUPPLIER	Ohms (nominal); for 1 to N
Spectral Purity:		
Phase Noise	TBP BY SUPPLIER	dBc/Hz; for 1 to N @ specified offsets(i.e.,100Hz,1 KHz,10 KHz, 100KHz, 1 MHz)
Harmonic Spurious	TBP BY SUPPLIER	dBc/Hz for 1 to N
Non –Harmonic Spurious	TBP BY SUPPLIER	dBc/Hz for 1 to N

Reference Frequency Inputs/Outputs:	Test/Validation Conditions	Units of Measure
Ref. Frequency Output (RFO)Frequency	TBP BY SUPPLIER	MHz
RFO Signal Amplitude	TBP BY SUPPLIER	dBm
RFO Output Impedance	TBP BY SUPPLIER	Nominal Ohms (i.e., 50 or 75 ohms)
RFO Frequency Stability	TBP BY SUPPLIER	Aging rate/day, absolute accuracy over a 1 year period, & environmental effects on frequency.
Ref Frequency Input(RFI) Frequency	TBP BY SUPPLIER	MHz
RFI Lock Frequency Range	TBP BY SUPPLIER	X to Y MHz
RFI Signal Input Level Range	TBP BY SUPPLIER	X to Y dBm
RFI Input Impedance	TBP BY SUPPLIER	Nominal Ohms(i.e., 50 or 75 Ohms)

2.0 Power Related Parameters:

Recommended Specifications:

Parameter	Test/Validation Conditions	Units of Measure
AC Voltage	TBP BY SUPPLIER	VAC
AC Current	TBP BY SUPPLIER	Amps
Phase	TBP BY SUPPLIER	Phase
DC Voltage (s)	TBP BY SUPPLIER	VDC
DC Current	TBP BY SUPPLIER	Amps
Power	TBP BY SUPPLIER	Watts

3.0 Related Physical Parameters:

Recommended Specifications:

Parameter	Test/Validation Conditions	Units of Measure/Description
Connector Type	Inspection	TBP BY SUPPLIER
Dimensions/Form Factor	Inspection	Rack/VXI/PXI/LXI
Weight	TBP BY SUPPLIER	Lbs.
Environmental Class Standard	TBP BY SUPPLIER	TBP BY SUPPLIER
EMI/EMC Class Standard	TBP BY SUPPLIER	TBP BY SUPPLIER

4.0 COMMUNICATIONS & CONTROL:

4.1 Controllability/Software Driver

Each LO artifact shall be controlled by an IVI compliant driver. At the present time it is envisioned that different LO artifacts may have similar but different hardware controllable attributes/functions thus precluding the possible use of a common IVI Application Programming Interface (API). In this instance, a base class driver for external LOs encompassing a minimum but essential set of LO hardware attributes/functions (i.e.; LO Output #1) shall be required. Suppliers are encouraged to provide extensions to the base class (TBP) LO driver which makes full utility of their LO's functionality.

Parameter	Test /Validation Conditions	Units of Measure
IVI SW Driver	TBP BY SUPPLIER	N/A

4.2 Internal/External Control:

Define whether the subject LO can be controlled via an external or internal controller, or both.

Parameter	Test /Validation Conditions	Units of Measure
Internal/External Control	TBP BY SUPPLIER	N/A

4.3 Supported Busses:

Define which, if any, of the following busses can be used to provide external control:

Recommended Specifications:

Parameter	Test/Validation Conditions	Units of Measure/Description
External Control	Inspection	GPIB,VXI,PXI, LXI, other

5.0 Validation:

Each manufacturer/supplier of a LO artifact will be responsible for independently validating per best commercial practices each of the specification parameters, as applicable to a manufacturer`s/supplier`s particular product, described in this document. From time to time it is anticipated that Best Commercial Practice validation methodologies will be provided as an addendum to this document addressing some of the more problematic and misunderstood LO specification parameters.