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QuickApp Receiver Analysis

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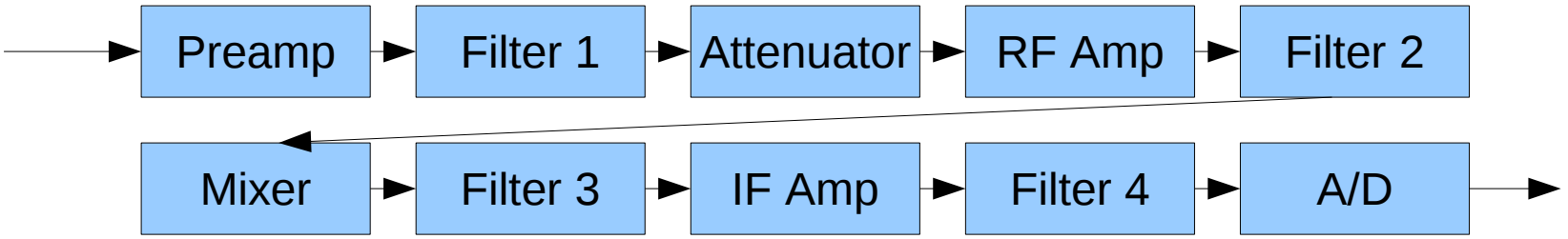
Abstract

- The finger-friendly eightolives QuickApp Receiver Analysis tool analyzes gain, noise and dynamic range for typical single conversion analog or digital receivers.
- The tool provides first order computations to help in the design, evaluation and comparison of different receiver configurations.

Receiver Basics



- A radio receiver consists of an interconnection of filters, attenuators, amplifiers, mixer and perhaps A/D converter and digital processing.
- Selecting characteristics of gain, bandwidth and Noise Figure associated with each stage affects the overall receiver performance

Receiver Basics

- Power Gain for a stage is typically specified in decibels (db) = 10 log(Pout / Pin)
- Noise Factor is the ratio of input signal to noise ratio to output signal to noise ratio
  - F = (Sin/Nin) / (Sout/Nout)
  - When specified in db, F is called Noise Figure (NF)
- Bandwidth represents the 3 db bandwidth of a stage expressed in Hz
- Maximum Input Voltage to a stage represents the largest peak-to-peak signal that can be applied with the stage “still being linear” (1 db compression level)

More on Maximum Input Voltage

- The Maximum Input Voltage parameter is used because it can be readily *estimated* for a design stage
  - Intercept Point data such as IP1, IP3 are items that are easily *measured* on hardware but more difficult to estimate during design
- The Maximum Input Voltage is similar to the “1 db compression point” concept used for Blocking Dynamic Range

A/D Converters

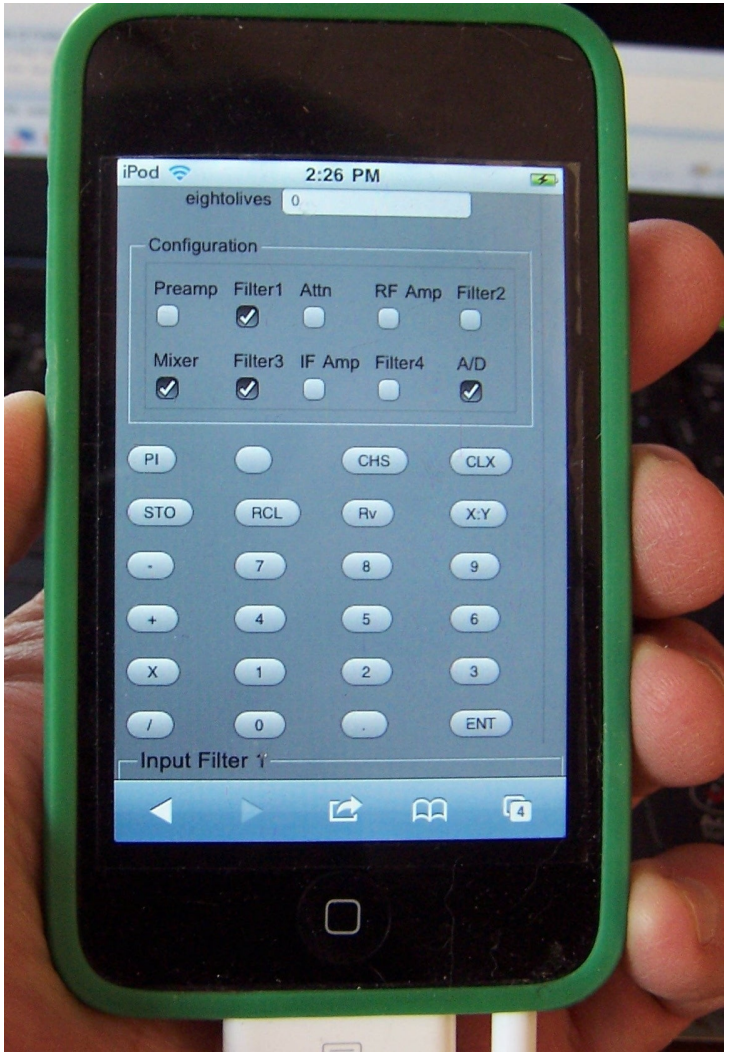
- Digital receivers sample an analog signal using an A/D converter. The A/D converter samples the signal at sample rate Fs producing digital samples with B bit resolution
- Fs must be at least 2x the highest frequency of interest
- A/Ds quantize the signal with a minimum resolution of LSB = (Max Input Voltage / 2**B)
- This produces quantization noise of LSB / SQRT(12) over the Fs/2 bandwidth
- Generally the input noise/signal level should be greater than 2 LSBs for proper detection

Digital Post Processing

- Digital Post Processing of sampled data by a Digital Signal Processor is estimated by the tool as filtering a specific bandwidth from the A/D data
- The specified post processing bandwidth must be less than Fs/2

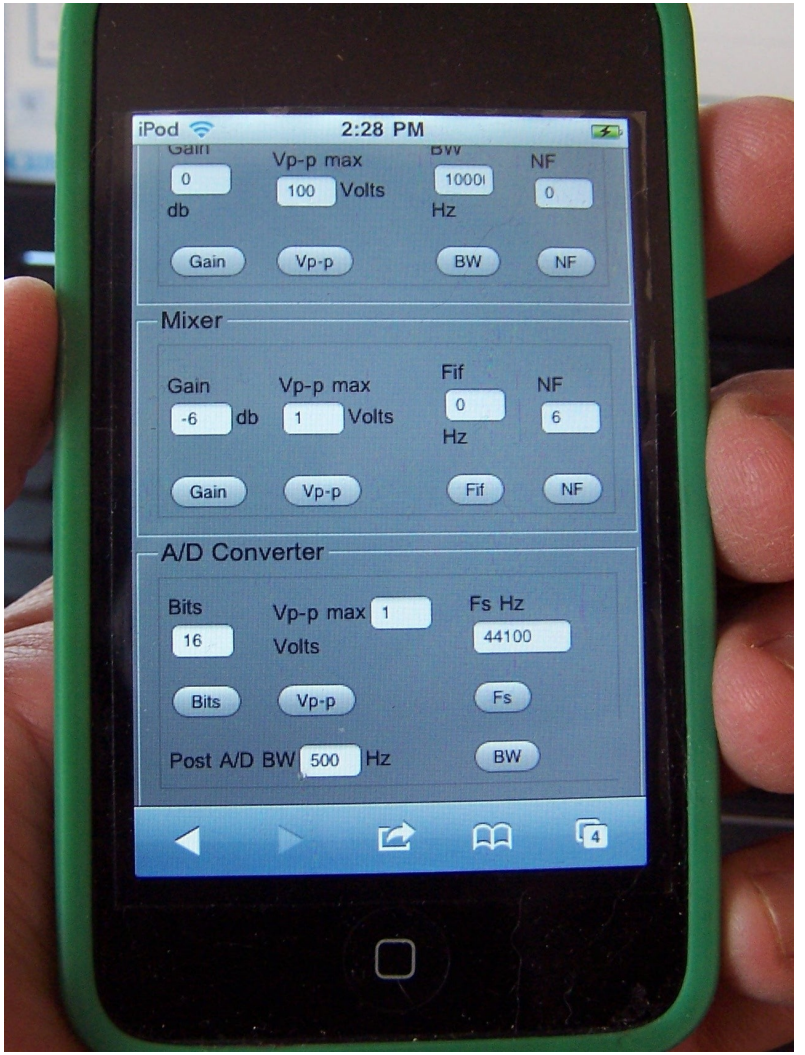
How To Use The App

- First, define the radio configuration by checking which functional blocks are included in the receiver.
- Detailed specification sections are displayed for each block selected.



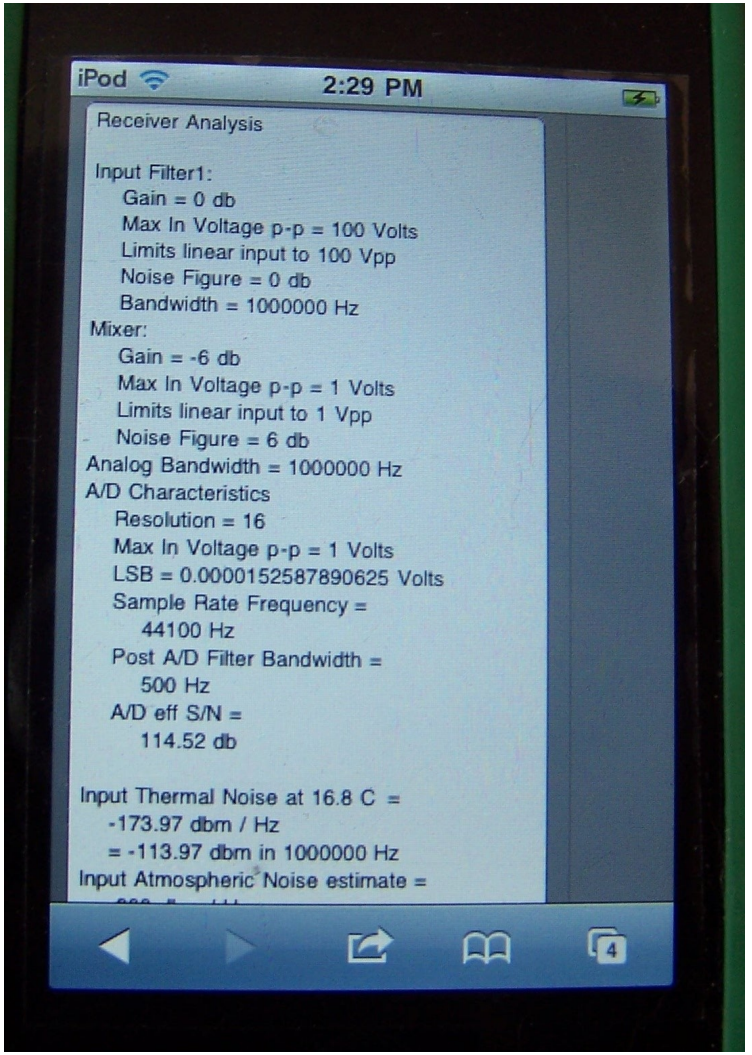
Using the App

- Edit the detailed specifications for each block
  - Use either the numeric keys followed by the appropriate entry button
  - Or enter data directly into the text fields



Report Window At Bottom

- The Report Window summarizes the design block characteristics and shows the resulting analysis.



What the App Tells You

- The report summarizes the configuration
- The report highlights
  - Total signal gain, S/N ratio, dynamic range
  - Stages limiting input signal level dynamic range
  - Noise Figure at the A/D and overall

Input Noise

- The default input noise source is the thermal noise estimate at the standard temperature of 16.8 degrees C.
- You can specify atmospheric noise as
  - A custom level in dbm/Hz or
  - Select default values for urban, day or night conditions for a specific frequency below 30 MHz .
  - The default value of -200 dbm/Hz basically represents no atmospheric noise

Atmospheric Noise

- Estimates for atmospheric noise vary widely
- It is a function of frequency, location, season, time of day

QuickApp Definitions

- Gain
  - The power gain of a design element expressed in db
  - Negative numbers reflect power loss
  - -3db is ½ power; -6 db is ½ voltage or ¼ power
- Bandwidth
  - A measure of a filter's passband -3db points in Hz
- Noise Figure (NF)
  - A measure in db of noise added by a design element
  - For stages with loss, the NF is equal to the magnitude of the loss

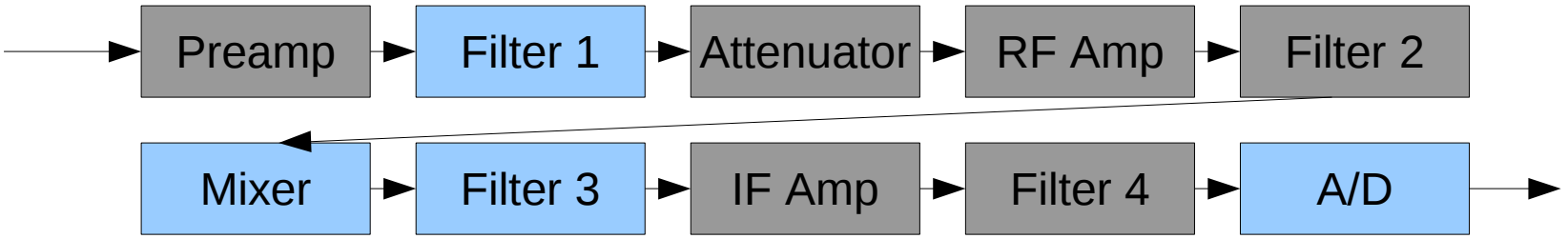
QuickApp Definitions

- Vp-p max
  - An estimate of the maximum signal voltage peak to peak that can be applied to a design element without signal compression (max signal for linear operation)
  - For an amplifier, Vp-p max is the equivalent peak to peak voltage level for a signal of Blocking Level power
  - For passive filters, Vp-p should reflect the maximum voltage capabilities of components used
  - For A/D converter, Vp-p is the peak-to-peak input voltage that the device can properly convert

Definition of Terms

- Noise Floor or Minimum Discernible Signal (MDS)
  - Signal level that produces the same output power as the internally generated receiver noise
- Blocking Dynamic Range (DR)
  - Difference in db between the Noise Floor and the level that causes 1 db of gain compression
- IMD Dynamic Range (IMD DR)
  - Difference in db between the Noise Floor and the level of two signals, F1 and F2, that produces the same output power as the internally generated receiver noise at frequencies (2 F1 – F2) or (2 F2 - F1).

Example 1



- The default settings of the tool are used for this example.
  - Filter 1 with 1 MHz bandwidth, 0 db loss, 0 db NF
  - Mixer with -6 db loss, 6 db NF, 1 Vp-p max input
  - Filter 3 with -6 db loss, 6 db NF, 500 Hz BW
  - A/D 16 bits at 44,100 Hz sample rate with 500 Hz post processing filter

Example 1 Report

Input Filter1:

Gain = 0 db

Max In Voltage p-p = 100 Volts

Limits linear input to 100 Vpp

Noise Figure = 0 db

Bandwidth = 1000000 Hz

Mixer:

Gain = -6 db

Max In Voltage p-p = 1 Volts

Limits linear input to 1 Vpp

Noise Figure = 6 db

Post Mixer Filter3:

Gain = -6 db

Max In Voltage p-p = 100 Volts

Noise Figure = 6 db

Bandwidth = 500 Hz

Analog Bandwidth = 500 Hz

A/D Characteristics
Resolution = 16
Max In Voltage p-p = 1 Volts
LSB = 0.0000152587890625 Volts
Sample Rate Frequency =
44100 Hz
Post A/D Filter Bandwidth =
500 Hz
A/D eff S/N =
114.52 db

Input Thermal Noise at 16.8 C =
-173.97 dbm / Hz
= -146.98 dbm in 500 Hz
Input Atmospheric Noise estimate =
-200 dbm / Hz
Total Input Noise =
-146.97 dbm in 500 Hz

Noise Analog at A/D = -146.97 dbm
= 2.6299951181311454e-8 Vp-p
MDS is limited by A/D LSB
Max signal power at output = -8.02 dbm
Max signal at A/D = 0.08 Vrms, 0.25 Vp-p
A/D signal power = -8.02 dbm
A/D noise power = -110.54 dbm
Max S/N = 102.52 dbm

Blocking Dynamic Range =

102.52 dbm

MDS = 21.4738288559969 uVrms

Noise Floor = -134.97 dbm

Total Gain = -12 db

Total Analog Noise Figure = 12 db

Total Noise Figure = 48.43 db

Maximum linear input =

1 Vp-p

0.3535533905932738 Vrms

3.979664145792851 dbm

The Analog Noise level at A/D is much less than the A/D Noise Power. The A/D limits overall S/N

The Mixer limits the max signal at the A/D

Example 1 Improvements

	Configuration	Total NF (db)	MDS uV	Blocking DR (db)	Max Input Voltage Vp-p	Total Gain (db)	Max A/D Input Vp-p
1	Example 1 Baseline	48.4	21.5	102.5	1	-12	0.25
2	Use 24 bit A/D	12.3	0.08	138.7	1	-12	0.25
3	Add 20 db RF AMP(3db NF)	3.3	0.01	127.6	0.1	8	0.25
4a	Add 15 db IF AMP	3.6	0.01	124.3	0.07	23	1
or							
4b	Increase Mixer Vp-p to 4V	3.3	0.01	137.2	0.3	8	0.75
5b	Increase RF Amp Vp-p to .5	3.3	0.01	139.6	0.4	8	1

Strategy:
Since the S/N eff of the 16 bit A/D was only 114 db, first use a better A/D.
NF of the first stages drive total NF so add a low noise RF Amp.
To fully use the A/D input range, either add an IF Amp or use a better Mixer and RF Amp.

Example 2 – Using a Pre-amp

- Demonstrates that adding a preamp improves NF at the expense of dynamic range
- First model a “poor” receiver by selecting only IF Amp in configuration
  - Set NF to 20 db, BW to 500 Hz, Vp-p to .003, Gain to 0
- Observe that the report shows
  - Blocking Dynamic Range = 80.5 db
  - Noise Floor = -126.97 dbm

Example 2

- Add the Preamp to the configuration
- Set the Preamp gain to 20 db, NF to 3 db
- Observe in the report:
  - Total Noise Figure = 4.75 db
  - Dynamic Range = 75.75 db
  - Noise Floor = -142.22 dbm
- The Noise Floor and NF were improved at the expense of Dynamic Range

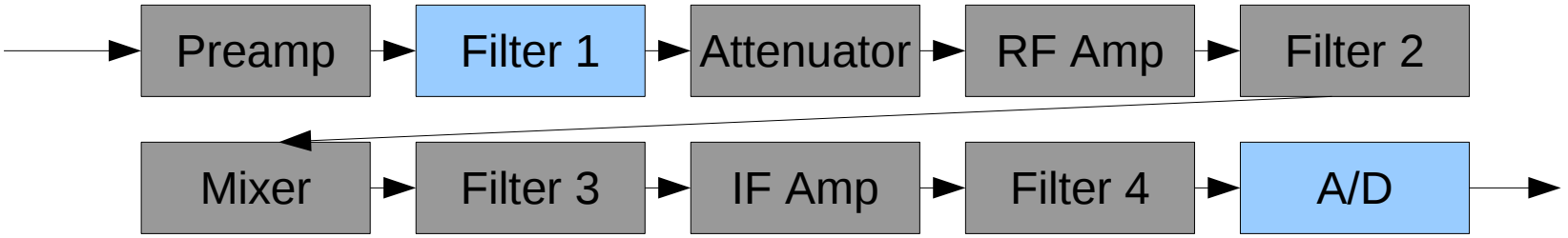
Example 3 - Attenuator

- First model a “poor” receiver by selecting only IF Amp in configuration
  - Set NF to 20 db, BW to 500 Hz, Vp-p to 0.003, Gain to 0
- Observe that the report shows
  - Blocking Dynamic Range = 80.5 db
  - Noise Floor = -126.97 dbm
  - MDS = 0.1 uV
  - Max input voltage = 0.003 Vp-p

Example 3

- Add an attenuator with gain of -20 db
- Observe
  - Total Noise Figure = 40 db
  - Dynamic Range = 80.5 db
  - Noise Floor = -106 dbm
  - MDS = 1 uV
  - Max input level = .03 Vp-p
- Adding an attenuator increases NF and Max input level while dynamic range remains constant

Example 4 – Direct A/D of RF



- For this example use:
  - Filter 1 with 1 MHz bandwidth, 0 db loss, 0 db NF
  - A/D 14 bits at 62.5 MHz sample rate with 500 Hz post processing filter

Example 4

- Note that the report shows a low NF of .11 db
  - This is primarily due to the high sample rate vs the final bandwidth of interest (i.e. a lot of digital processing)
- MDS is, however, 21.6 uV limited by the A/D
- Blocking Dynamic Range is 117.8 db

Hints

- Bookmark the menu page so can easily access the tools
- A mini dbm calculator is found at the bottom of the tool. You can use it to quickly convert between dbm, Vrms and Vp-p values

For more information

- Check the QuickApps Overview for more info on the other apps from the tutorials page at: http://www.eightolives.com/tutorials.htm
- Review bug reports and status from the QuickApps home page at: http://www.eightolives.com/docs/Mobile/index.htm