ADCs for Software Radios

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Fabrication Processes
ADC Technology Trends

• Applications drive technology development
• At volume, ADC function moves to SOC block
  – disk drives, pro audio, ADSL, cable modems, NB radios, scanners, digital cameras
• Technology Development Trends (12 bit 20MSPS)

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>84</td>
<td>20 W</td>
<td>Board</td>
<td>60 dB</td>
<td>$4K</td>
<td>Radar</td>
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<tr>
<td>88</td>
<td>5 W</td>
<td>Hybrid</td>
<td>62 dB</td>
<td>$1K</td>
<td>Missiles</td>
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<td>92</td>
<td>2 W</td>
<td>bipolar</td>
<td>63 dB</td>
<td>$200</td>
<td>Instruments</td>
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<td>96</td>
<td>0.4W</td>
<td>CMOS</td>
<td>65 dB</td>
<td>$20</td>
<td>Medical</td>
</tr>
<tr>
<td>98</td>
<td>0.2W</td>
<td>core</td>
<td>65 dB</td>
<td>$2</td>
<td>Image. ASIC</td>
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</tbody>
</table>
ADC: Not all created equal

• Critical specifications for radio applications
• Dynamic range - correlates with # of bits?
  – SNR, Harmonic distortion, SFDR
    • may only roughly correlate with nominal # of bits
  – Aperture jitter - limits at high input frequency
• Sample rate - must obey Nyquist criteria
  – IF sampling performance
  – must understand channel bandwidth vs. IF
What Kind of Software Radio?

- Software radio - adaptive bandwidth & modulation?
  - Narrowband PCS
    - 25, 12.5, 6.25 KHz BW by same radio
    - Must provide service for 1 month on single A Cell
    - Tune at RF, Sigma Delta ADC, extremely low power
  - Programmable base station (Macro)
    - Multiple channels in licensed band (15 MHz)
    - Various types of signals in band (IS-136, CDMA, GSM)
    - Tune and filter in digital domain
    - ADC linearity often limits receiver performance
ADC Errors effect Receivers

- **Static Errors**
  - non linearity in encoder transfer function
  - can create harmonics in frequency domain
- **Dynamic Errors**
  - sampling jitter - increases noise at high Ain
  - T/H linearity - increase in noise & harmonics
- **Noise**
  - sampling, component, thermal
ADC *error avoidance* Techniques

- **Oversampling** -
  - decreases noise in band of interest (*improves SNR*)
  - facilitates digital filtering/ “processing gain”

- **Dither** -
  - smooths the encoder transfer function reducing spurs (requires excellent T/H at high Ain)

- **IF sampling** -
  - can move harmonics out of analysis bandwidth
  - can filter amp harmonics with IF filters & reduce analog component count
AD6640: -80 dBfs Spurs

Sampling rate = 65MSPS; dc to 32.5MHz; Ain = 15.5 MHz
AD6640-1st Nyquist Performance

1st Nyquist Zone Narrow Band ADC Performance

Sampling rate = 65MSPS; 12.5 to 18.5MHz; Ain = 15.5 MHz
AD6640 3rd Nyquist Zone

3rd Nyquist Zone Full Band ADC Performance

Sampling rate = 65MSPS; 65 to 97.5 MHz; Ain = 80.5 MHz
AD6640: 7th Nyquist Zone

Sampling rate = 65MSPS; 193 to 225MHz; Ain = 200 MHz
7th Nyquist Zone - Zoom

Sampling rate = 65MSPS; 197.5 to 202.5 MHz; Ain = 200 MHz
## Processing Gain & Oversampling

<table>
<thead>
<tr>
<th>Standard</th>
<th>Chan. BW</th>
<th>Symbol Rate</th>
<th>Samp. rate</th>
<th>Proc. Gain*</th>
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<tbody>
<tr>
<td><strong>IF Sampling</strong></td>
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<tr>
<td>IS-136</td>
<td>30 KHz</td>
<td>48.6 Kbit/sec</td>
<td>9.72 MSPS</td>
<td>22 dB</td>
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<td>GSM</td>
<td>200 KHz</td>
<td>270.83 Kbit/s</td>
<td>6.5 MSPS</td>
<td>12 dB</td>
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<tr>
<td>CDMA</td>
<td>1.23 MHz</td>
<td>1.228 Mbits/s</td>
<td>19.66 MSPS</td>
<td>9 dB</td>
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<tr>
<td><strong>Wide band</strong></td>
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<td></td>
</tr>
<tr>
<td>IS-136</td>
<td>30 KHz</td>
<td>48.6 Kbit/sec</td>
<td>58.32 MSPS</td>
<td>29 dB</td>
</tr>
<tr>
<td>GSM</td>
<td>200 KHz</td>
<td>270.83 Kbit/s</td>
<td>65 MSPS</td>
<td>22 dB</td>
</tr>
<tr>
<td>CDMA</td>
<td>1.23 MHz</td>
<td>1.228 Mbits/s</td>
<td>58.98 MSPS</td>
<td>14 dB</td>
</tr>
<tr>
<td>3G</td>
<td>5MHz</td>
<td>4.096 Mbits/s</td>
<td>65.53 MSPS</td>
<td>9 dB</td>
</tr>
</tbody>
</table>

* Assumes 1 sample/symbol

**Processing Gain = 10 log (Sample rate/2* channel BW)**
Multi-Channel RX Challenges

High Dynamic Range Radio

High SFDR ADC

Radio Base Station

RF/IF stage receiver

ADC

Digital Filter (channelizer)

DSP Channel 1

Digital Filter (channelizer)

DSP Channel 2

Digital Filter (channelizer)

DSP Channel n

Public Telephone Network
AD6620 Functions
NCO and Filter Stages

AD6620
Dual Channel Decimating Receiver
Accepts real or complex input words: provides tuning and decimation filtering
65 MSPS Single channel inputs or 32.5 MSPS Dual Channel Mode
NCO worst spur better than -105dBc; 0.02 Hz tuning resolution
CIC2 Fixed Coefficient Filter decimates 1 to 16; CIC5 Fixed Coefficient Filter decimates 1 to 32
Programmable RAM based FIR filter with programmable decimates 1-32
1700 Million Operations per second at 250 micro-watts/MOP
Design Filter Using AD6620 software

Composite Filter Spectral Response

-3 dB Composite Response

Filter Impulse Response
Modular Evaluation Boards

AD6640 -
12 bit 65MSPS
IF Sampling ADC

AD6620
Receive Signal Processor

AD6600 -
Diversity Receiver ADC
Multi-carrier Receivers Overview

Radio Base Station

RF/IF stage receiver → ADC → Digital Filter (channelizer) → DSP Channel 1 → Public Telephone Network

Digital Filter (channelizer) → DSP Channel 2

Digital Filter (channelizer) → DSP Channel n

Frequency vs. Signal Strength

Solutions for Digital Radio

3/4/99 - 19
AD6640 + AD6620: GSM

**Wideband GSM receiver (AD6640+AD6620)**

**Sampling rate = 65MSPS; IF = 12.5 MHz to 18.5 MHz**
(noise floor increased due to lower decimation rate)
Wideband GSM receiver (AD6640+AD6620)

Yellow - Pico Cell Mask;  Purple - Macro Cell Mask;
GSM Receiver: IF Sampling

Yellow - Pico Cell Mask;  Purple - Macro Cell Mask;

Sampling Rate: 65MSPS;  Ain 77.5 to 83.5 MHz

Solutions for Digital Radio
AD6640 + AD6620: IS-136

Sampling rate = 65MSPS; IF = 12.5 MHz to 18.5 MHz
(noise floor reduced due to narrow IS-136 filter)
Meets IS-136 Specification

Sampling rate = 65MSPS; IF = 12.5 MHz to 18.5 MHz
(noise floor reduced due to narrow IS-136 filter)
Narrowband Chipset comparison (*IF to digitizer(s)*)

Traditional: Two channels required for diversity  total cost = $200+

**Total cost <$100**
GSM, IF sampling Ref. Design
"IF" Gain-Ranging Technology

Signal range = 30dB AGC + 60dB ADC = 90dB
Sampling 170 MHz IF
IF sampling chipset: meets GSM requirements

Sampling rate = 6.5 MSPS; IF = 167 MHz to 173 MHz
Conclusions

- ADC technology improving dramatically in many ways
- ADC manufacturers need volume applications to drive R/D investment
- System understanding drives ADC innovations
- Multi-mode, Multi Channel Rx chipsets available
  - performance limited by ADC
- IF Sampling Chipset (AD6600+6620+6630)
  - available and meets GSM requirements
  - requires some analog filtering
  - High IF sampling decreases “RF” costs
More Information

- AD6640, AD6620, AD6630 and AD6600 chips, app notes and evaluation boards available from Analog Devices
- search at www.analog.com