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DSP in HF Radios

How DSP implements typical transceiver functions

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What is DSP and what does it do?

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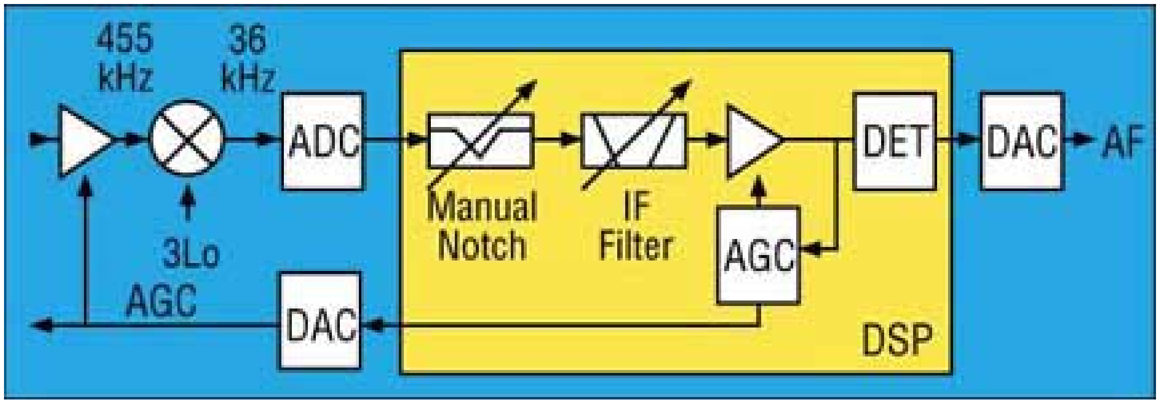
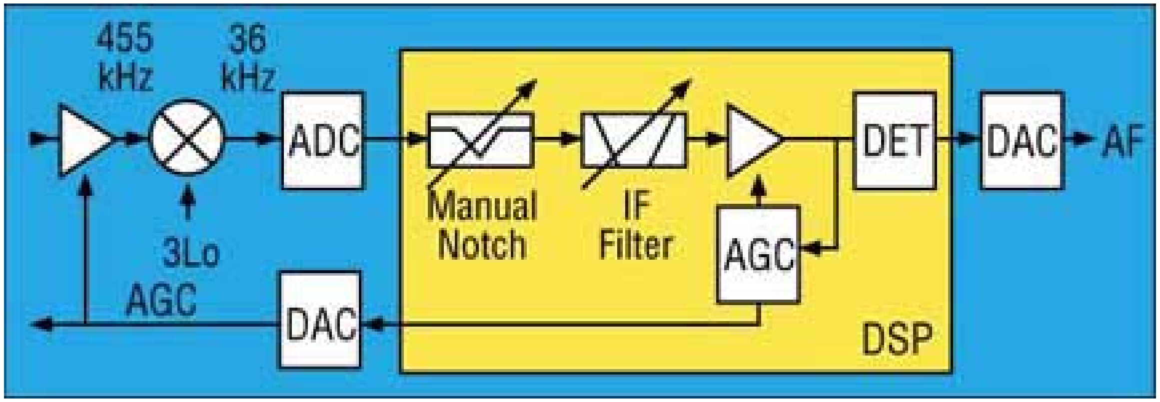
- **DSP: D**igital **S**ignal **P**rocessing. Analogue signals are digitized in A/D converter (ADC), processed in DSP IC (a specialized CPU), then re-converted to analogue in D/A converter (DAC).
- **DSP** allows much more complex signal processing and manipulation with much simpler circuitry (reduced parts count/cost) and much greater stability/repeatability than analogue designs. No alignment or “tweaking” is required.

ADC Considerations – influence on overall receiver design



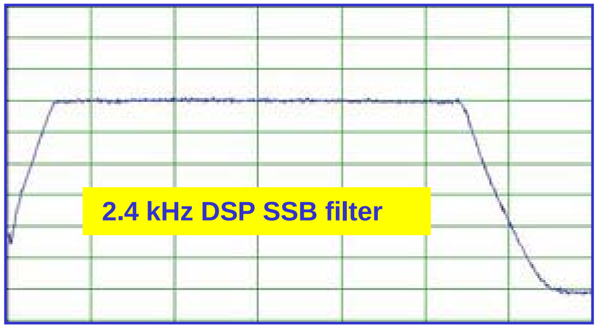
- **ADC** is final IF stage of superhet.
- Max. input power to ADC yields “all 1’s” at output.
- Preceding analogue circuits must hold ADC input level safely below this point.
- Theoretical dynamic range of 24-bit ADC = 24*6 = 144 dB (all 0’s to all 1’s). ADC noise floor sets practical limit of 20 usable bits (120 dB).
- AGC “stretches” ADC dynamic range, but limitations of analogue RF & IF circuits ahead of ADC input will limit overall dynamic range of receiver system.

DSP Functions in Receiver

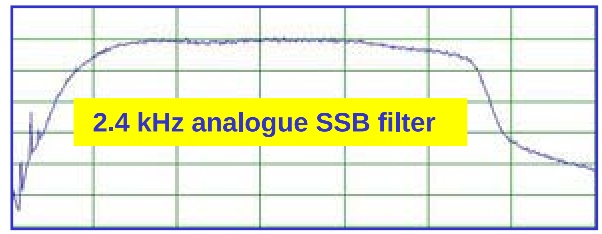


- RX selectivity filtering & manual notch filter (pre-AGC).
- Noise Blanker (NB) *in some designs.*
- AGC.
- Demodulation (all modes).
- In "DET" block:
  - **Noise Reduction (NR).**
  - **Auto notch.**
  - **CW pitch adjustment.**
  - **RTTY twin-peak filter & decoder/reader.**

DSP IF Filter Advantages



No optional filters to buy, *ever!*



- IF filters as narrow as **50 Hz** are possible; not practical in analogue filters.
- **Group delay** is constant across passband; thus, no ringing at narrow BW settings.
- **Phase distortion** is negligible; filter does not degrade CW/data signals in narrow BW.
- Zero **"insertion loss"**; no terminating-impedance, temperature-drift or alignment issues.
- **Shape factors** and **stopband attenuation** far superior to analogue, without concerns about insertion loss or phase distortion at passband edges.
- **Selectable shape factors** allow filter optimization to suit varying band and signal conditions.
- **Manual notch filter** stopband -70 dB or better, vs. -40 dB for analogue 9 MHz notch in conventional receiver.
- **Continuously-variable** bandwidth, not feasible with analogue filters.
- **Twin Passband Tuning** shifts upper and lower passband flanks independently.
- **CW** and **RTTY** filters optimized for those modes.

AGC and Noise Blanker in a DSP Receiver

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- **AGC (Automatic Gain Control):**
  - **AGC** is derived within the DSP after IF filtering; adjusts gain inside DSP, between IF filtering & demodulation. It also generates a bitstream which a dedicated DAC converts to a DC AGC voltage. This voltage controls stage gain of analogue IF amplifiers. DSP AGC parameters are ***stable.***
  - AGC "stretches" receiver dynamic range.
  - DSP allows wide range of AGC **time-constant** settings.
  - **“RF Gain”** control raises DSP AGC threshold.
  - DSP-derived AGC is sometimes paired with an analogue AGC loop, using detector at ADC input *(not in Icom DSP radios).*
- **NB (Noise Blanker)**
  - Earlier IF-DSP receivers (incl. IC-756Pro3) have pulse-type analogue NB in IF chain prior to ADC input. Newest trend is an NB algorithm in the DSP *(e.g. IC-7000, IC-7800).*
  - With DSP NB, fewer freq. conversions prior to ADC eliminate pulse-stretching due to cascaded analogue IF filters.

DSP Noise Reduction

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- **Noise Reduction (NR)**
  - *Often makes the difference between “copy” and “no copy”.*
  - Not feasible in analogue technology.
  - NR discriminates between low-correlation (speech, tone) and high-correlation (noise) signals. Computes out high-correlation signals.
  - NR is a **heuristic** (learning) process; builds up history of compared signals. Pro3 reinitializes NR approx. every 15 sec.
  - NR can improve S/N ratio by up to 20 dB, but causes slight loss of highs in recovered audio.
  - 16-step NR control allows best compromise between noise suppression and intelligibility.
  - NR is less effective at narrow IF bandwidth (CW, RTTY).

Demodulation and associated DSP features

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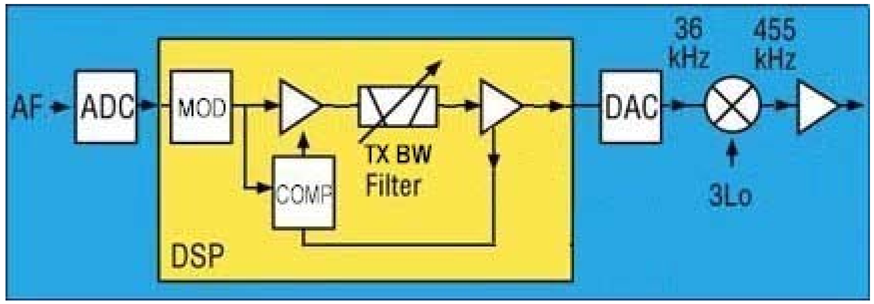
- DSP demodulation process **never** needs alignment *(no “BFO”).*
  - Models phasing-type product detector for SSB, CW, digital modes. Suppresses unwanted sideband via phase cancellation.
  - DSP demodulation does not distort recovered baseband.
  - Adds AM sidebands in phase; models discriminator for FM.
  - CW pitch control allows operator to vary CW pitch for comfortable copy, without tuning off the receive frequency.
  - Dedicated RTTY demodulation process demodulates FSK, decodes Baudot code and displays received text on radio’s TFT screen. RTTY twin-peak filter is tuned to mark and space tones. Adjustable demod. threshold for accurate copy in presence of noise. *No external TU or modem required.*
  - In some radios (e.g. IC-7800), DSP demodulation process also drives “waterfall” and vector displays, and decodes PSK31.

DSP Functions in Transmitter



- Baseband processing.
- Modulation and keying.
- IF-level speech compression.
- Transmitted-signal monitor.
- Occupied-bandwidth management .
- ALC (in some designs).

Baseband Processing in DSP Transmitter

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- Speech amplifier drives analogue input of ADC.
- Baseband processing sets transmit AF level.
- Also provides bass and treble **equalization** to optimize AF response with a wide range of microphones.
- Unlike some analogue “EQ”, DSP equalization does not add noise or distortion to baseband. No external analogue audio devices are needed; potential EMC/RFI issues are eliminated.
- Maintains correct **AM** carrier/sideband amplitude relationship for desired % modulation (max. 100%).

DSP IF-Level Compression

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- **IF-level** compression: after modulation, prior to TX BW filtering.
- Fast-attack, slow-decay. Compression level is adjustable; 6 dB is optimum for SSB.
- DSP compression process does not significantly distort compressed signal; does not generate unwanted sidebands or “splatter”.
- Compression in digital domain is much simpler and more cost-effective than any analogue compressor circuit.
- DSP compression is stable; no alignment required.

Management of TX occupied bandwidth in DSP

- **Occupied-bandwidth management (TX BW filtering).**
  - Sets SSB TX occupied bandwidth.
    - 3 selectable SSB TX bandwidths (Wide, Mid, Narrow). Low- and high-end cutoff frequencies individually configurable for each BW selection (in IC-756Pro3).
    - SSB TX BW limited to 2.9 kHz.
  - Sets AM occupied bandwidth (limited to 5.8 kHz).
  - CW TX waveform rise-time is adjustable to minimize key-clicks.
  - FSK mark frequency, shift and keying polarity are adjustable.
  - Limits TX **FM** peak deviation (accurately) to ±5 or ±2.5 kHz as function of RX IF filter selection.

DSP ALC Implementation

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- In some transmitter designs, ALC voltage is fed back to a voltage-sensing point on the DSP IC. This varies the transmit gain within the DSP. This facilitates adjustment of ALC parameters (attack & decay times, threshold.)
- In the Icom DSP-based transceivers, the ALC loop is **purely analogue**. ALC voltage is fed back to gain-controlled transmit IF amplifier.

DSP in Spectrum Scope

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- **IC-756Pro series etc. have analogue spectrum scope.**
- **IC-7800 Spectrum Scope has dedicated DSP “back end”.**
- **DSP functions as an <u>FFT spectrum analyzer</u>.**
- **DSP offers much better linearity, accuracy and resolution than analogue scope. DSP does not require alignment.**
- **Resolution bandwidth (RBW) is adjustable. (RBW is fixed in analogue scope.)**
- **Scope is usable for on-air IMD and spectral-purity measurements.**

References

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1. **IC-756Pro II Technical Report**

2. **Basic Concept of Icom DSP**