A Low Cost Single Chip VDL Compatible Transceiver ASIC

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Abstract: Recent trends in commercial communications system components have focussed almost exclusively on cellular telephone technology. As many of the traditional sources of receiver components have discontinued non-cellular telephone products, the designers of avionics and other low volume radio applications find themselves increasingly unable to find highly integrated components. This is particularly true for low power, low cost applications which cannot afford the lavish current consumption of the software defined radio approach increasingly taken by certified device manufacturers.

In this paper, we describe a low power transceiver chip targeting applications from low VHF to low UHF frequencies typical of avionics systems. The chip encompasses a selectable single or double conversion design for the receiver and a low power IF upconversion transmitter. All local oscillators are synthesized and integrated into the chip. An on-chip I-Q modulator and demodulator provide baseband modulation and demodulation capability allowing the use of low power, fixed point signal processing components for signal demodulation.

The goal of this program is to demonstrate a low cost VDL mode-3 transceiver using this chip to receive text weather information sent using 4-slot TDMA with no support for voice. The data will be sent from an experimental ground station. This work is funded by NASA Glenn Research Center.

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Introduction

- **Rationale for a Single Chip Radio**
- **Chip Architecture**
- **Radio Chip Specification**
- **Application Demonstration System**
- **Conclusion**

Rationale for Radio on a Chip

- Commercial communications system components increasingly focussed on cellular telephone technology.
  - Larger market than general purpose radio circuits
  - Many traditional sources of generic radio components have quit the market.
  - General purpose radio chip market is too small & profits too limited to appeal to most chip vendors

Rationale for Radio on a Chip

- Bring technology into the Aeronautical sector
  - Reduces issues with obsolescence
    - reduces product life cycle costs
- Custom designs tailored to specific applications
  - Designed specifically for avionics market
- Reduced component counts are possible
  - Highly integrated designs mean fewer external components

Rationale for Radio on a Chip

- Control obsolescence
  - Dependence on vendor removed

- Control performance parameters
  - Able to tailor performance to your requirements

Rationale for Radio on a Chip

- Expensive to create
  - Design costs typically exceed $1M
- Limited markets
  - Some compromises may be required to increase the market for the design (cost spreading)
  - Per unit costs may run higher than commercial components
- Dependence on foundry process cycles
  - Process for making the chip can go obsolete

Chip Architecture - Rcvr
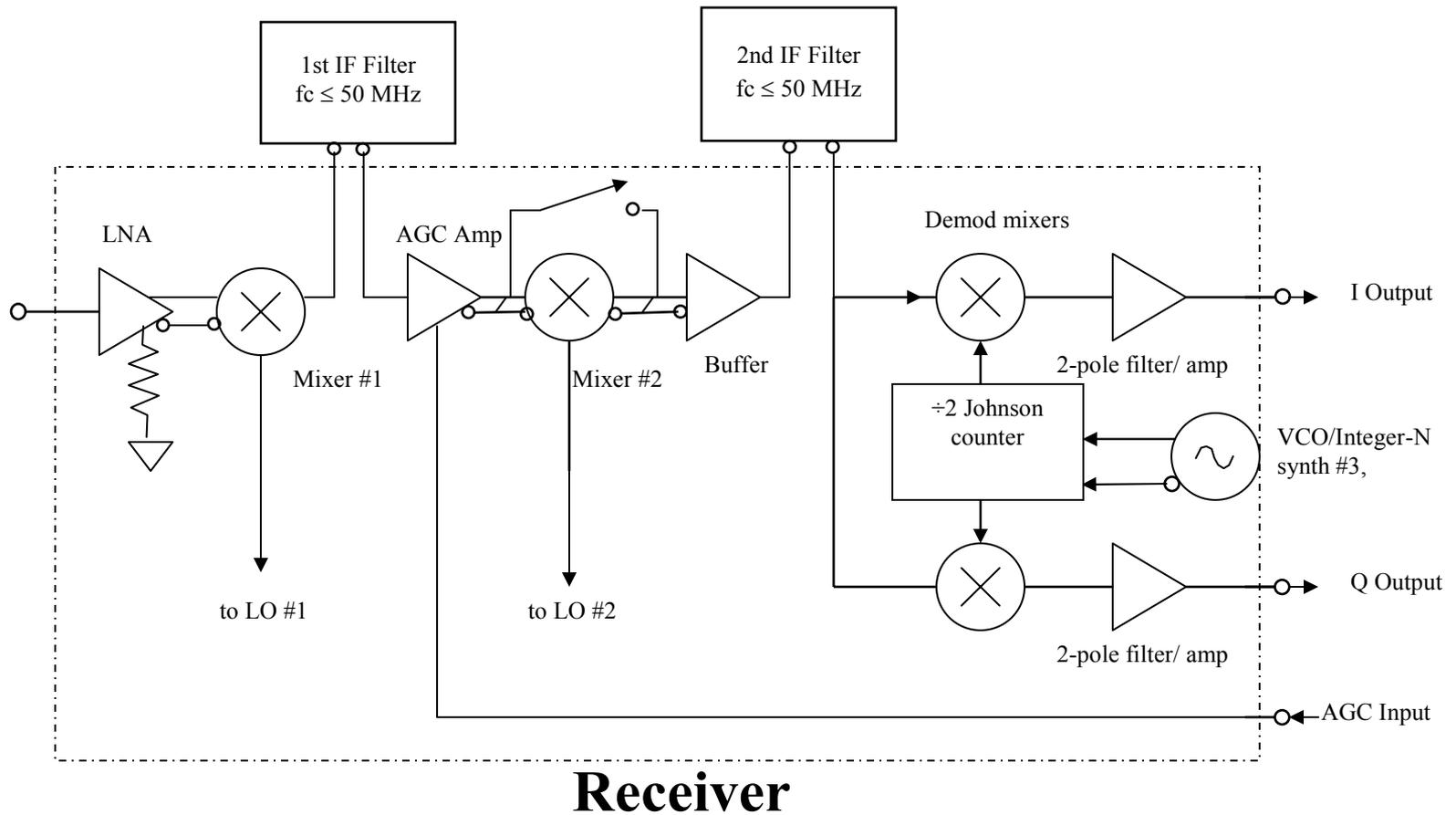
Receiver

Chip Architecture - Xmtr
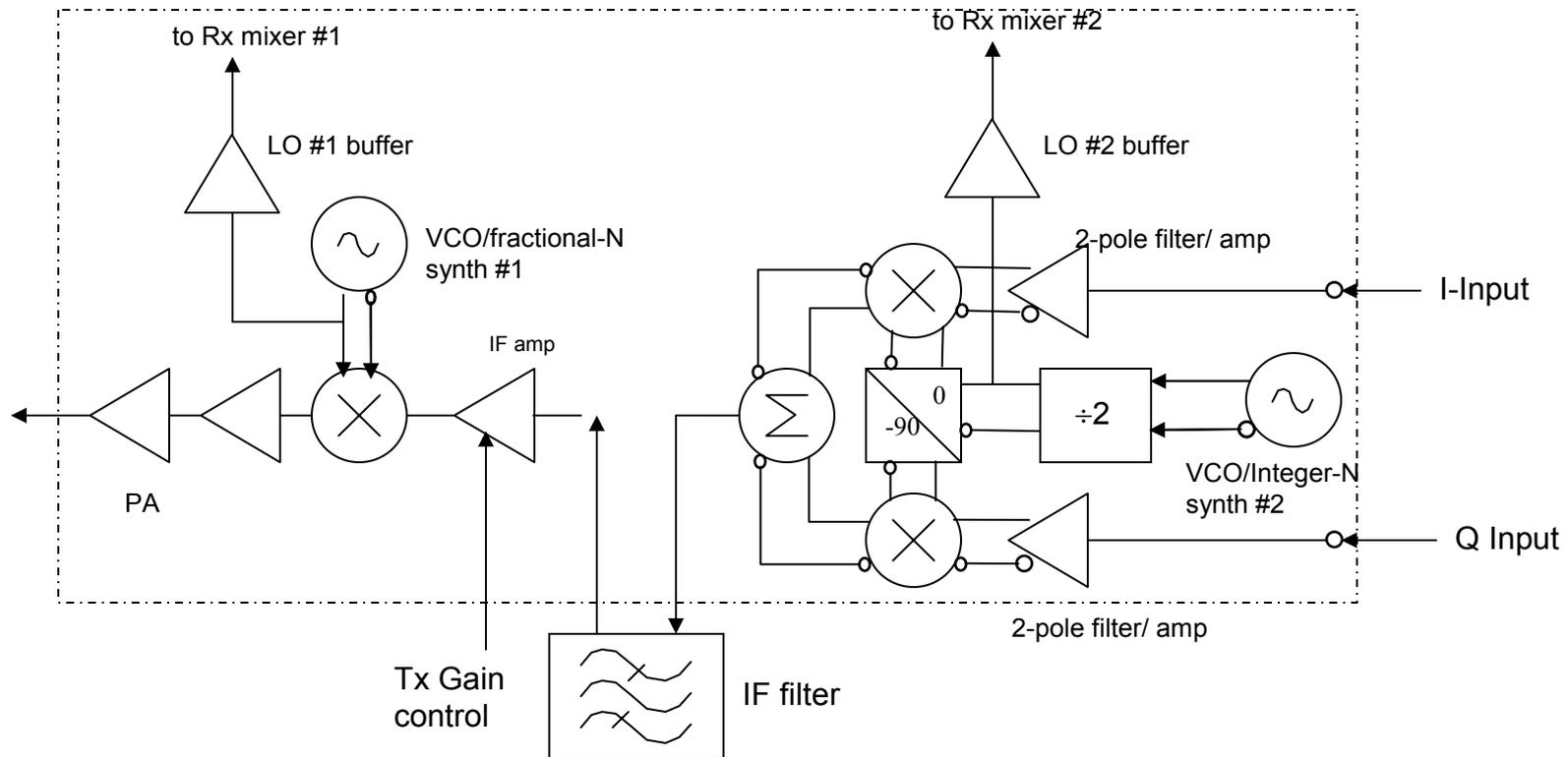
Transmitter

Chip Architecture, cont'd

- Super-heterodyne single/double (switchable) conversion receiver
  - Can be used in either single or double conversion mode
  - Higher performance than direct conversion receivers
  - Better noise figure than direct conversion receivers
  - Higher IP3 point than direct conversion systems

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Chip Architecture, cont'd

- Why not a more software defined design?
  - Software defined radios are extremely flexible
  - Can adapt to new modulation types with firmware modifications
  - Significant designer control over performance
  - Software radios cost point is higher
  - Maturity of the technology
  - Too power hungry for battery powered applications
    - ill suited to low power applications.

Chip Architecture, cont'd

- Analog I/Q demodulator
  - Lower overall power consumption than digital down-conversion and demodulation
  - Uses Johnson counters for nearly perfect I/Q LO generation
- Three integrated local oscillators
  - external tank and tuning components required.

Chip Architecture, cont'd

- Fully integrated synthesizers for all LO's
  - Integer-N designs for the 2nd & 3rd LO
  - Fractional-N for the 1st LO
    - Offers improved LO noise vis-à-vis integer-N designs
    - Faster frequency switching than integer-N synthesizers.

System Architecture
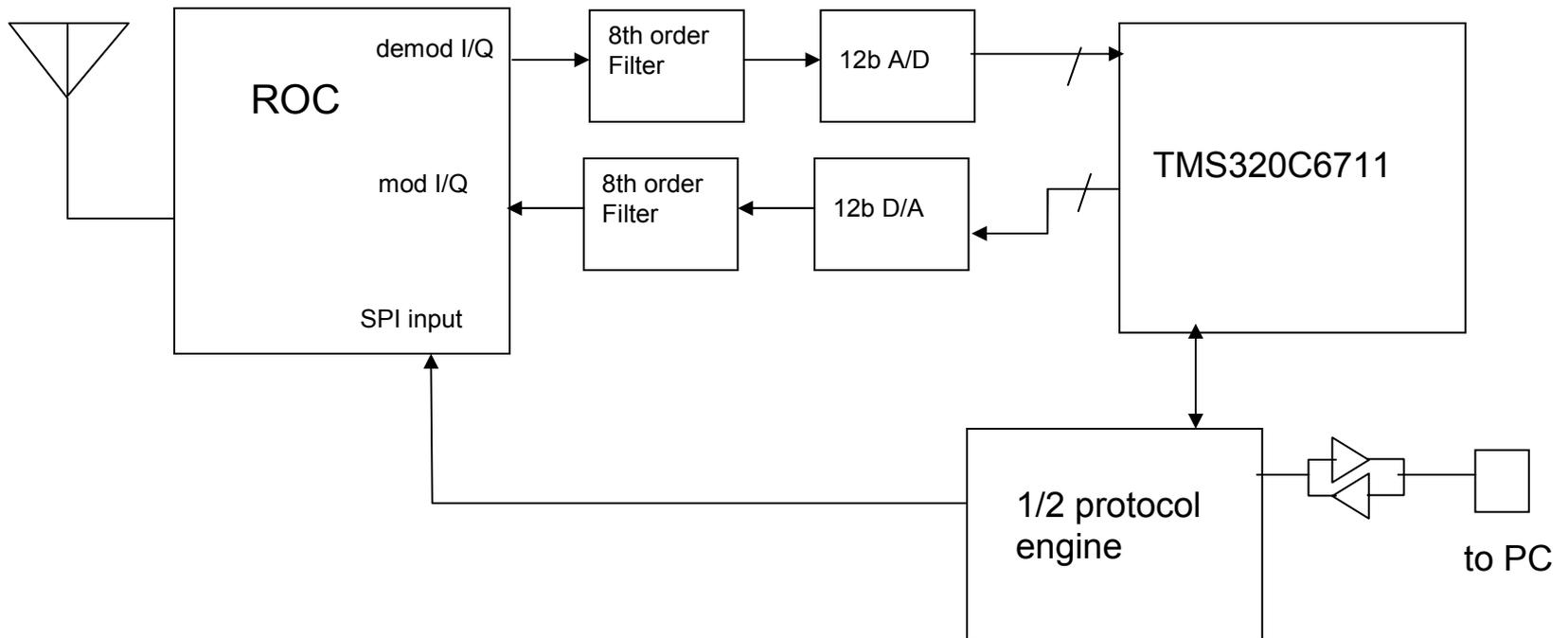
Transceiver architecture is very simple

Application Range

- Initial target is low cost devices
  - cost sensitive market
  - widest possible ranges of users
    - EFB - Air Transport
    - Low cost NEXCOM transceiver - General Aviation
  - graduate to expanded markets with later designs
- Battery operation
  - independent of aircraft systems

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Application Range

- Target operating range is 50MHz to 450MHz
  - Covers marker beacon, comm, nav, ILS, glideslope, & MilCom bands
    - larger application market means lower per-unit costs

Application Range

- Present design targets for VDL applications
  - Present IIP3 point is too low for fully certified NEXCOM communications products
  - Future designs will address higher degrees of certification

Chip Specifications

DC Characteristics (25 °C)

Parameter	Conditions	Min.	Typ.	Max.	Units
Power supply	Vdd	3.0		5.0	V
	Idss	40		75	mA
Logic Interface	Vih (3.0V < Vdd < 5.0V)	Vdd/2 + 0.6		Vdd + 0.6	V
	Vil (3.0V < Vdd < 5.0V)	Vss		0.8	V
	Voh (3.0V < Vdd < 5.0V, Isrc < 3 mA)	Vdd – 0.5		Vdd – 0.5	V
	Vol (3.0V < Vdd < 5.0V, Isink < 10 mA)	0.4		0.5	V

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Chip Specifications

AC Characteristics

Parameter	Conditions	Min.	Typical	Max	Units
Operating frequency range		20		450	MHz
Rx noise figure			4		dB
Rx IIP3			4		dBm
1st IF bandwidth	-3dB bandwidth	2		45	MHz
2nd IF bandwidth	-3dB bandwidth			15	MHz
I/Q demodulator bandwidth	-3dB bandwidth			1	MHz
Demodulator output				1	Vp-p
I/Q modulator bandwidth	-3dB bandwidth			1	MHz
I/Q modulator input				1	Vp-p
I/Q Modulator bandwidth	-3dB bandwidth	5		70	MHz
Transmitter IF amp gain range		-10		20	dB
Output power step size			6		dB
# power steps			5		
Transmitter output power				10	dBm

Vdd = 5.0V, 25°C

Chip Status

- 2nd pass chip submitted to AMI for fabrication

- Expect parts from fab by 20 July, 2004

Application Demonstration

- VDL mode-3 data link
  - Pressing need to get better information to pilots
  - Better info improves flight safety
  - Weather is a significant cause of fatal accidents

Why a Data Link Demonstration?

Would you rather have this?

2004/04/06 17:20 KBJI 061720Z 061818 33012KT P6SM SKC FM0000 VRB06KT P6SM SCT250 FM0800 15007KT P6SM SCT120 TEMPO 1115 BKN080 FM1500 18007KT P6SM BKN080 PROB30 1518 -RA OVC030

Why a Data Link Demonstration?

Or, would you prefer this:

A picture just might be worth more than 1000 words...

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Data Link Demonstration

- Data links can provide rich and varied information

- Bidirectional data links allow the pilot to request specific information not otherwise available

Demonstration radio is intended to prove a concept, leading to a product

Conclusion

- Radio-on-a-chip can tailored to meet specific requirements
  - Product life-cycle costs can be significantly reduced
  - High initial cost requires careful consideration in deciding to design your own chips
- High levels of integration are possible
  - results in potentially significant reductions in circuit board complexity