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A CMOS Wireless Synchronization and Control System for Sensor Modules in MRI Scanners

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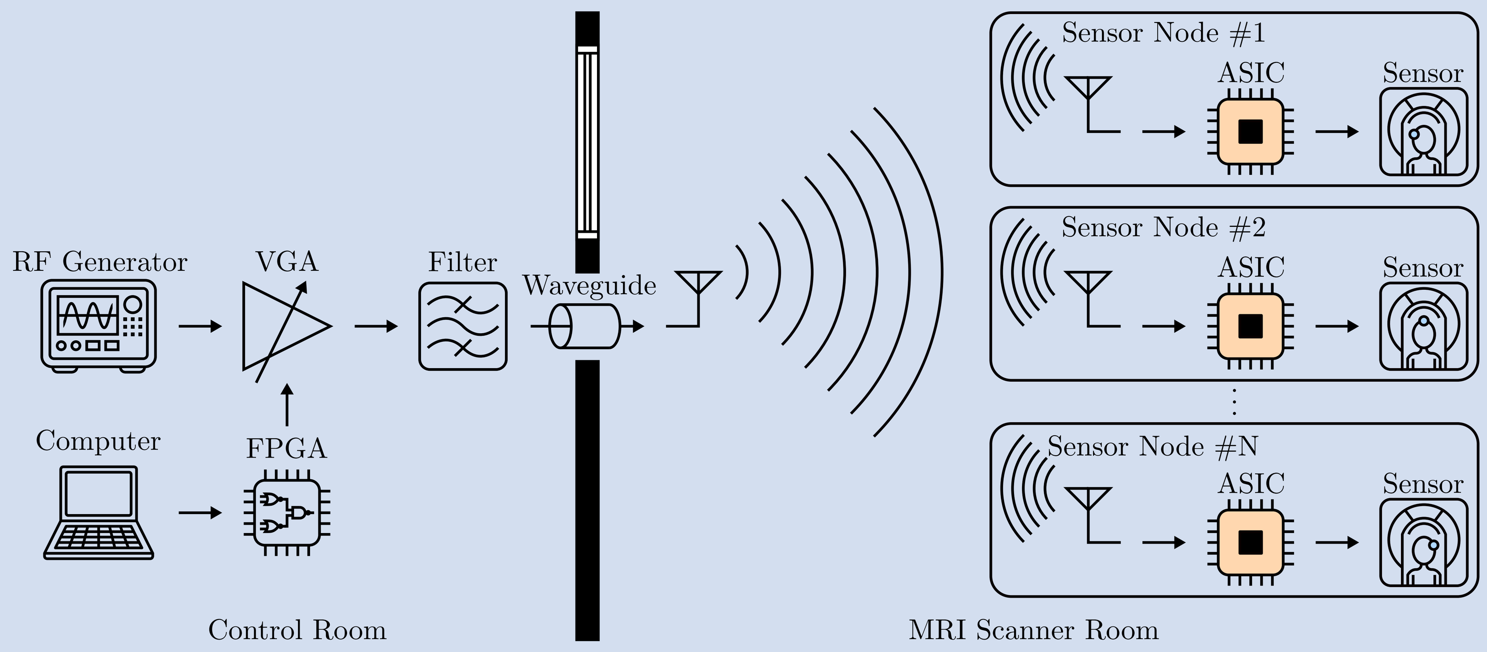
1 Introduction

- **Magnetic Resonance Imaging** (MRI): one of the most widely used imaging techniques in medical diagnostics and biomedical research
- **Wireless motion tracking**: Several sensors need to be aligned in phase to record motion data [1]

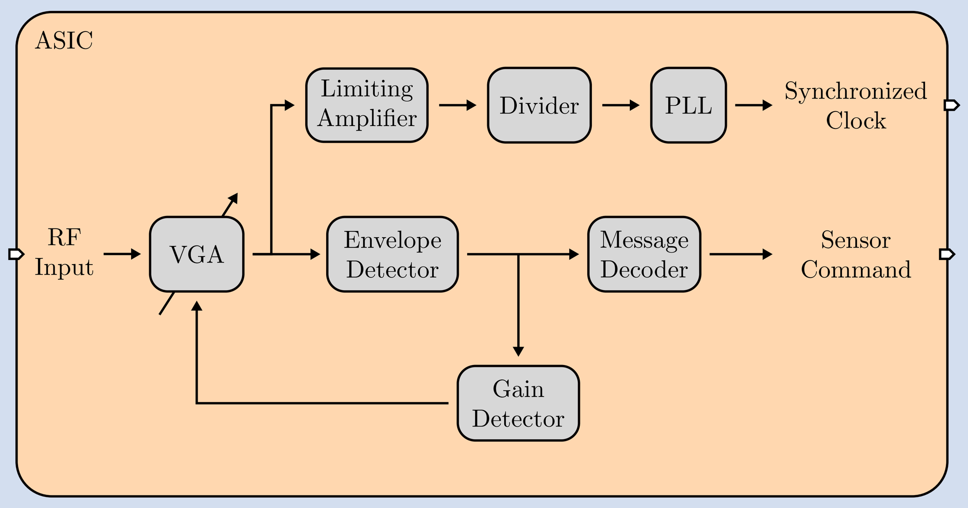
⇒ ASIC: **synchronization** and **triggering** remote sensors in an MRI scanner



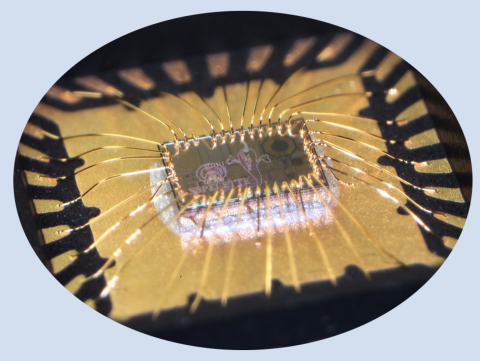
- Consideration: short triggering events (ca. 1 µs) and low activity (duty cycle around 1 %)

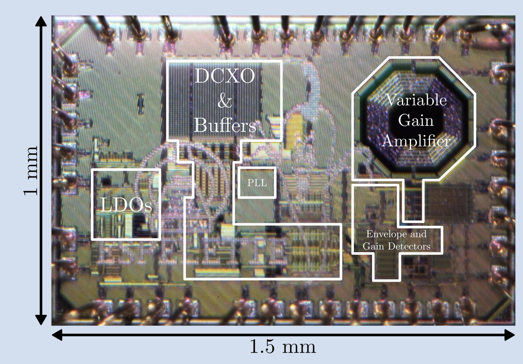
2 Control Setup & ASIC Architecture

- Synchronization: Broadcasting an RF tone around **1 GHz** in **ISM** or **SRD** frequency bands
- Sensor commands: Overlaid **AM** scheme with a two-level **ASK**



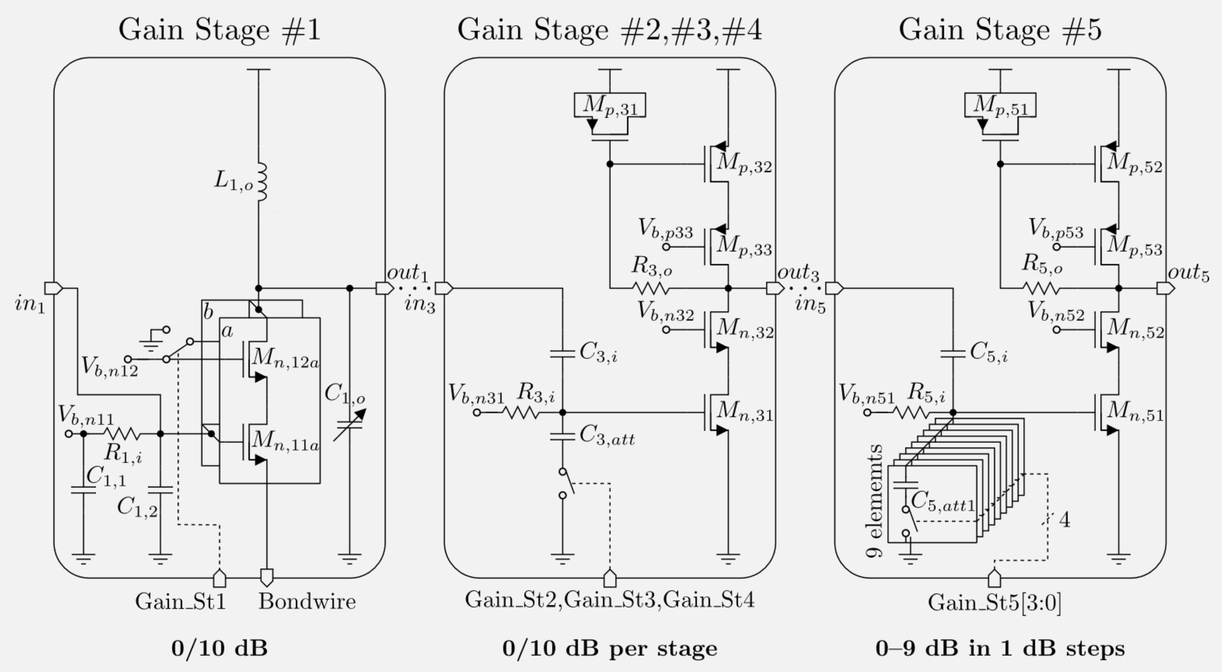
- Integrated in a bulk **65nm CMOS** technology in an area of **1.5 mm²**



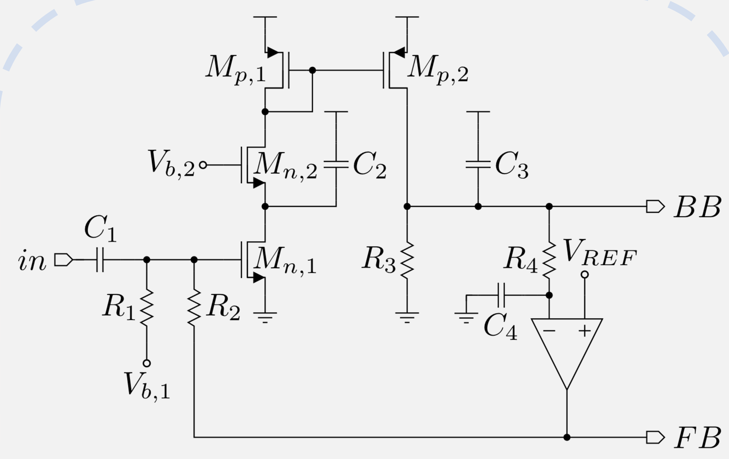


3 Circuit Implementation

- **Five** successive amplification **stages**
- 70 dB of gain: **49 dB range** in **1 dB steps**
- **Active inductance** as load for stages 2–5 [2]

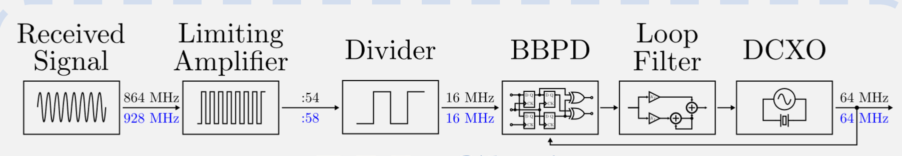


ASIC VGA

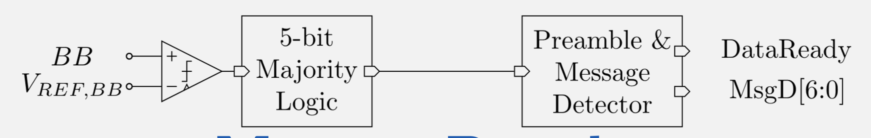


- **Envelope extraction** of the input signal
- Further filtering to **estimate** the **signal level**

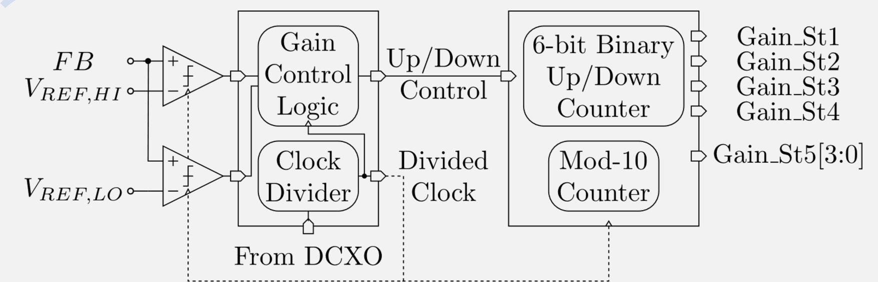
Envelope Detector



PLL Chain



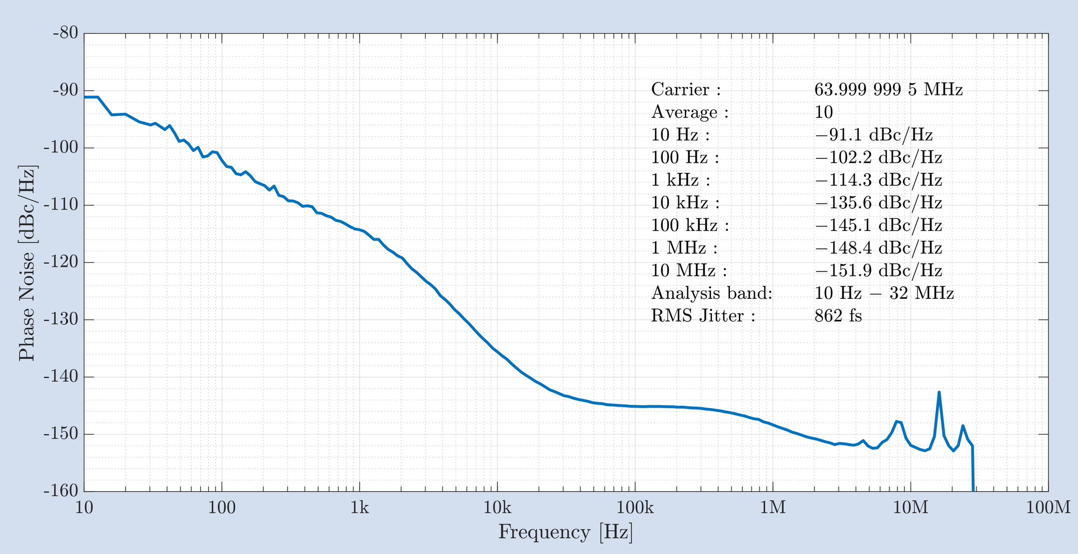
Message Decoder



Gain Detector

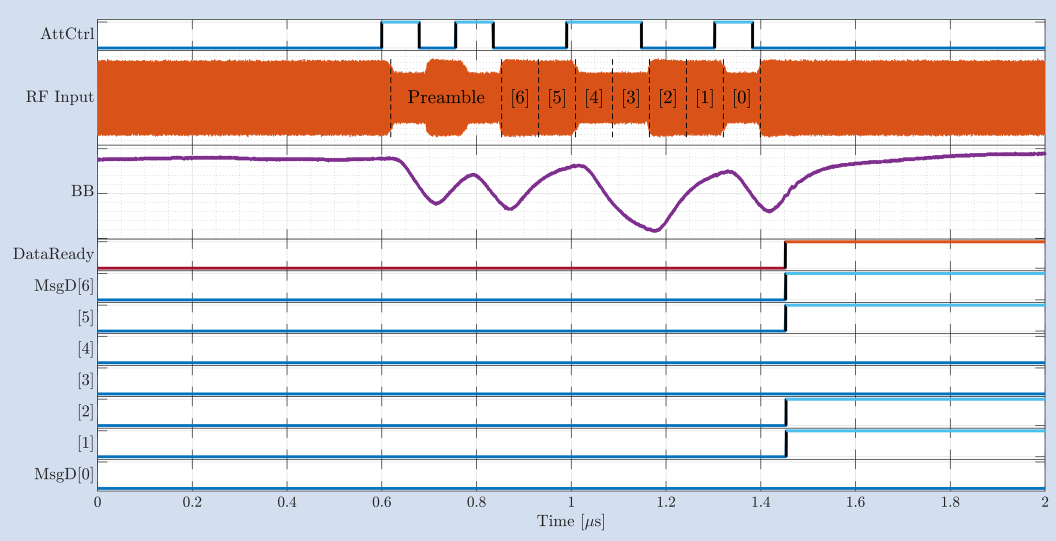
4 Measurements

Verified in a 3T whole-body MRI system

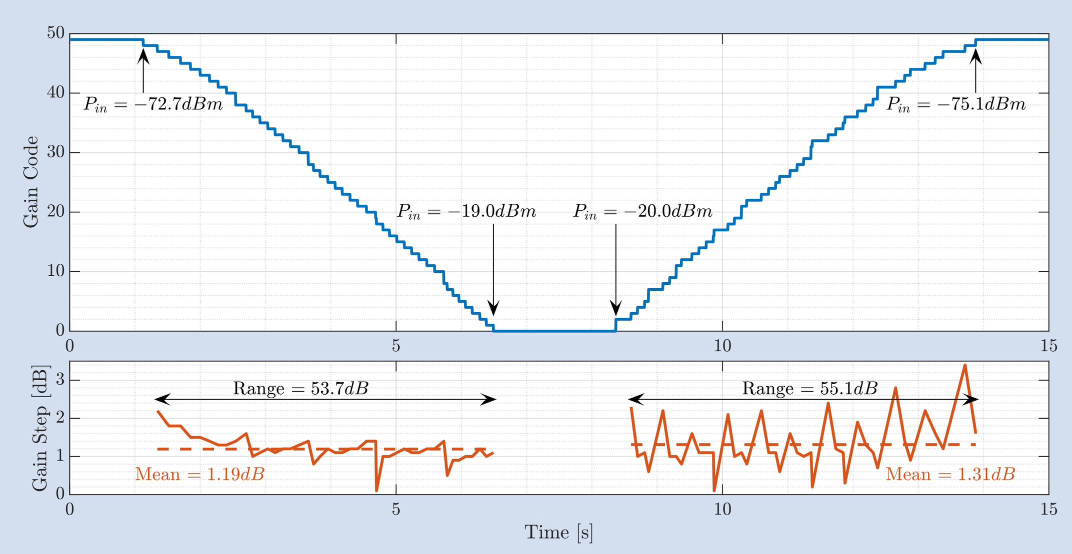


✓ PLL locked for $\mathbf{P_{in} > -57}$ **dBm**

✓ Sub-picosecond integrated jitter



✓ Successful transmission of commands for $\mathbf{P_{in} > -67}$ **dBm**



✓ Monotonic gain switching with a sensitivity below **−75 dBm**

5 Conclusion

- ASIC + Control setup → Continuously synchronize while concurrently communicating with sensors in an MRI system
- Only 5.2 mW, including two LDOs to power the crystal oscillator
- Sensitivity sufficient to compensate for the system's clock transmission loss

References

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