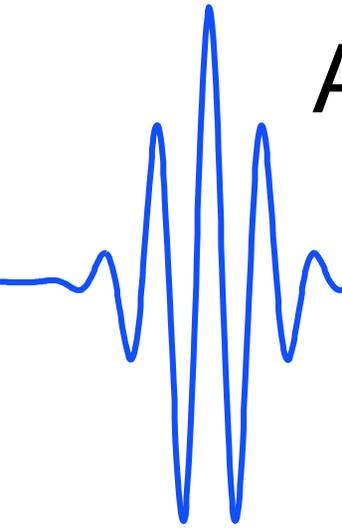
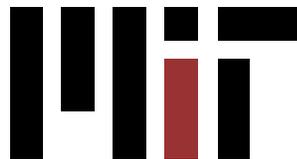


RM01D-3



A 3.1-10.6 GHz Ultra-Wideband Pulse-Shaping Mixer

David Wentzloff and
Anantha Chandrakasan



Massachusetts Institute of Technology
Cambridge, MA



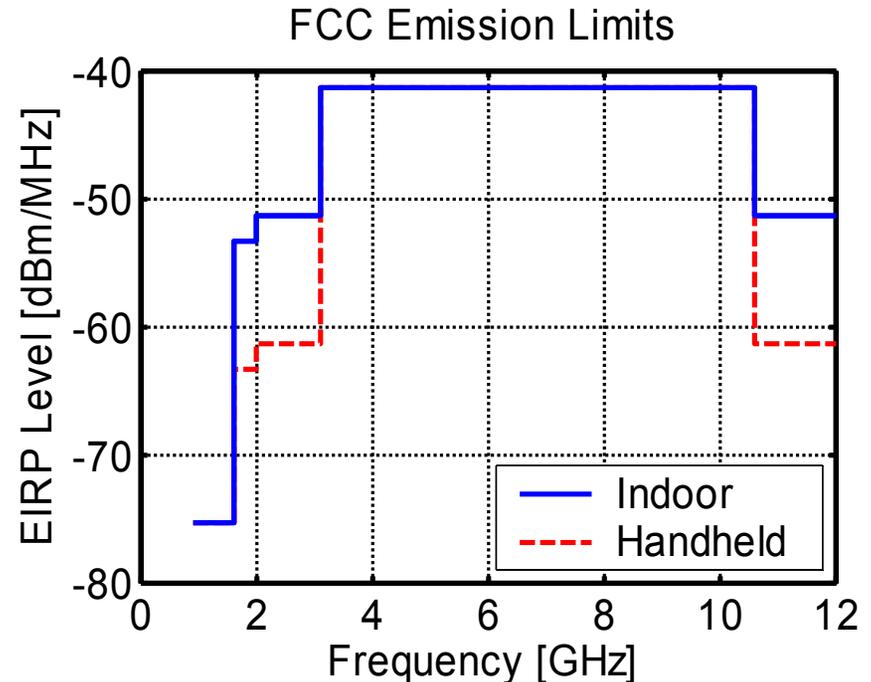
Outline

- MIT UWB transceiver architecture
- Pulse shaping and generation
- Transmitter architecture
- Results



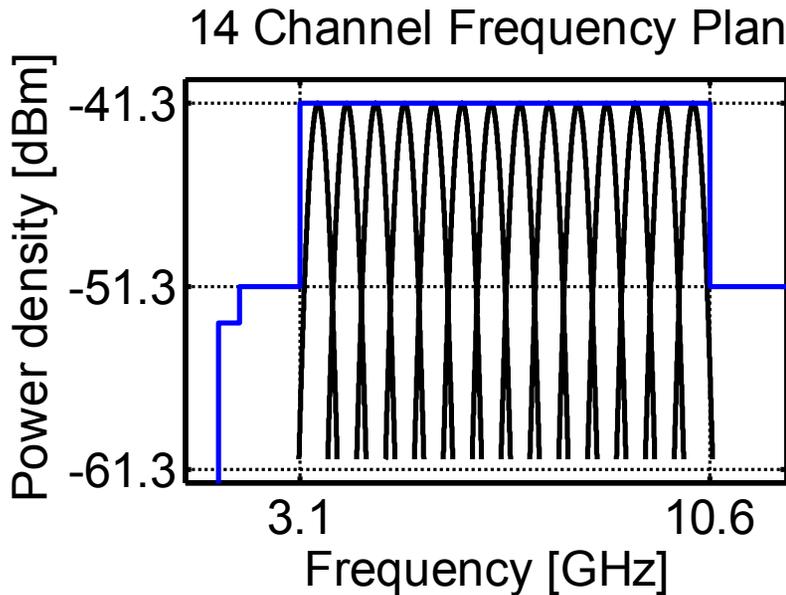
UWB Overview

- UWB is an overlay technology
- FCC restrictions
 - Min BW: 500MHz
 - Max avg. power: -41.3dBm/MHz
- 802.15.3a
 - 1st generation: 3.1~5GHz
 - Pulses in one 1.3GHz channel
 - OFDM in three 528MHz channels, hopping

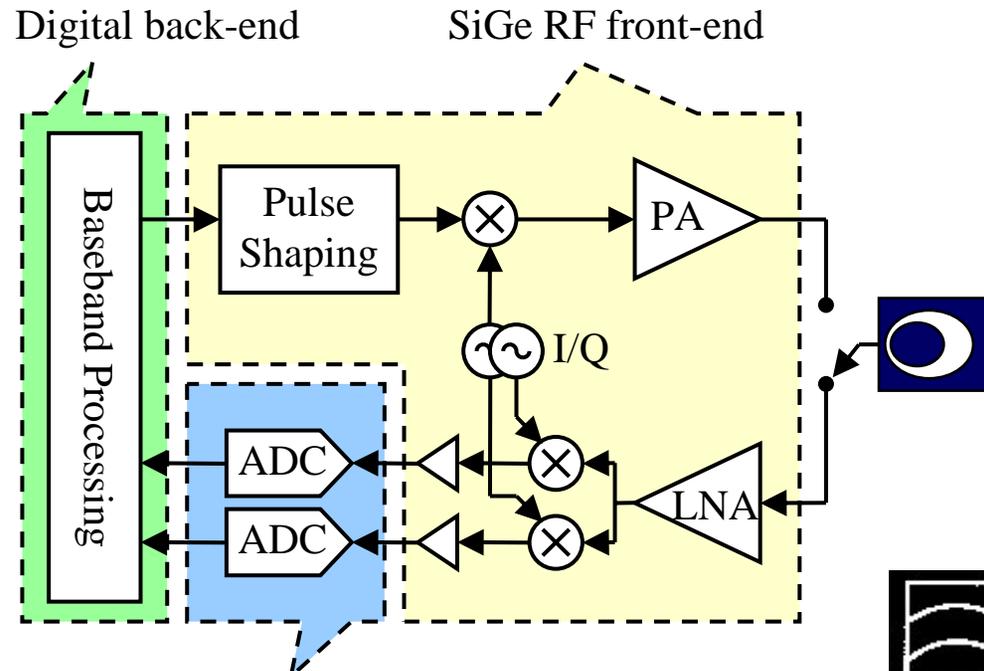


MIT Architecture

- Message transmitted in BPSK Gaussian pulses
- Direct-conversion to/from the UWB band
- 4-bit ADC sufficient for AWGN and interferers
- All synchronization and demodulation in the digital domain



RFIC - Long Beac



5-bit, 500MS/s dual ADC



Design Challenges

- Generate Gaussian pulse shape
- Tunability from 3.1-10.6 GHz
- Matched BPSK pulses
- Meet FCC requirements, spectral mask, LO feedthrough

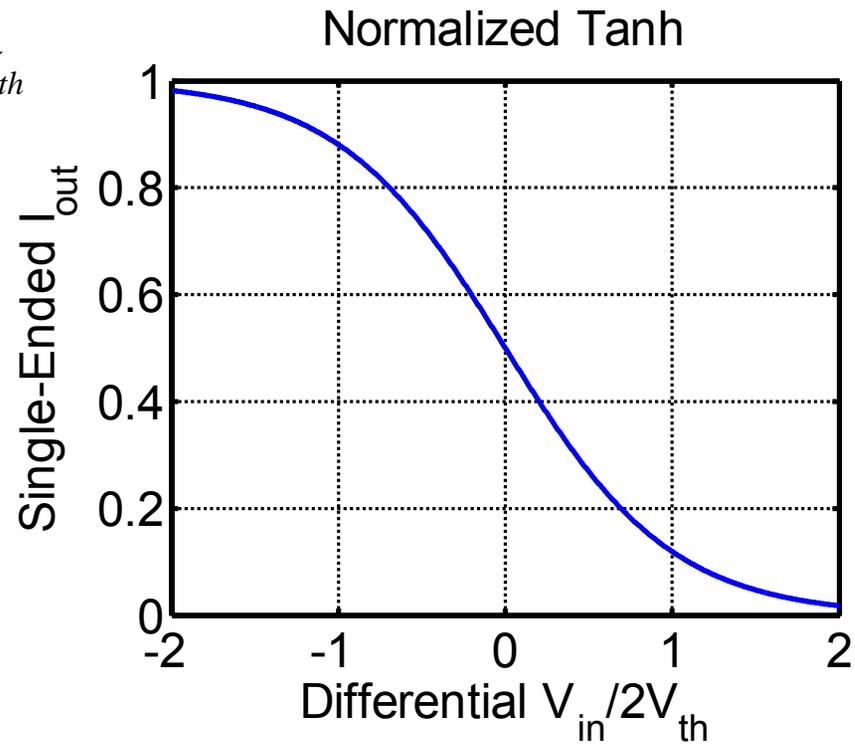
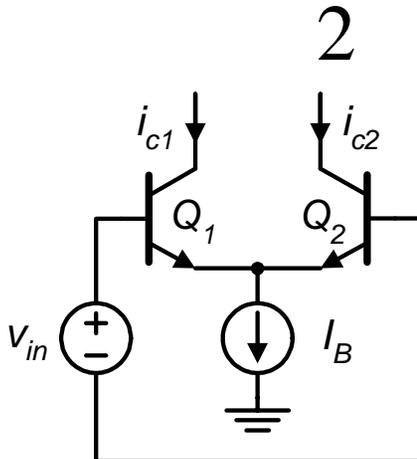


Gaussian Approximation

- Exploit exponential behavior of a BJT
- *Tanh* response used to approximate a Gaussian

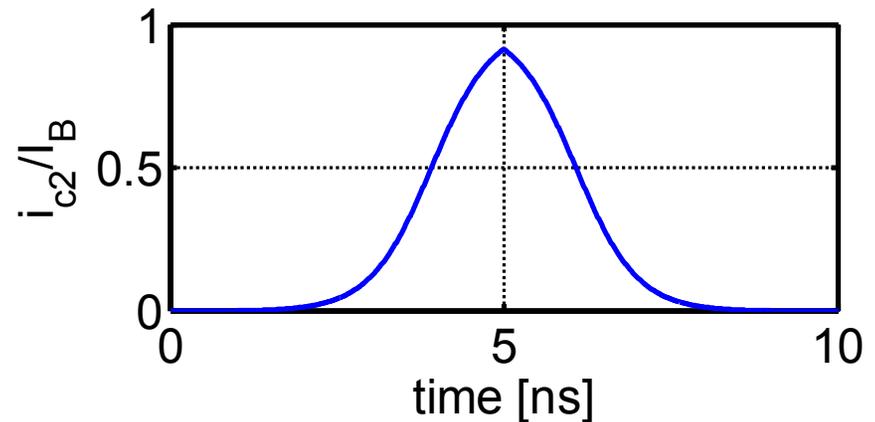
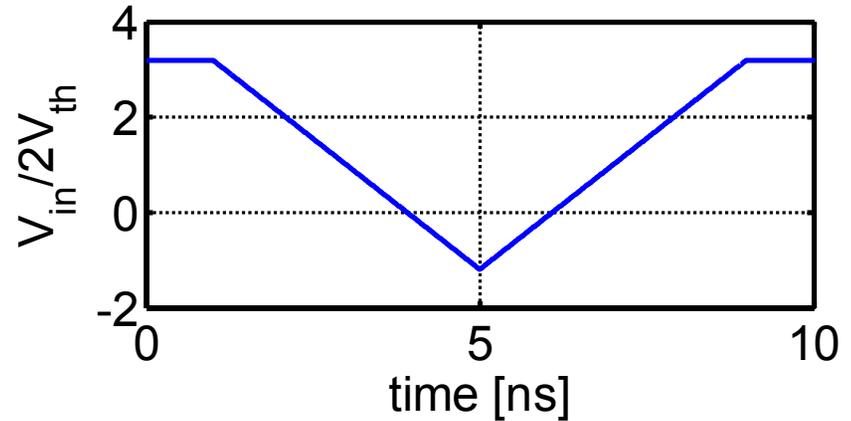
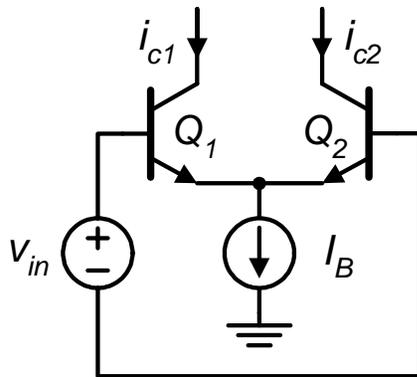
$$I_B = i_{c1} + i_{c2} \quad i_{cn} = I_S e^{v_{ben}/V_{th}}$$

$$i_{c2}/I_B = \frac{1 - \tanh(v_{in}/2V_{th})}{2}$$



Pulse Shaping

- Apply a triangle signal to differential pair
- For appropriate input signal, output current approximates Gaussian pulse

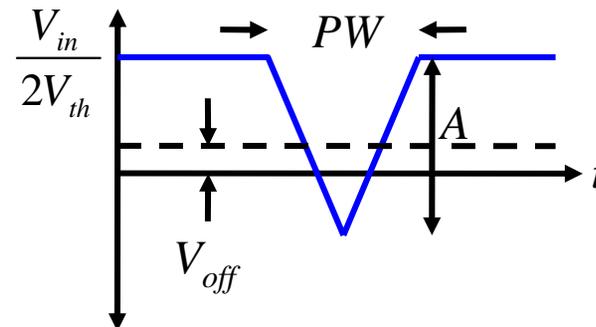


Pulse Shape Optimization

- Goal: determine A , PW , V_{off} that minimize the MSE between $\sim \tanh$ pulse and Gaussian reference pulse

$$V_{Gauss} = V_p e^{-t^2/2\sigma^2}$$

- Found empirically by sweeping parameter values and calculating MSE
- Optima found for a range of values of σ

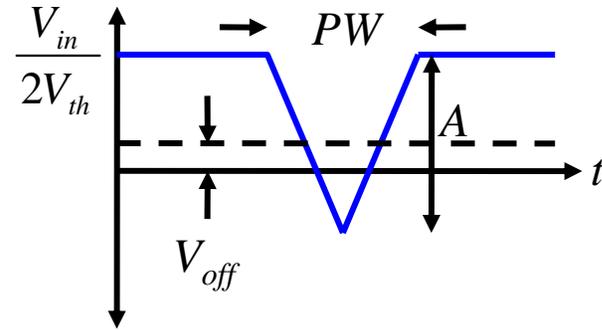


Empirical Results

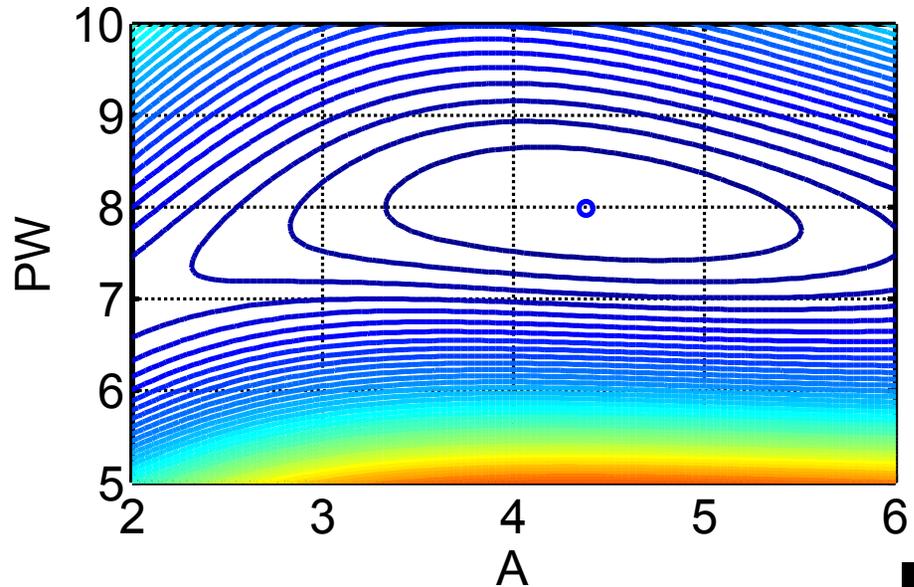
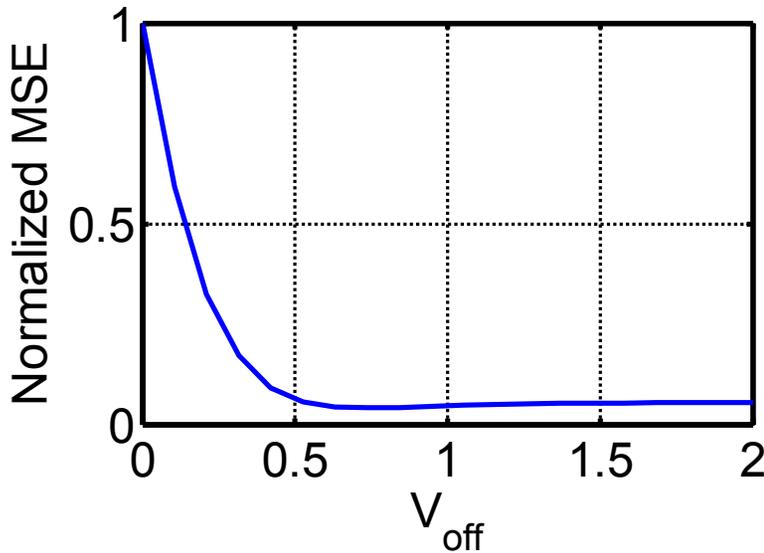
$$V_{off} \geq 1$$

$$A = 2.4 + 2.0 \cdot V_{off}$$

$$PW = \sigma(4.37 + 3.61 \cdot V_{off})$$



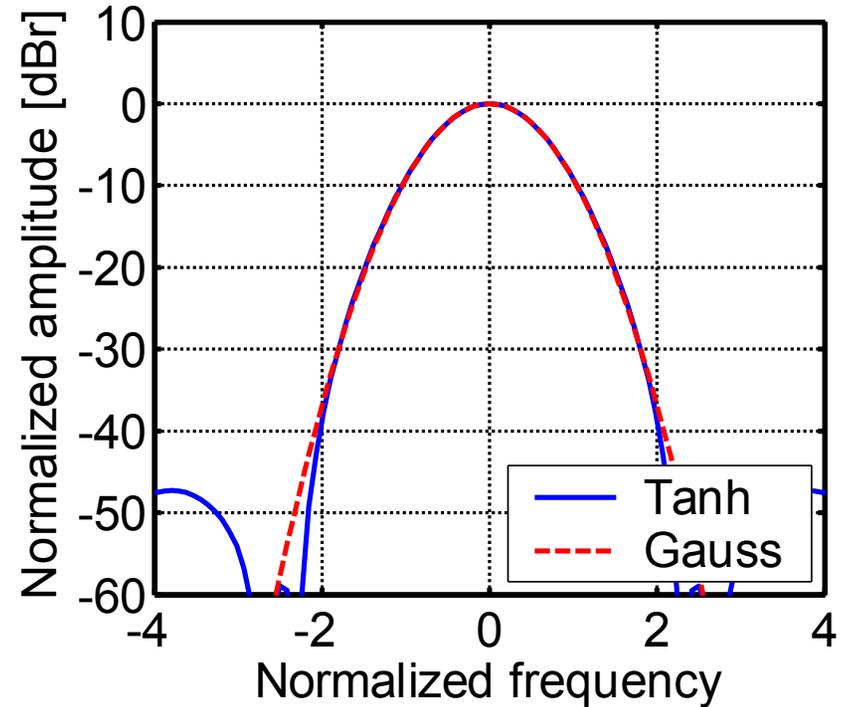
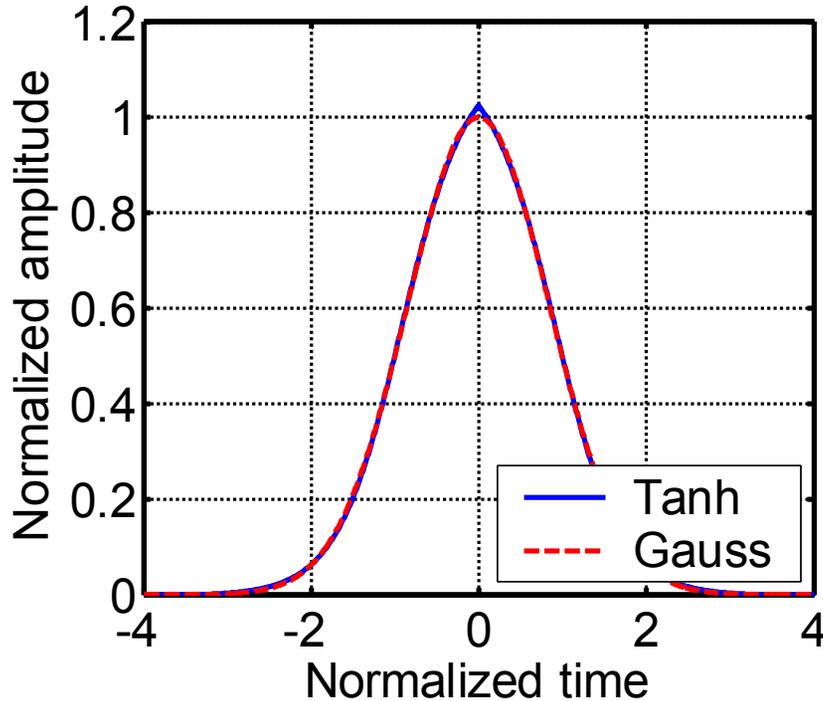
Optimum for $\sigma=1$



- Only PW a function of σ for fixed V_{off}



Resulting Pulse

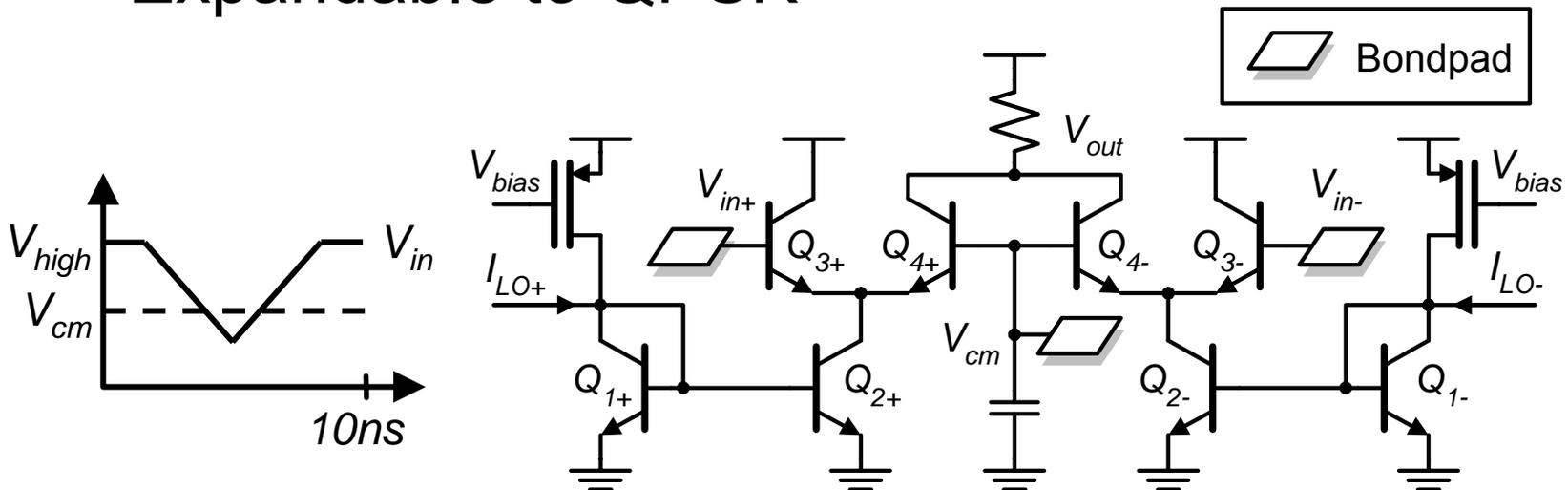


- Max in-band error in spectrum: **1.7%**
- Small percent of power out of band



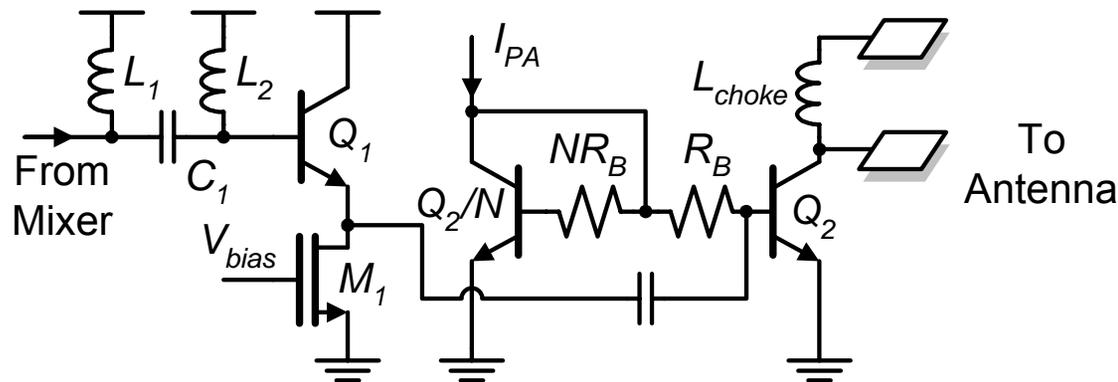
BPSK Pulse Generator

- Up-conversion, pulse shaping in one circuit
- LO feedthrough reduced by increasing $(V_{high} - V_{cm})$ until limited by parasitics, biasing
- LO cancellation from double balanced mixer
- Expandable to QPSK



RF Amplifier

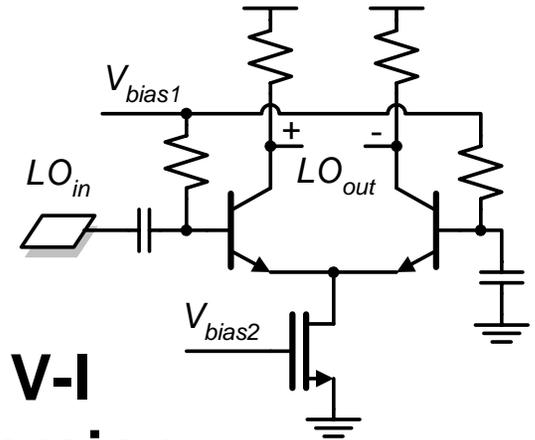
- Mixer output filtered by 2nd order highpass reducing emissions below 3.1 GHz
- Output buffered by class A amplifier
- UWB antenna provides $S_{11} < -10\text{dB}$ for UWB frequency range, open-circuit at DC



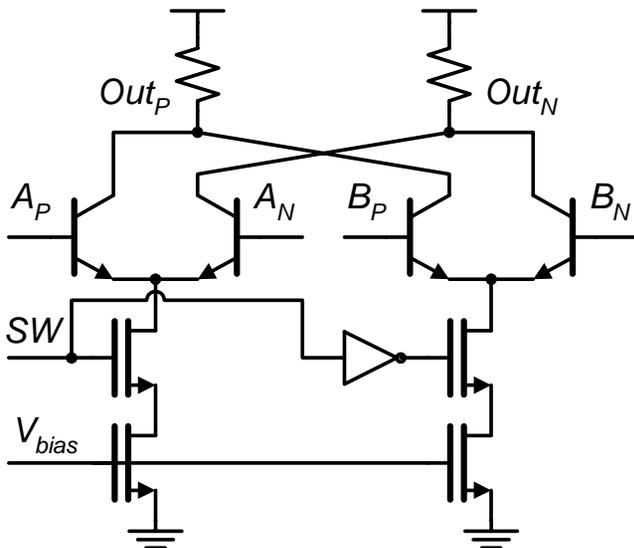
Local Oscillator Buffering

- Differential LO routing
- R-loaded ECL buffers
- V-to-I conversion from resistors driving diode-connected BJT

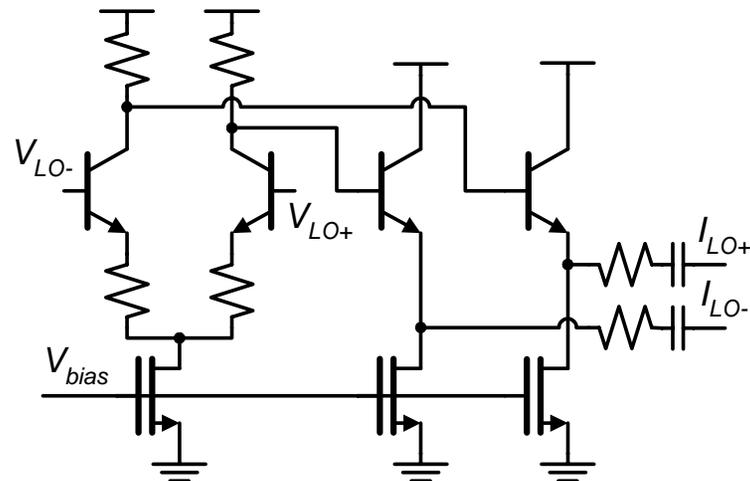
1-2 Conversion



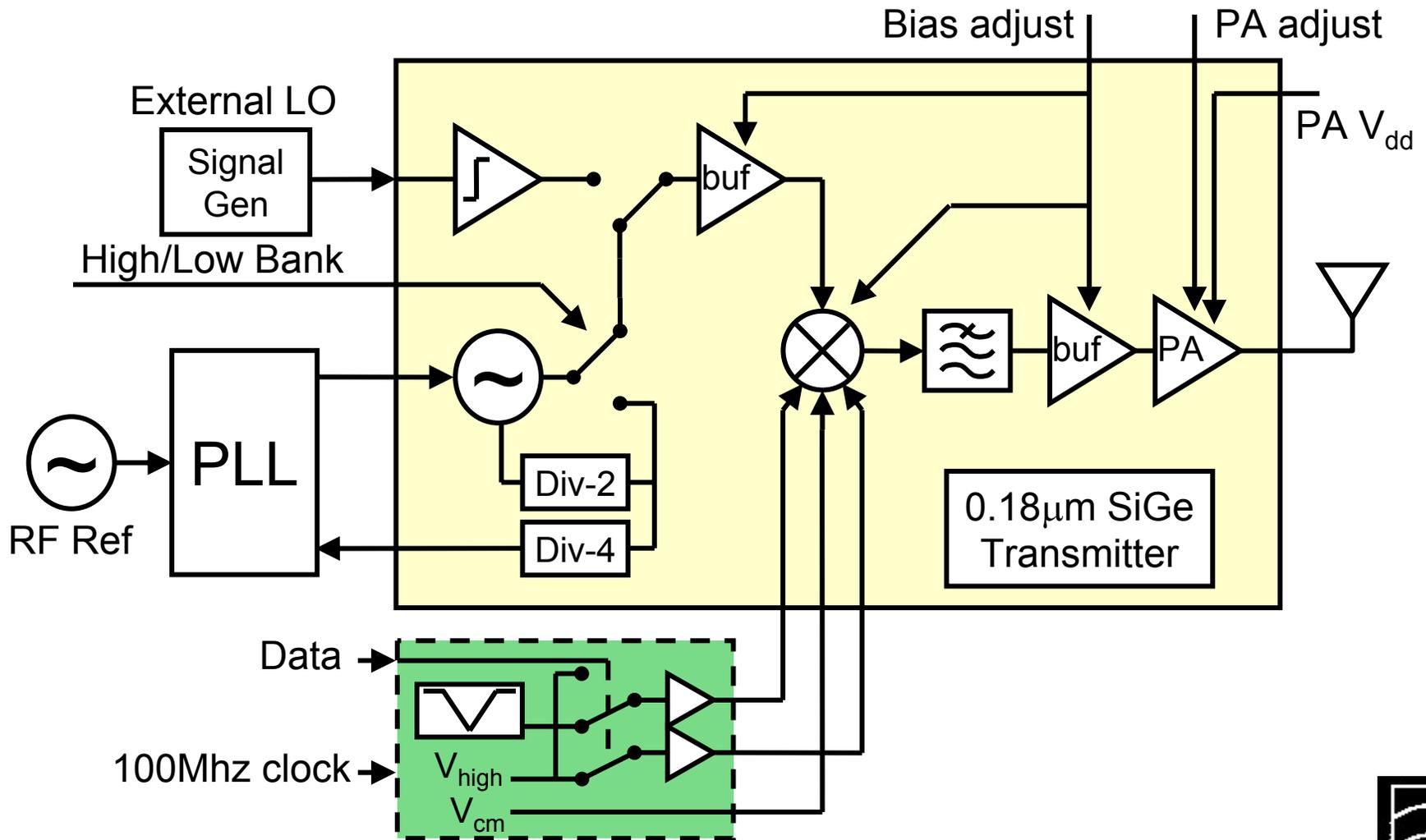
LO Switch



LO V-I Conversion

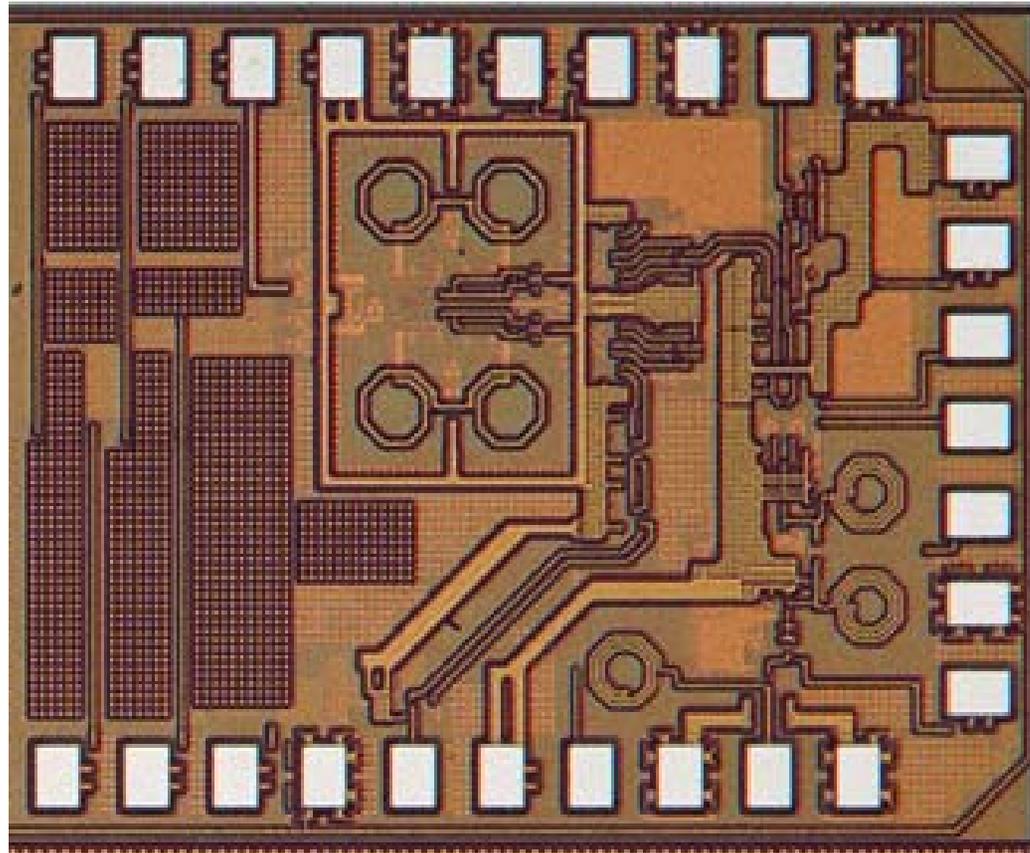


Transmitter Architecture



Die Photo

← 1.7mm →

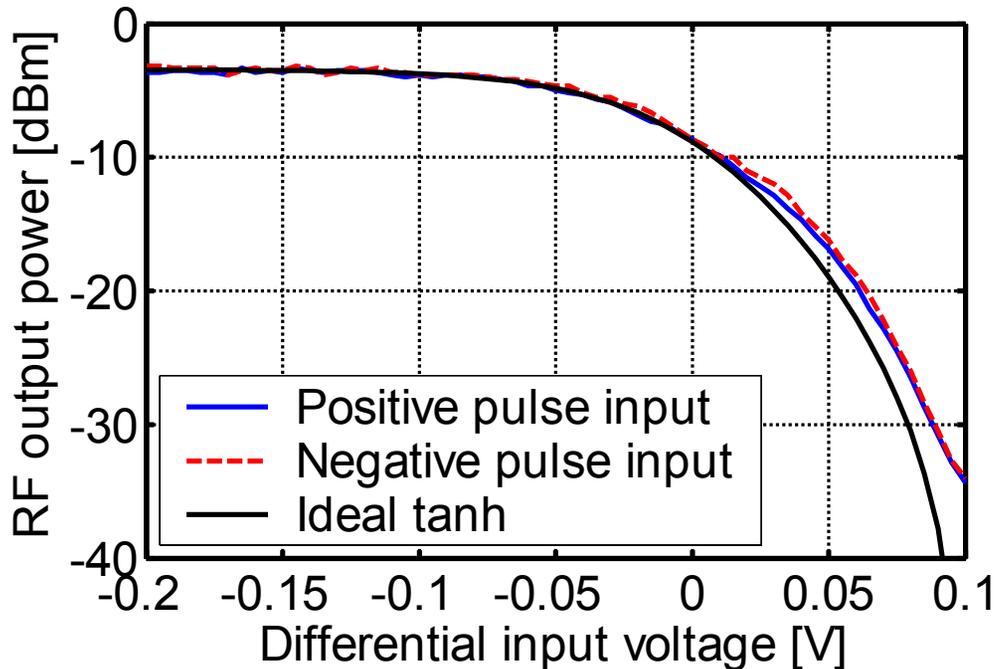


↑ 1.4mm ↓

Power [mW]	
Mixer + LO	25.2
PA	6.1
Total	31.3



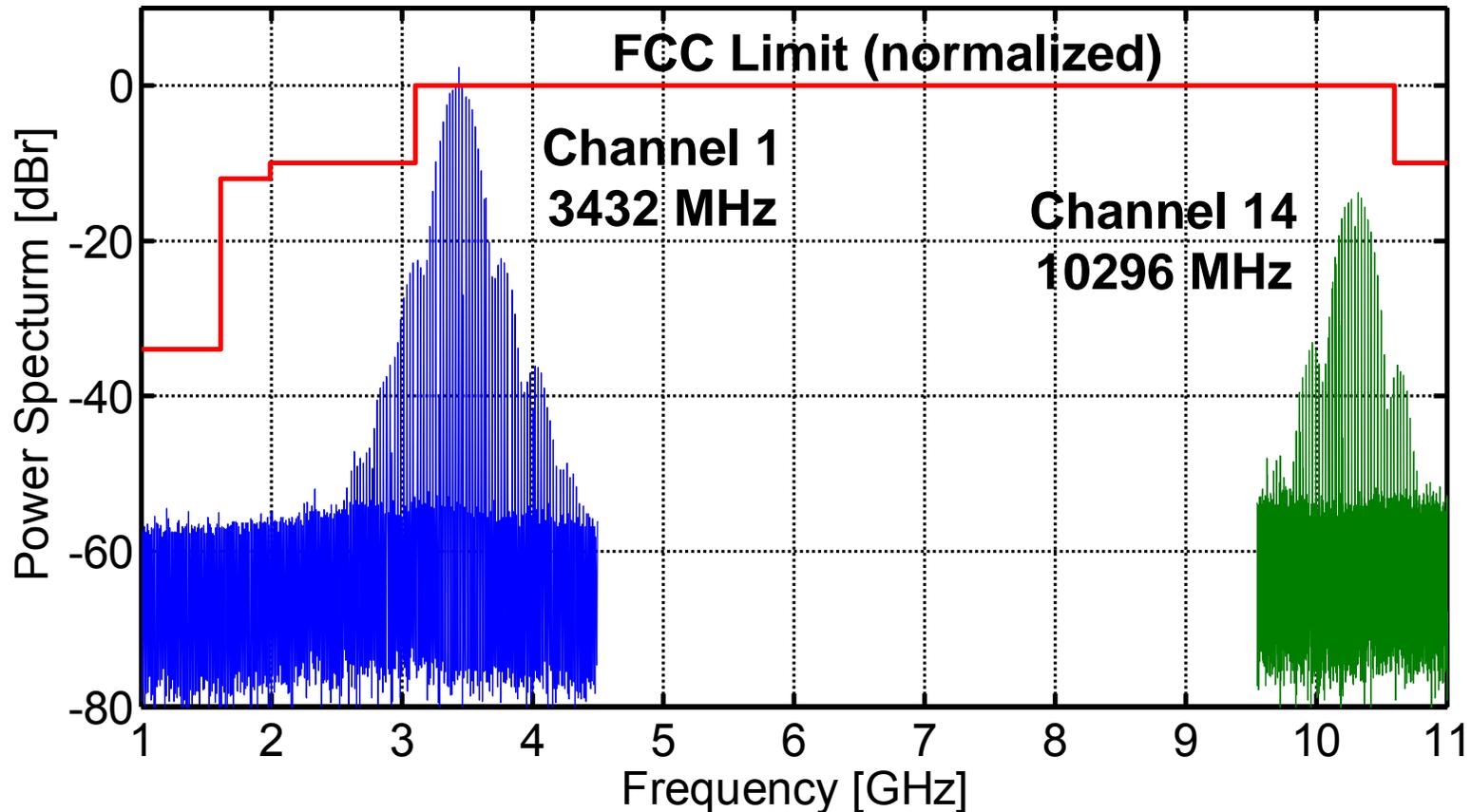
Steady-State Matching



- Measured matching with on-chip VCO
- Comparison to ideal *tanh* response
- Finite LO feedthrough



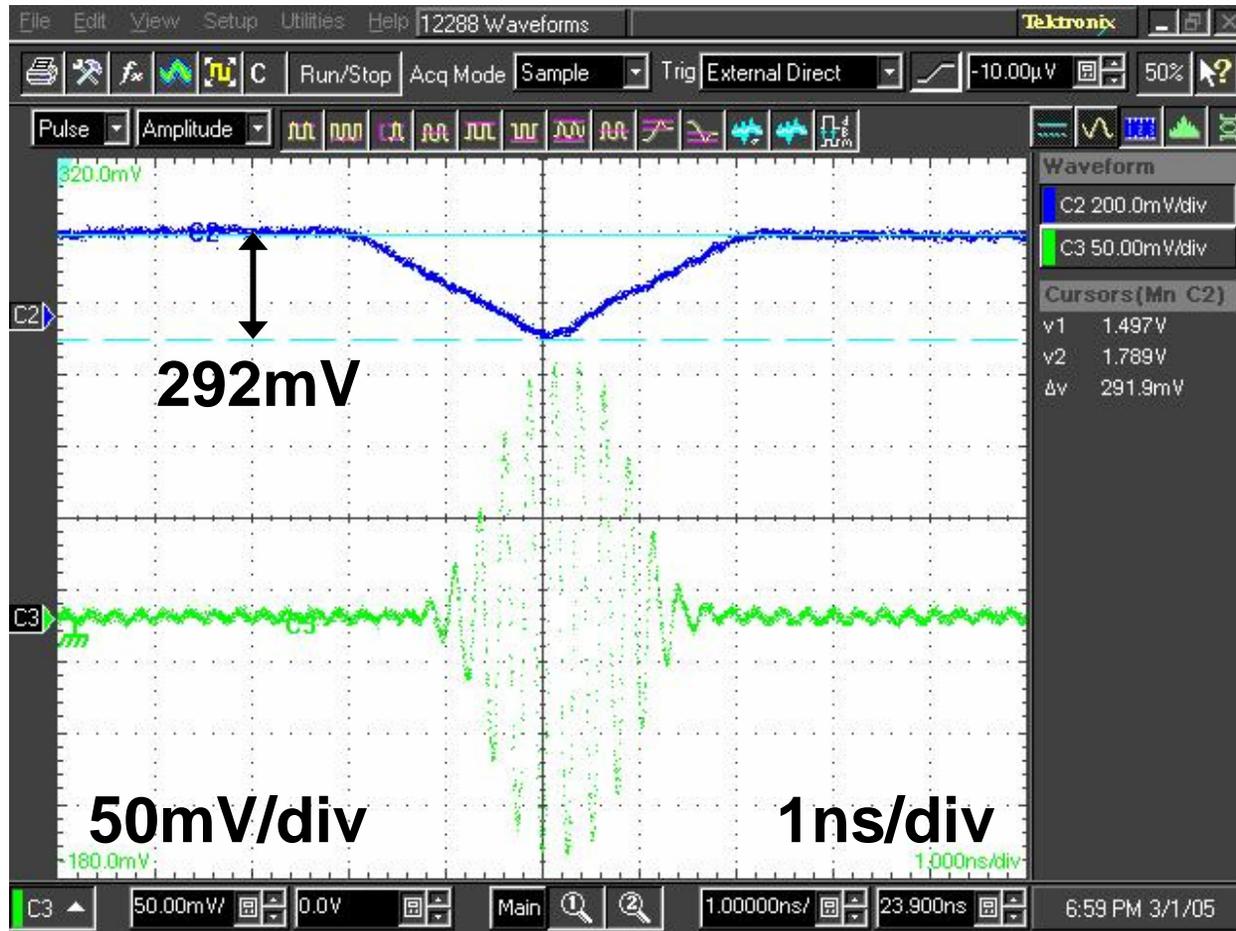
Measured Spectrum



- No spectral lines for random data
 - Amplitude reduced, spectral envelope preserved



Measured Pulse



- Pulse shaping, BPSK matching limited by packaging



Conclusions

- The Gaussian pulse shape has desirable time- and frequency-domain responses
 - Can be approximated using the *tanh* transfer function of a differential pair
- The proposed pulse shaping technique has several benefits:
 - No “reset” phase in pulse generator
 - BPSK from inverted LO
 - Mixing and pulse shaping in one circuit
 - Generate triangle with known techniques

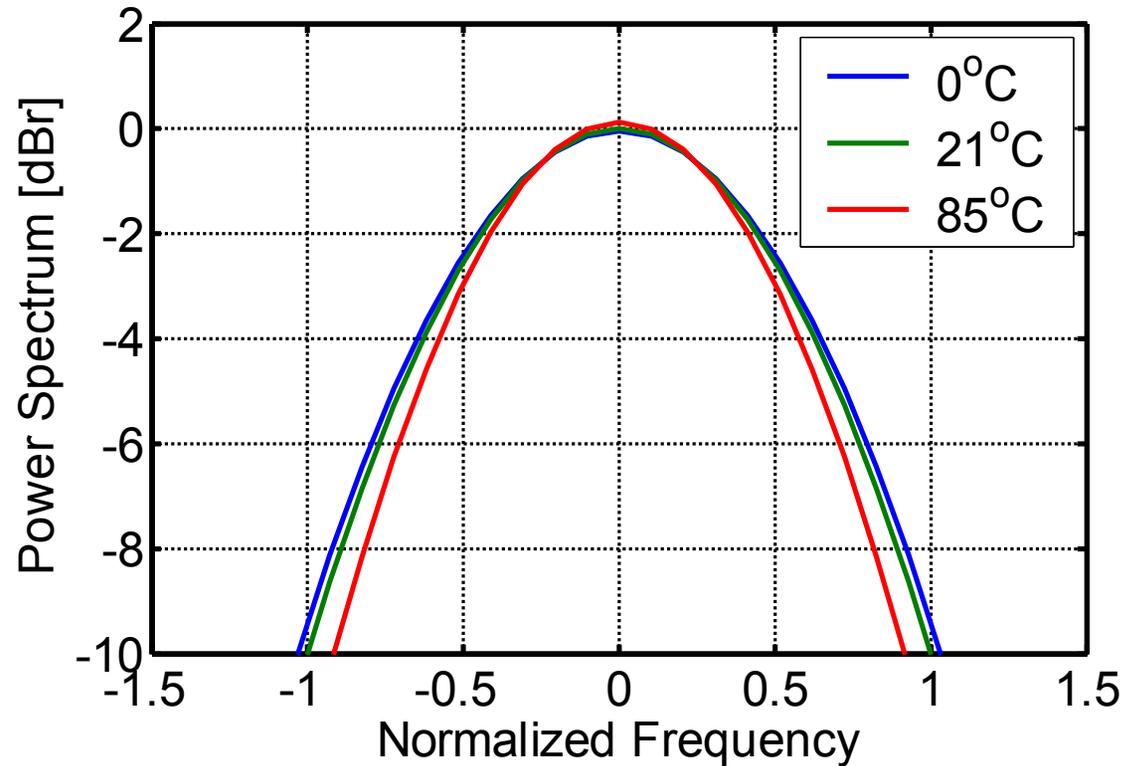


Acknowledgements

- HP-MIT Alliance
- National Science Foundation



Modeled Temperature Variation



- Between 0-85°C
 - 3% increase, 8% decrease in BW
 - -0.05dB to 0.13dB change in amplitude

