Impulse Radar and CTBV Processing

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Content

Content

A basic short range impulse radar

Main components:

- Pulse generator.
- Sampler with multiple-gigahertz sample rate.

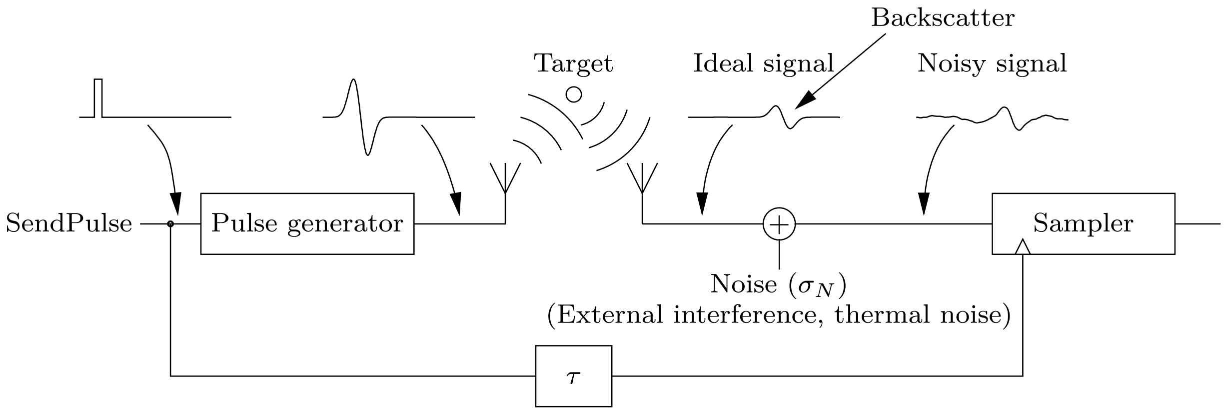

Figure: Basic radar.

Content

Overview

Swept threshold sampler features:

- Novel approach.
- Exploits high speed digital performance of CMOS.
- Less analog signal processing.
- Simple circuits.
- Enables very high sample rate.

How it works (1)

- Threshold input signal (analog → continuous-time digital signal).
- Sample digital value at high rate.

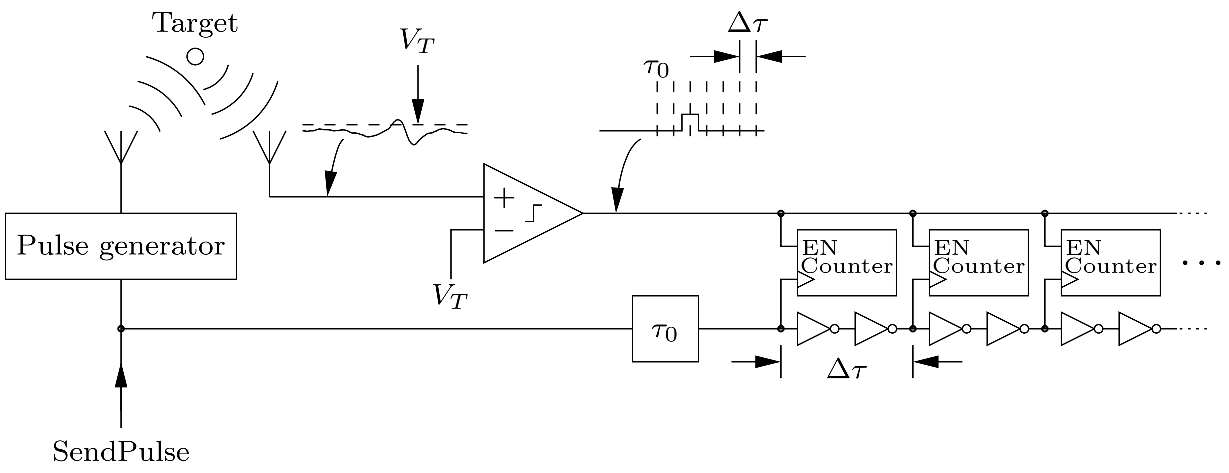

Figure: Swept threshold sampler.

How it works (2)

- Repeat for all threshold levels.

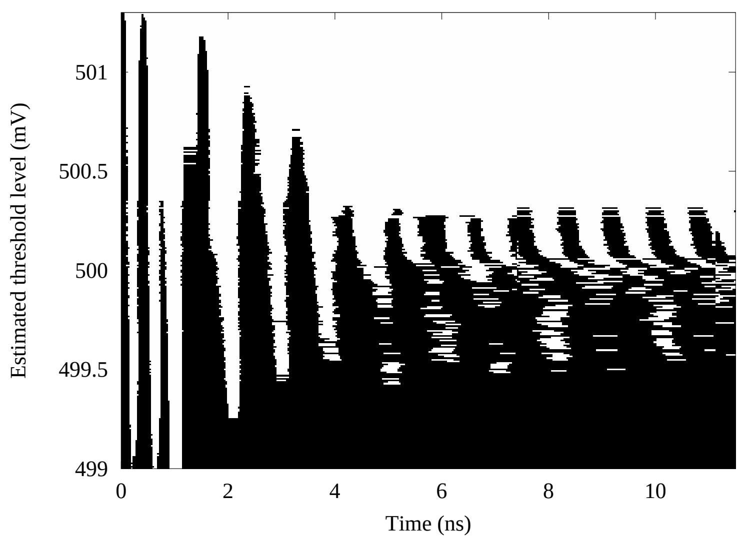

Figure: Sweep of threshold level.

How it works (3)

- Sum vertically to get readout curve.
- Use repetition to average out noise.

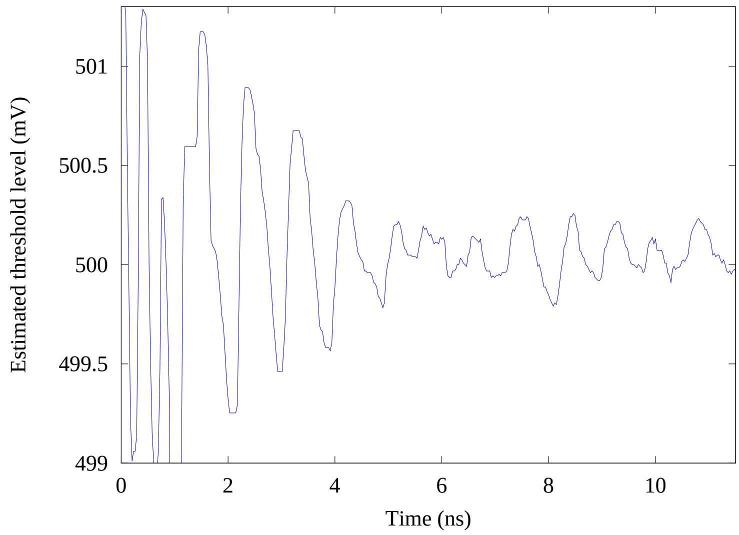

Figure: Radar readout curve.

Content

What if there is very much noise?

If noise ≈ signal:

- Leave threshold at DC level, don't sweep (the threshold will always be able to "get hold of" the signal due to the noise).
- Integrate a lot of samples.

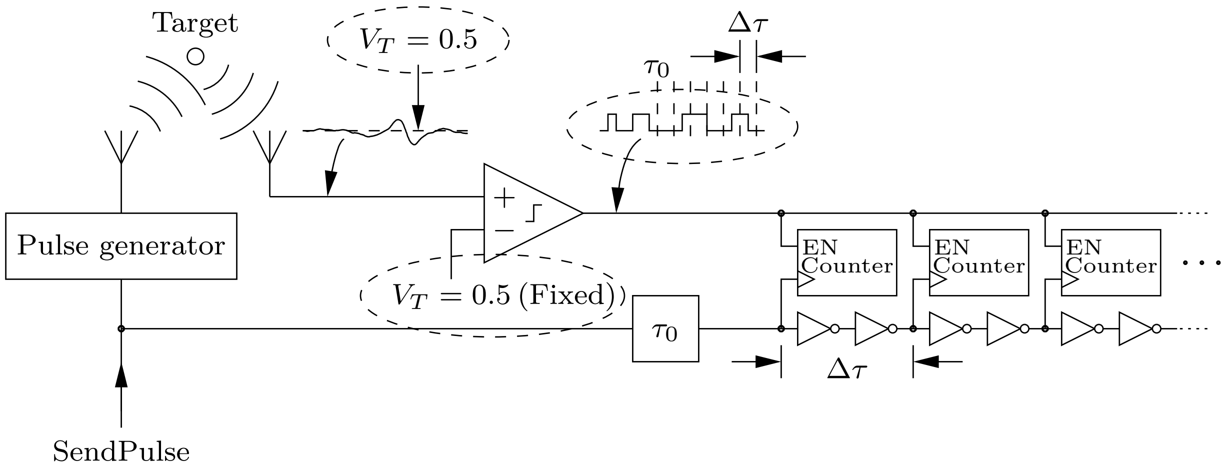

Figure: Stochastic resonance sampler.

How to read out a signal

- Readout value is $P(V_{in}(\tau) > 0.5)$ (plus some noise).
- Use that value to calculate signal value in units of σ_N.
- If σ_N is known, calculate the signal voltage value.

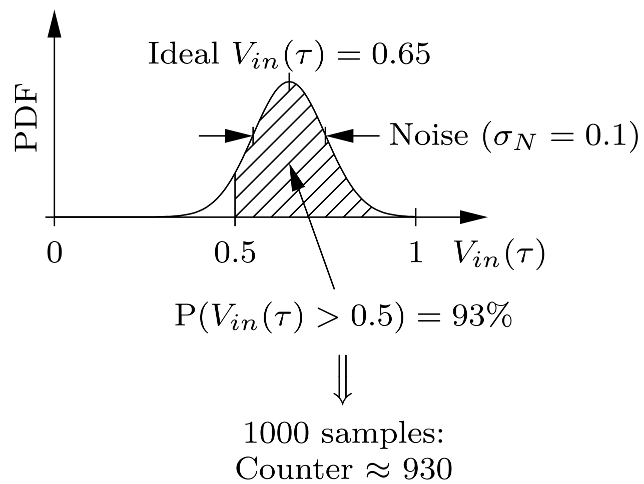

Figure: Stochastic resonance sampling principle.

Properties of stochastic resonance sampler

- We call this "stochastic resonance sampling" (after the "stochastic resonance" effect).
- Simple system, but actually very close to ideal sampler.
- Requires very much noise (low SNR).
- Not currently used in the radar (too high SNR).

Integration required to achieve a given SNR.

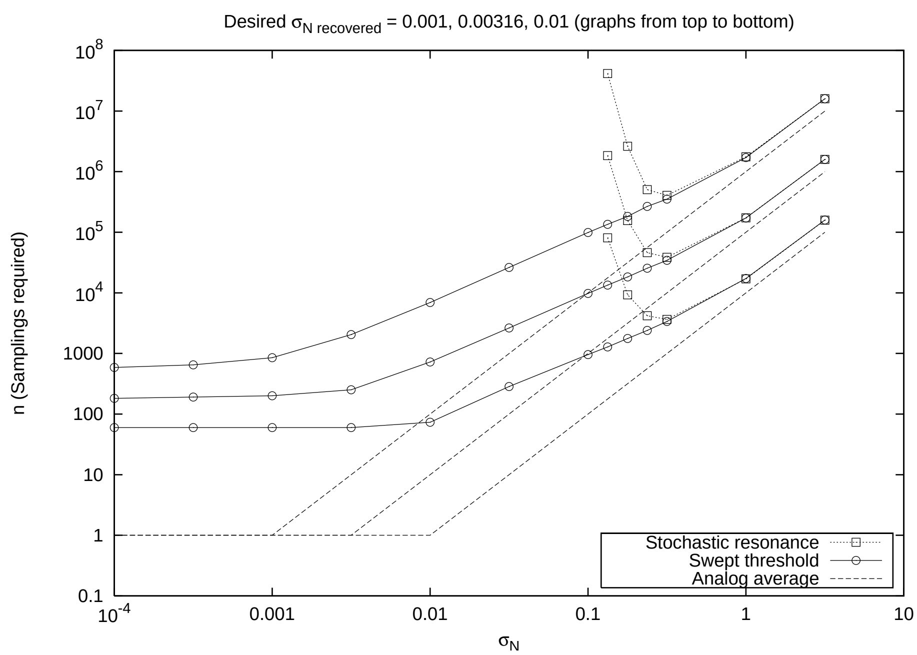

Figure: Integration required to achieve a given SNR.

Content

Implementation

- Approx. 1×1 mm 90 nm CMOS chip.
- Sweep controller logic on chip.
- SPI for setting registers and getting readout.
- 35 GHz sampling rate.
- 128 parallel samplers.
- 48 MHz PRF.
- Detecting millimeter-movement at close range.
- Detecting centimeter-movement at 15 m distance.

Pulse generator.

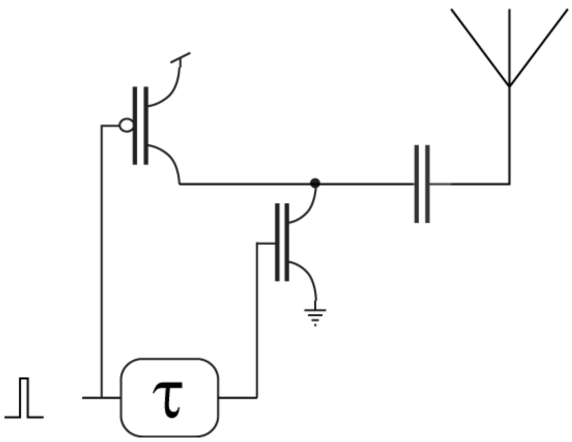

Figure: Pulse generator.

Programmable initial delay.

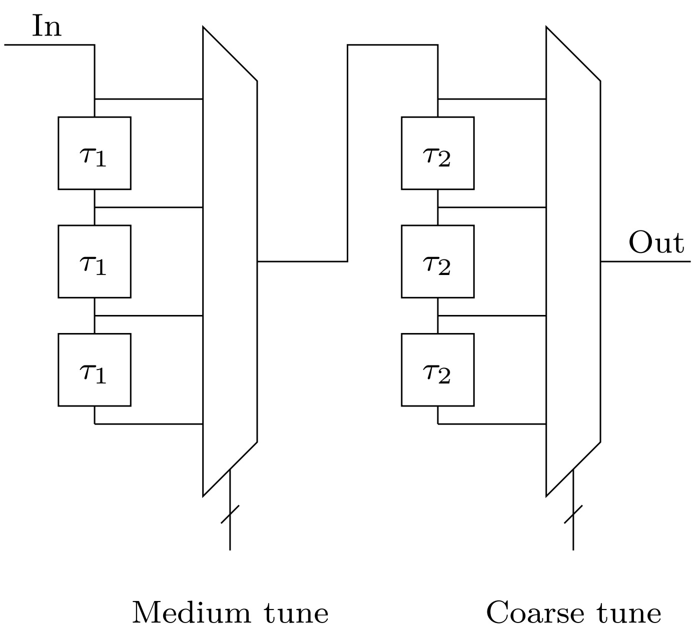

Figure: Programmable initial delay.

Zoom-thresholder.

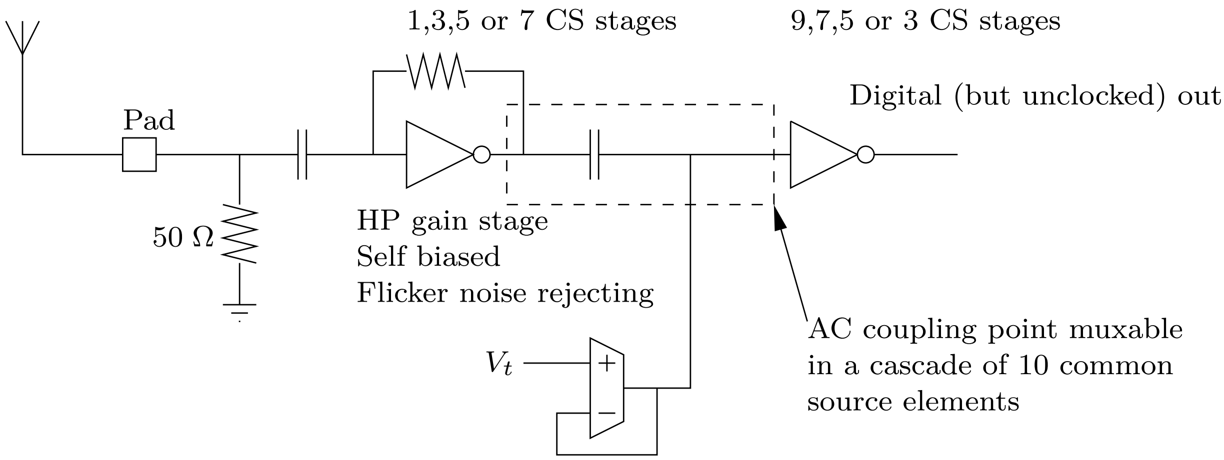

Figure: Zoom-thresholder.

Zoom-thresholder common source element.

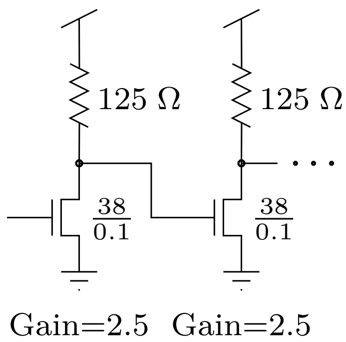

Figure: Zoom-thresholder common source element.

Content

Continuous-Time Binary Value (CTBV) signal processing

Unclocked digital signals worked well for radar. Trying to generalize, introducing the term:
Continuous-Time Binary Value (CTBV) signal processing.

		Time	
		Discrete	Continuous
Value	Binary	Digital	CTBV
	Continuous	Analog sampled-data (switch-cap...)	Analog

Figure: Signal processing domains.

CTBV signal representation.

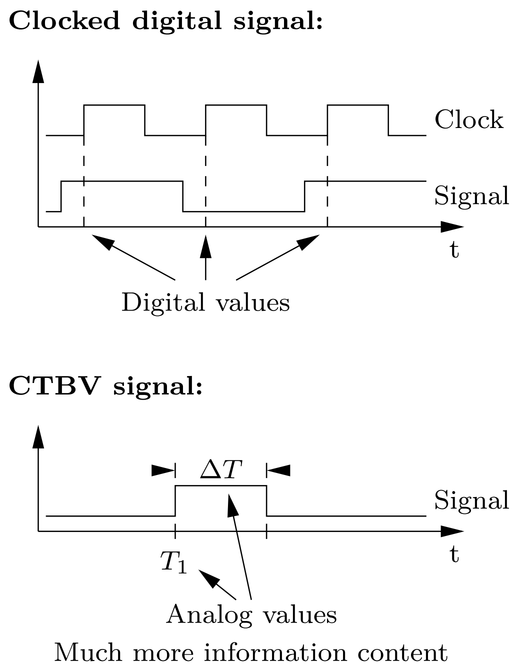

Figure: CTBV signal representation.

CTBV example circuits.

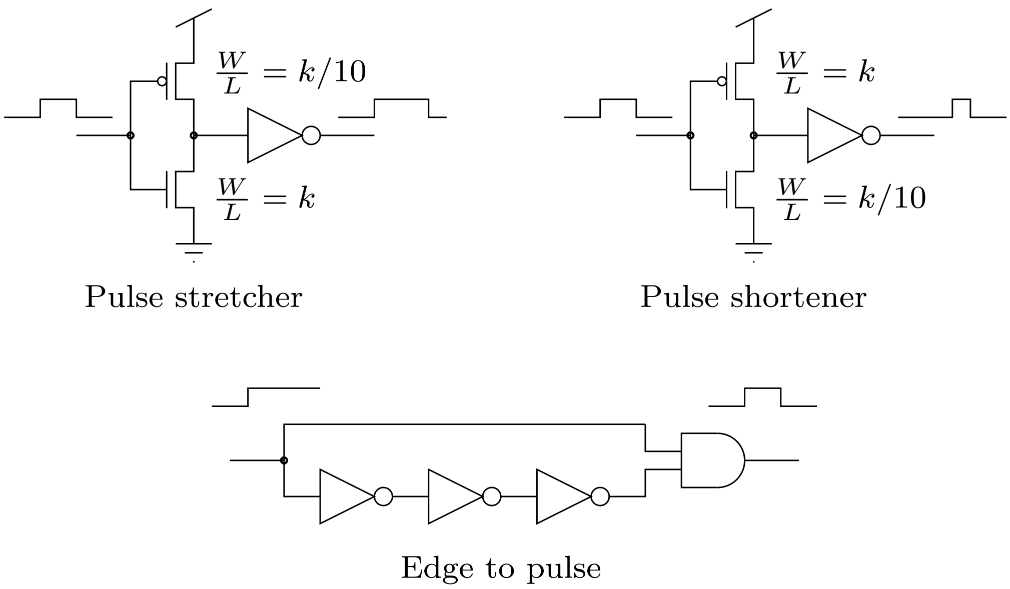

Figure: CTBV example circuits.

CTBV operations

Some CTBV operations:

- Delay.
- Logic.
- Pulse shaping.
- Sampling.

CTBV advantages

Advantages of CTBV signal processing:

- Advanced processing (pattern detection, etc.).
- Simple circuits.
- High speed. Gate delays (10–20 ps) or below (using time differences).
- No clock: Faster, saves power.
- Low power (simple, unclocked cicuits).
- Perfect for fine-pitch CMOS technology (cheap, high speed digital, poor analog performance).

CTBV challenges

Challenges with CTBV signal processing:

- Limited functionality: Not a general replacement for the other signal processing domains.
- Minimum pulse width requirements: Too short pulses might get lost.
- Phase noise: Limits the SNR of the signals (e.g. a pulse width).
- Device mismatch: Unpredictable delays.

CTBV future work

What can be done with CTBV?

- Bubble-sorter (successfully implemented).
- Parallel counter (may be used in UWB-IR data receiver).
- More advanced circuits?

The End

Questions?