

An RF Solution to the Dead Reckoning Problem

What is Dead Reckoning?

The canonical way to attempt to tell how far a wheeled robot has moved is to count rotations of the wheel. This method of determining position by how far the robot has moved is called **dead reckoning**. One way to do this would be to have an optical sensor near the axle count spokes passing a point as the wheel rotates.

What's the Problem With Dead Reckoning?

The problem is **slip**. The wheel is continually slipping, and so just because the robot is traveling doesn't mean the wheel is rotating. Errors are cumulative, and even very small slips add up.

An RF Solution

A remote station broadcasts a sine wave. A receiver on the robot compares the phase of the sine wave to that of a locally generated reference. The distance from the station to the robot can be determined from the phase difference, and with several stations, triangulation can be used to get the robot's position.

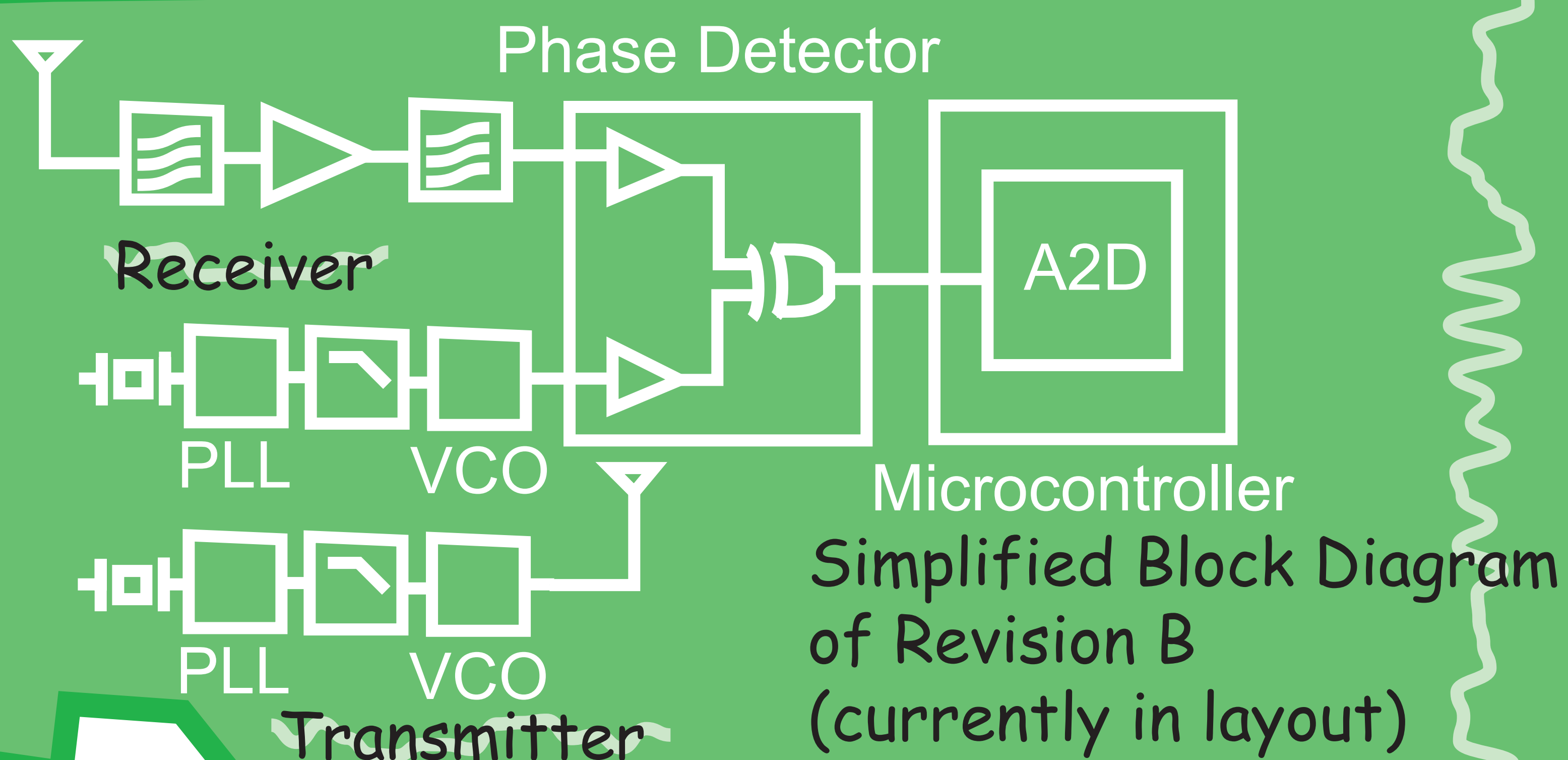
Determining Distance

The distance between the robot and the station is given by $\lambda * (n + \phi/360) + \alpha$.

- λ is the wavelength of the sine wave
- ϕ is the phase difference
- α is the distance between the two when the system is started
- n is a count of the number of **abrupt** 180 to -180 transitions minus the number of abrupt -180 to 180 transitions the robot has encountered

What About Slip?

Unless the robot moves so fast that the abrupt transitions cannot be detected, there is no need to worry about slip.



Abrupt 180 to -180 transition

The phase difference goes as a saw wave with respect to the distance between the broadcasting station and the robot.

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Key Design Considerations

RF Band Selection

Small changes in phase are difficult to detect. Therefore, λ needs to be small enough that a measurable change in distance results in a detectable phase shift. The commercially free 2.4GHz band is ideal. Many components are available and the wavelength is about .125m, so that one degree of phase shift equals .35mm.

Phase Detector Design

The phase detector must have no amplitude dependence. The design uses logarithmic amplifiers to convert both inputs into square waves of equal amplitude. These signals feed an XOR gate. This results in a detection based entirely on zero crossings.

Phase Locked Loop Optimization

Noise can vary the sine wave's phase, frequency and amplitude. All of these can contribute to fake zero crossings.* The system's PLL is the primary determinant of signal integrity. Our PLL's loop filter is optimized to minimize RMS phase noise and obtain the lowest reference spurs possible while keeping the high order capacitor well above the VCO's input capacitance. The reference frequency is also chosen to be as large as possible to minimize reference spurs near the center frequency. Since the device does not need many channels nor need to switch channels, there is no downside to these optimizations.

*we can low pass filter the phase detector's output to eliminate some of the inevitable noise that accompanies all systems

Could This Thing Work?

Simulations indicate that the phase is detectable to about 2 degrees, for an accuracy of .7mm. In addition, the analog to digital converter in the microcontroller is capable of about 75,000 samples per second. If you assume it needs 100 samples per wavelength not to slip, it could support a unit traveling up to 210 miles per hour!