Typical Doppler Signal Amplifier

Application Note AN-04

AN-04 Typical Doppler Signal Amplifier

About This Document

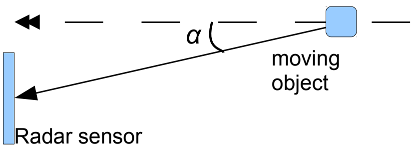
This application note describes a simple IF signal amplifier for Radar sensors without internal amplifier. The described circuit covers a typical application for person detection. It can and should be adapted to the specific application.

Consider using our Starter Kit ST100 to get familiar with Doppler Radar sensors.
Please find more information here: http://www.rfbeam.ch/products/st100-starterkit

Doppler Signal Basics

A moving object in range of a Radar sensor (often called "transceiver ") generates a low frequency output signal. Frequency depends on the object speed. Amplitude depends on distance, reflectivity and size of the object. Doppler frequency f_d is proportional to the object speed v:

$$f_d = v \cdot \frac{44\text{Hz}}{km/h} \cdot \cos\alpha$$ or $$f_d = v \cdot \frac{158\text{Hz}}{m/s} \cdot \cos\alpha$$ with



Note that the angle of the moving object reduces Doppler frequency.

Amplifier Circuit

Most sensors of the K-LCx family do not have an integrated amplifier. This makes these devices universal and low cost. Different applications need different amplification and frequency response. Sensor output amplitude can range from less than 100nV to some mV .

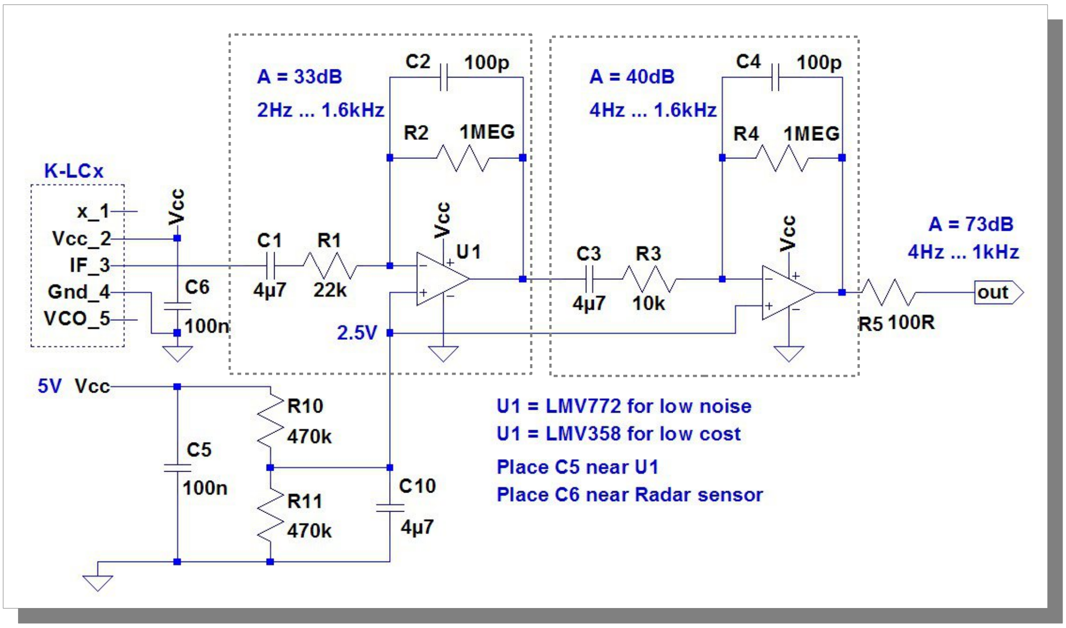


Fig. 1: Amplifier schematic

The circuit in Fig. 1 can be used as amplifier stage for person movement detectors. With K-LC1a, distances from 0.1 meters to approx. 10m can be achieved. Please refer also to our selection guide for more information on different sensors.
The following chapter shows different ways to adapt the circuit.

Component Selection

You may adapt the circuit to your application. For certain low range applications, one amplifier with a gain of A = 100 (40dB) or less may be sufficient.
Components in Fig. 1 have been chosen with same values where possible in order to reduce production cost.

Filter

☞ You get best results by limiting bandwidth to the real needs. For detecting Persons, this is around 4Hz to 400Hz.
Signal to noise ratio (SNR) will be increased by limiting bandwidth. The higher the SNR, the higher the detectable distance.

High pass filters in Fig. 1 are built by C1, R1 and C3, R3. They limit the lowest detectable speed.
Low Pass Filters in Fig. 1 are built by C2,R2 and C4, R4. They limit the highest detectable speed.

$$f_c = \frac{1}{2 \cdot \pi \cdot R \cdot C}$$

R2 and R4 should not exceed 1M because of offset currents and noise immunity.

Op Amp

Most applications need high gain amplification. Select operational amplifiers by following important criteria:

- Single supply type
- Input offset voltage
- Gain bandwidth product
- Noise
- Rail to rail output

LMV 772 http://www.ti.com/lit/gpn/lmv772 is an excellent amplifier with low noise and good gain bandwidth product.
LMV 358 http://www.ti.com/lit/gpn/lmv358 is an optimal choice for simple, low speed movement and low cost detectors.

Gain

Typical gain used in movement and speed detectors ranges from A=60dB (1000) to A=80dB (10'000).
Gain in Fig. 1 is determined by

$$A_1 = -(R2/R1) \; ; \; A_2 = -(R4/R3) \; \rightarrow \; A_{total} = A_1 \cdot A_2$$

☞ Be aware of offset voltages and temperature drift when defining the amplifications. Both effects will be multiplied by the gain factor.

Power Supply

Output signal of Radar sensors is influenced by the supply voltage. Because of the high gain amplification, supply voltage noise is visible at the amplifier output.

Prefer using linear voltage regulator for sensor and amplifier supply.
For power efficiency, consider using a dual stage approach with switch mode regulator followed by a linear regulator.

Provide separate traces to amplifier and to digital power consumers. Blinking LED, processor and relais may cause interferences at the output of the high gain amplifier.

Signal Processing

Performance of Radar based detectors depends on the quality of signal processing.

Comparator

A simple comparator connected to the output of the amplifier may be sufficient for short distance applications.
With a window comparator, we get better sensitivity as well as double frequency.

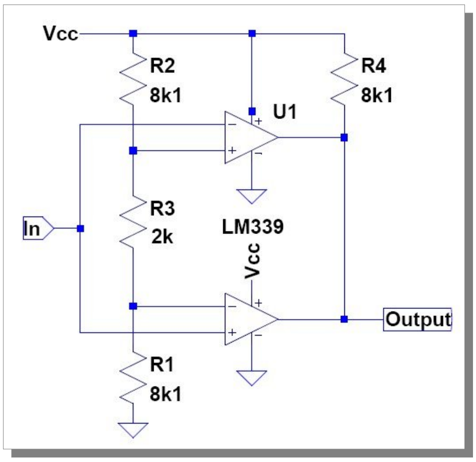


Fig. 2: Principle of window comparator

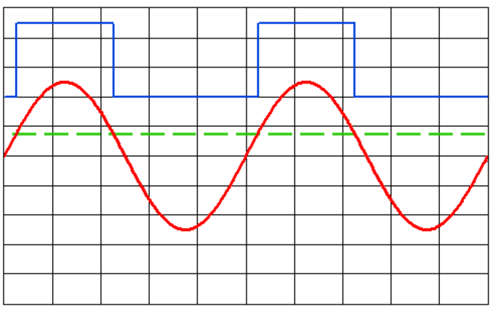


Fig. 3: Simple single comparator

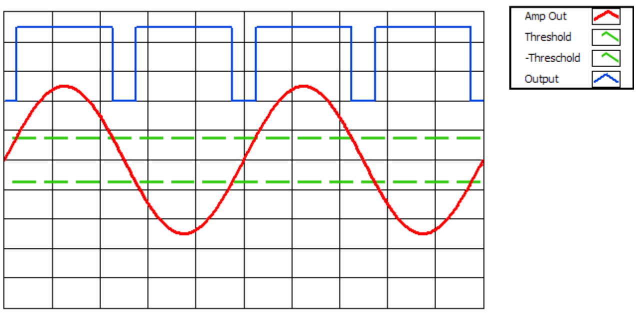


Fig. 4: Window comparator

Comparator output may be connected to a retriggerable timer or to a micro-controller in order to get a constant signal during movement.

Output signal always contains noise. → Provide a hysteresis in the comparator circuit

AN-04 Typical Doppler Signal Amplifier

Digital Processing

Processing with comparators may be sufficient for many applications.
Digital processing (FFT) however allows to get many more features and reliability:

- Enhancing detection distance
- Suppressing interferences (fluorescent lights, ventilators, ...)
- Distinguishing objects (persons, vehicles, animals, ...)
- Exact speed measurement
- Multiple objects detection

I/Q Directional Processing

Some RFbeam sensors provide I and Q outputs. This allows differentiating between approaching and receding objects.
Each channel must be amplified separately. Sensor output signals are phase shifted by +90° or -90° depending on the movement direction.

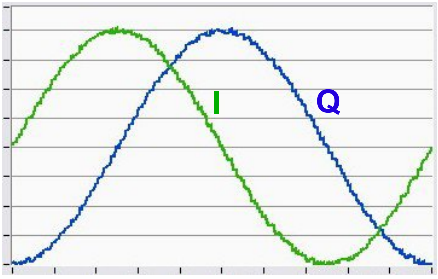


Fig. 5: Approaching object

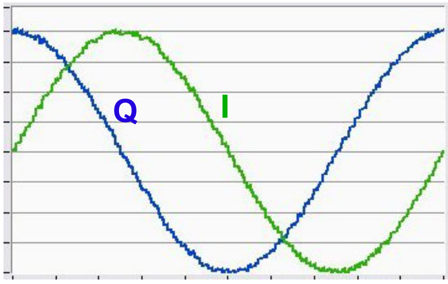


Fig. 6: Receding object

Tips And Hints

- Use at least dual layer PCB with ground plane
- Use separated ground traces for analog and digital parts
- Place K-LCx sensor as close to the amplifier input as possible
- Make signal lines as short as possible
- Explore Radar basics using RFbeam ST100 starter kit or ST200 evaluation kit
- Use RFbeam K-DT1 Doppler simulator to optimize your circuit

Output signals of Radar transceivers are often called 'IF' signals. This is an abbreviation of **I**ntermediate **F**requency. The IF signal is created by mixing transmitter frequency (24GHz) with the reflected signal from moving objects.
The IF frequency is low and ranges typically from some Hz to some kHz (44Hz per m/s or 158Hz per km/h).
In our application, IF signal is also called Doppler signal.

Revision History

Version 1.0	April 16, 2012	Initial Release
Version 1.1	Aug. 18, 2012	R10, R11 new 470k for improved power supply noise rejection