Radar solutions for multicopters

Integrating a radar sensor in an open-source flight controller

Abstract

Multicopters are part of an emerging market that is growing incredibly fast. In its infancy, the market for multicopters and drones started out as a bit of a novelty, as small hand-held toys that possessed limited functionality and abilities. A few years later and we are seeing them in almost all facets of our lives, used in a wide variety of applications ranging from flying camera platforms to tools used for inspecting hazardous environments. Some companies are exploring and implementing multicopter solutions such as flying delivery services, live streaming events and even agricultural applications. The list of possibilities for multicopters grows longer each day.

Multicopters are offering us the unprecedented ability to go to places we could never go before and do things that were impossible just a few years ago. With the rapid rise in commercial and private applications, there is a need for more and more sophisticated control systems to meet the demands of the new ways multicopters are being used. Radar is one area that is extensively used by multicopters. Infineon’s Distance2Go in combination with the open source software Cleanflight provides an excellent way to easily and quickly implement a simple but highly effective 24 GHz radar solution for multicopters that accurately measures speed, distance, and direction of movement.
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1 Introduction

Radar can be loosely defined as an object detection system that uses the reflection of radio waves to detect the range, angle, and speed of objects in the environment. It is used every day for things such as monitoring and controlling commercial flights, military and defense applications, and tracking weather events. Radar has also been adopted for automotive sensor solutions, UAV collision avoidance, service-robot obstacle avoidance, and a wide variety of other applications.

Radar-based sensors are preferred over other common sensors such as laser rangefinders, optical sensors, or acoustic sensors. Radars are better than optical sensors because they are not affected by sunlight, smoke, fog, dust, and other factors that typically affect or interfere with optical wavelength detection. Radar typically has better directionality and range than acoustic sensors, and they are not affected by environmental noise. In addition, a single radar sensor can detect more than one object at a time, while the acoustic systems are limited to focusing on a single source or object. Radar has long been the core of aviation navigation systems and more recently it is a fundamental part of the advancement in automotive technologies with new designs implementing radar-based features such as adaptive cruise control and even autonomous driving. Currently, no other sensor can provide all of the functionality that radar is capable of providing.

1.1 LARIX multicopter demo board

Figure 1 shows the LARIX multicopter demo board. This board forms the heart of an Infineon-based multicopter flight control system. It is built around an Infineon XMC4500 ARM® Cortex®-M4 32-bit industrial microcontroller, a combination of low-voltage MOSFETs, the DPS310 high resolution pressure sensor and the MPU9250 InvenSense inertial measurement unit (IMU) provide the additional functionality that make up the electronic powertrain, motor control, and flight sensing functional blocks.

![LARIX Multicopter-Board:](image)

**Figure 1** The LARIX multicopter demo board
Various motor control boards can be used with the LARIX multicopter demo board. In this example, Infineon uses the PINUS motor control board (see Figure 2). This board has an XMC1302 speed controller, dual low-voltage MOSFETs, and an IR2301S gate driver.

**Figure 2** PINUS motor control board

### 1.2 Distance2Go radar demo board

The Distance2Go is a 24 GHz radar demo board, which is shown in Figure 3. The Distance2Go development kit provides everything required to implement and test various sensing applications in the 24 GHz ISM band. This includes Frequency Modulated Continuous Wave (FMCW) distance measurement, Doppler-based direction of movement detection, and target speed measurement.

The Distance2Go kit uses the BGT24MTR11, a 24 GHz highly integrated RF MMIC, and the XMC4200 ARM® Cortex®-M4, a 32-bit industrial microcontroller for the radar signal processing. The Distance2Go can detect objects between 0.5 meters and 30 meters away with an accuracy of 20 centimeters. It has a 20° (simulated) horizontal and a 42° (simulated) vertical field of view.

**Figure 3** The Distance2Go radar demo board
1.3 Cleanflight

Cleanflight is a 32-bit open-source flight controller application which was developed by Dominic Clifton and is released under the GNU GPL v3.0. It is release as a multi-platform Chrome application through the Google Chrome web store (see Figure 4). Details about the software, including links to the installation media, source code, documentation and license can be found on the Cleanflight website at http://cleanflight.com/.

Cleanflight is designed for multirotor and fixed-wing aircraft, and it supports a wide variety of hardware designs and rotor counts. It has two primary components, the firmware which runs on the flight controller board, and the configuration GUI which is used to set parameters, flight modes and calibrate sensors.

The Cleanflight software simplifies the process of setting up and configuring a multicopter. The software has a well-documented abstraction layer that can easily be adapted to support the wide range of microcontrollers, boards and sensor combinations that are on the market.

Figure 4 The Cleanflight user interface
2 Integrate the Distance2Go in the Cleanflight flight controller

The Distance2Go must be physically connected to the LARIX board, and then set up in the Cleanflight software. The Cleanflight software must be adapted to communicate with the Distance2Go because the default software configuration does not support radar sensors.

2.1 Connect the Distance2Go to the LARIX board

The Distance2Go must be connected to pin P4.0 on the LARIX board, as shown in Figure 5. This pin is linked to USIC module 2 channel 1 in the XMC4500. This USIC channel is referred to as SERIAL_PORT_USART3 in the Cleanflight software. A UART protocol is used for the communication between the radar sensor and the LARIX board.

Note: The UART protocol is defined for one Distance2Go, but can be adapted to support two or more Distance2Go boards in a daisy chain configuration.

2.2 Adapt and configure the Cleanflight software

The Cleanflight software must be adapted and configured to communicate with the Distance2Go. The UML diagram shown in Figure 6 illustrates the key blocks that must be coded. The code can be split into two segments, the configuration of the UART when the flight controller is initialized, and the reception and processing of radar data. The easiest way to check if the radar data is ready is to configure the USIC module to trigger an interrupt when the data in the receive buffer reaches the defined frame length. The radar data can be displayed in the Cleanflight configurator GUI by writing the data to the predefined debug variables.
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Note: Infineon uses the DAVE 4 software environment to integrate the Distance2Go in the existing Cleanflight code. This Eclipse-based IDE for Infineon XMC microcontrollers combines standard C-coding with the implementation of pre-defined applications (APPs).

The radar data (distance and velocity) can be used to add new functionalities in Cleanflight such as a collision avoidance controller (radar sensor facing forward), or a measured distance to altitude control algorithm (radar sensor facing downwards).

2.3 UART Protocol Specifications

The Distance2Go measures (at approximately 35 Hz) the distance to, and velocity of the nearest target and transmits the data over the UART interface to the LARIX board. The UART protocol used for the communication is shown in Table 1. A Cyclic Redundancy Check (CRC) is used to detect transmission errors and verify the validity of the data. The CRC-8 calculation is done by the Flexible CRC Engine (FCE) in the XMC4500 microcontroller.

<table>
<thead>
<tr>
<th>Frame index</th>
<th>Description</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Start byte</td>
<td>0xAA</td>
</tr>
<tr>
<td>1</td>
<td>Distance high byte</td>
<td>Distance in cm</td>
</tr>
<tr>
<td>2</td>
<td>Distance low byte</td>
<td>(16-bit integer)</td>
</tr>
<tr>
<td>3</td>
<td>Velocity high byte</td>
<td>Velocity in cm/s</td>
</tr>
<tr>
<td>4</td>
<td>Velocity low byte</td>
<td>(16-bit integer)</td>
</tr>
<tr>
<td>5</td>
<td>CRC byte</td>
<td>CRC-8 Checksum</td>
</tr>
<tr>
<td>6</td>
<td>Stop byte</td>
<td>0xBB</td>
</tr>
</tbody>
</table>

In a use case with more than one radar sensor (e.g. one sensor for collision avoidance and one sensor for altitude control), the sensors can be connected in a daisy chain topology as shown in Figure 7. In this use case, the UART protocol must be extended to include the distance and velocity values for the second sensor, and the Cleanflight software as well as the flight controller must be adapted.

Figure 6  UML diagram

Figure 7  Daisy chain implementation
3 Conclusion

Combining Infineon’s Distance2Go radar sensor with a LARIX multicopter demo board is relatively simple. It provides an excellent way to easily and quickly implement a simple but highly effective 24 GHz radar solution for multicopters that accurately measures speed, distance, and direction of movement. Flight controller software such as Cleanflight is simple to adapt and adjust to your specific needs and design applications. The ability to do rapid prototyping or features like 24 GHz radar sensing on a LARIX multicopter board will help bring your designs to market quickly and efficiently.