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DEVICE DRIVER FOR 3-AXIS ACCELEROMETER BASED ON ARM CORTEX-M0+ PROCESSOR

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Abstract

The use of accelerometers in aerial vehicles is crucial for measuring tilt (inclination) in order to control hovering. In this work, the driver software for 3-axis accelerometer device is developed based on the platform of ARM cortex M0+ processor. This driver software reads the values of acceleration of all 3 axes and computes roll, pitch and yaw tilt angles. This driver software is then integrated to open source freeRTOS operating system and then complete system using freeRTOS is tested by making system call from application software.

Keywords

Accelerometer, ARM Cortex M0+, Device Driver, Quad copter, RTOS

1. Introduction

Automatic control of aerial vehicle has been driving force of industries and research laboratories working in this area. The applications of autonomous vehicle have become pervasive, supported by rapid advances in semiconductor IC technology today. The embedded hardware and software are governing the operation of such complex autonomous vehicles. Many embedded systems nowadays contain real-time kernels for deterministic applications. This would necessitate knowing of how hardware and embedded operation system work, on the part of software engineers. Engineers should also know basic operation of processor, be able to program at register level and understand role of operating system.

This paper investigates the autonomous operation of quad copter (drone) equipped with accelerometer sensor. With its very simple mechanical design and compact sized quad-copter qualifies as a viable tool of mini Unmanned Aerial Vehicle (UAV) for various missions. During its operation, the first control objective is to ensure a stable flight (Martin and Salaun, 2010) during hovering at moderate velocities. This fundamental building block is then used to develop higher-level tasks such as path following, obstacle avoidance, automatic takeoff and landing, etc. Our objective is to develop software routing for measurement of accelerometer signals. In other words, we want to develop device driver for accelerometer and integrate this driver with real time operating system (Stewart and Jabcob, 1999) enabling independent access by user application.

The ARM based embedded processors are dominating embedded world with variety of cores to suit different applications. In our work, ARM cortex M0+ based hardware board called FRDM KL25Z is used. This is low cost, low power and compact board equipped with accelerometer sensor and supports few RTOSs. The RTOS is designed to simplify the access to various peripheral devices for developers. The system software routines responsible for accessing and communicating with peripherals are device drivers.

2. Background and Related Work

Usefulness of accelerometer in variety to applications has been reported in many literatures. Accelerometer based tilt sensor for orientation angle tracking of C-arm fluoroscopes are described in (Wolff, Lasso, Eblenkamp, Wintermantel andFichtinger, 2013). (Horowitz et al., 2003) presented the embedded controller design for autonomous control of a helicopter-based unmanned aerial vehicle (UAV) which employs accelerometers and gyroscopes that provide frequent measurements of angular rates and linear accelerations. Accelerometer based measurements for quadrotor flight are presented in (Leishman, Macdonald,Beard and McLain, 2014) and compared with actual values. Using hardware, the accelerometer directly measures the translational velocity, allowing more accurate estimates of the attitude and velocity of the vehicle. Quad rotor model that includes rotor drag component is developed by (Martin and Salaun, 2010). It explains the use of accelerometer feedback in control algorithms. In other work of (Premkumar, Sumithira, Sathishkumar and Ibrahim, 2015), gesture control of quadcopter using 3-axis accelerometer is presented.

Due to highly integrated nature of embedded systems, there is the requirement of communicating sensor peripheral module speedily and ensuring real time/deterministic performance. The optimized device drivers and efficient real time operating system (S. Wang, 2003) play key role for deterministic response. Device drivers are the system software routines that provide the bridge between peripheral devices on one side and the upper layers of the operating system and the application software on the other.

3. Accelerometer and Quadcopter

Accelerometers are MEMS based sensors that measure the acceleration (rate of change of velocity) of an object. They, however, do not measure absolute acceleration but rather measure the difference between acceleration of object and gravitational acceleration. The unit of measurement is either m/s^2or in G-force (g). A single G-force is equal to 9.8 m/s^2on planet earth. Accelerometers are used in variety of applications such fall detection (K. Ozcan and S. Velipasalar,2016), aircraft and missiles, drones (Martin and Salaun2010, Leishmanet al. 2014), vibration monitoring, automobile and medical. Accelerometers with analog interface show accelerations through varying voltage levels whereas digital interface can either communicate over SPI or I^2C communication protocols.

We shall now discuss the use of accelerometer measurement in controlling quad-copter flight. A quad-copter is a multi-copter lifted, propelled and maneuvered by four rotors placed symmetrically. Its operation is based on collective adjustment of group of rotor blades. The pitch and/or rotation rate of one or more rotor discs are tweaked to modify torque load and thrust which then control the hovering motion of this quad-copter. Each rotor produces thrust and torque about its centre of rotation, whereas the drag force is opposite to the vehicle's direction of flight. Yaw, Pitch and Roll are the three main axes which are needed to be controlled. As shown in Fig.1, given that the rotors 2 and 4 rotate counter-clockwise and the other two rotate clockwise, the net torque is zero due to the rotational axis. During hover, three axes are controlled by properly setting the direction and speed of four rotors as shown in Table1.

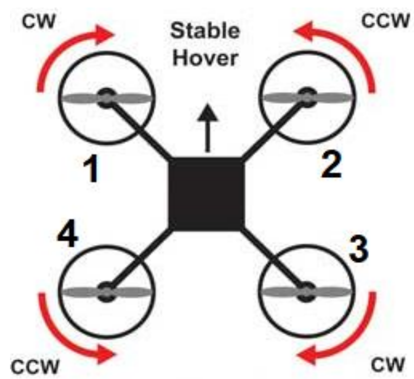


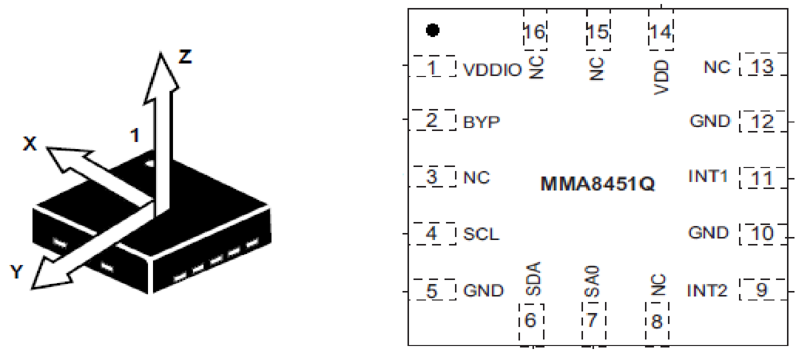
Figure 1: *Quad copter dynamics*

Table 1: *Axis control of quad copter*

Control Axis	Control Procedure
Yaw	Speed of either pair rotors 1 &3 OR 2&4 are increased in clockwise or anticlockwise direction
Roll	Speed of either rotors 1 & 4 or rotor 2 & 3 is increased
Pitch	Speed of either rotors 17&2 or rotors 3&4 is increased

4. Device Drivers for Accelerometer on FreeRTOS

We develop driver for 3-axis accelerometer available on FRDM cortex-M0+ board from FreeScale semiconductor. The driver routine reads all three angular inclinations namely yaw, roll and pitch and stores them in buffer memory. The accelerometer on board is MMA8451Q (Fig.2) which low-power, three-axis, capacitive micro machined (Datasheet, 2017). This accelerometer is housed with embedded functions with user programmable options and configurable to two interrupt sources. The measured values of acceleration are stored in registers as 14-bit 2's complement numbers. When the full-scale is set to 2g, the range of measurement is from -2g to +1.99975g and each count corresponds to 1g/4096(0.25 mg) at 14-bits resolution.



(a) (b)

Figure 2: *(a) Accelerometer axes (b) Pin diagram of MMA8451Q accelerometer*

For single axis (say x-axis) operation, the component of the gravity vector on the x-axis produces an output acceleration equal to the sine of the angle between the accelerometer x-axis and the horizon. The output acceleration for an ideal value of 1g gravity is

$$A_{x,OUT}[g] = 1g \times sin(\theta) \qquad (1)$$

For 3-axis device, an alternative method for inclination sensing with three axes is to determine the angle individually for each axis from a reference position. Without loss of generality, the x and y-axes in the plane of the horizon (0 g field) and the z-axis orthogonal to the horizon (1 g field) is taken as the orientation of the reference position. Let we define θ as the angle between the horizon and the x-axis of the accelerometer, ψ as the angle between the horizon and the y-axis of the accelerometer and φ as the angle between the gravity vector and the z-axis. Basic trigonometry can be used to show that the angles of inclination can be calculated using following equations:

$$\theta = tan^{-1}\left(\frac{A_{X,OUT}}{\sqrt{A_{Y,OUT}^2 + A_{Z,OUY}^2}}\right) \qquad (2)$$

$$\psi = tan^{-1}\left(\frac{A_{Y,OUT}}{\sqrt{A_{X,OUT}^2 + A_{Z,OUY}^2}}\right) \qquad (3)$$

$$\phi = tan^{-1}\left(\frac{\sqrt{A_{X,OUT}^2 + A_{Y,OUY}^2}}{A_{Z,OUT}}\right) \qquad (4)$$

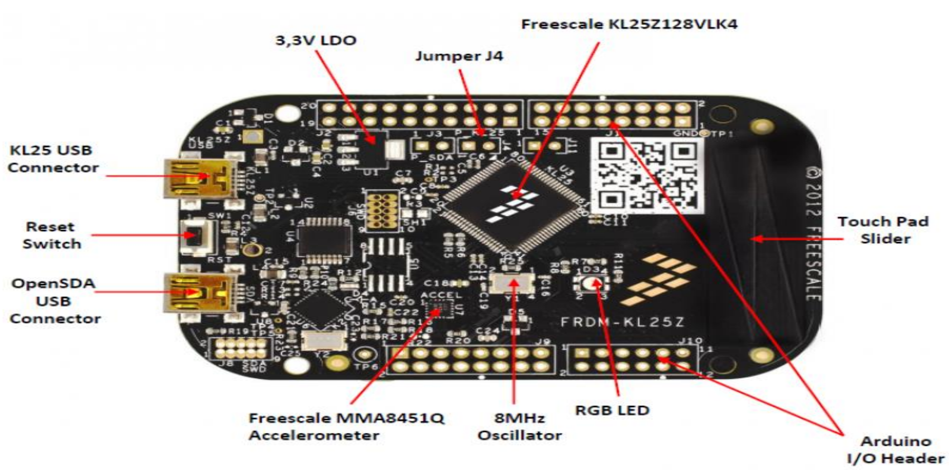


Figure 3: *FRDM KL25Z board with ARM cortex M0+*

The driver software for accelerometer for FRDM KL25z Cortex M0+ hardware board (Fig.3) is developed. The driver code works on interrupts received from MMQ accelerometer and then reading 3-axis data using I2C bus and store them in registers. The unit of values is g and values are 14-bit 2's complement data. After testing the correctness of driver using standalone routine, we integrate it to freeRTOS which is an open source real time operating system.

5. Conclusion

The tilts of aerial vehicle such as drone are measured with accuracy using accelerometer sensor. In this work, we have used 3-axis accelerometer of ARM cortex m0+ board and wrote driver software that communicates with accelerometer chip. The software is tested on hardware and displays correct reading of yaw, roll and pitch on LCD when the board is oriented manually. The driver is then integrated to freeRTOS so that operating system based application software can easily access through system call.

References

B. Horowitz, J. Liebman, C. Ma, T.J. Koo, A. S.Vincentelli and S.S. Sastry (2003). Platform-basedembedded software design and system integration for autonomous vehicles. Proc. of IEEE, vol.91, no.1. https://doi.org/10.1109/JPROC.2002.805827

D. B. Stewart and Bruce L. Jacob (1999).Hardware/Software Co-Design of I/O Interfacing Hardware and Real-Time Device Drivers for Embedded Systems. IEEE Real-Time Applications Symposium - Work-in-Progress Session, Vancounver, Canada.

Datasheet (2017). MMA8451Q: 3-axis, 14-bit/8-bit digital accelerometer. *NXP Semiconductors*. Retrieved from: Https://www.nxp.com/docs/en/data-sheet/MMA8451Q.pdf.

K. Ozcan and SenemVelipasalar (2016). Wearable Camera- and Accelerometer-Based Fall Detection on Portable Devices. IEEE EmbeddedSystems Letters, Vol.8, No.1, pp. 6-9. https://doi.org/10.1109/LES.2015.2487241

M. Bychkov and A. Fedorenko (2016). Microcontroller with ARM kernel and real time operating system. 2016 IX International Conferenceon Power Drives Systems (ICPDS), pp. 1-6. https://doi.org/10.1109/ICPDS.2016.7756684

M.Premkumar, T.R.Sumithira, D.Sathishkumar and A.M. Ibrahim (2015). Gesture and Stability Control of A Quadcopter Using 3-Axis Accelerometer. International Journal on Recent Technologies in Mechanical and Electrical Engineering.vol.2, no.10, pp.47-50.

Philippe Martin and ErwanSalaun (2010). The True Role of Accelerometer Feedback in Quadrotor Control. IEEE International Conference on Robotics and Automation (ICRA), https://doi.org/10.1109/ROBOT.2010.5509980

R. C.Leishman, J. C. Macdonald,R.W. Beard and T.W. McLain (2014). Quadrotors and Accelerometers:State Estimation with an Improved Dynamic Model IEEE Control Systems, vol.34, no.1, pp. 28-41. https://doi.org/10.1109/MCS.2013.2287362

S.Wang (2003). Synthesizing operating system based device drivers in embedded systems.First IEEE/ACM/IFIP Intl. Conf. on Hardware/Software Co-design and System Synthesis. pp. 37-44, https://doi.org/10.1109/CODESS.2003.1275253

T.Wolff, A. Lasso, M. Eblenkamp, E. Wintermantel and G. Fichtinger (2013).C-arm angle measurement with accelerometer for brachytherapy: an accuracy study. International Journal of Computer Assisted Radiology and Surgery, vol.9, no.1 pp.137-144. https://doi.org/10.1007/s11548-013-0918-3