Application Brief

Position Sensing in Smartwatches and Other Wearables

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Introduction

Smartwatches demand sensors that are compact, energy-efficient, and capable of delivering precise, contact-free measurements. The TMAG3001—a low-power, 3-axis Hall-effect sensor—offers advanced functionality tailored for wearable applications. This document discusses how the key features of TMAG3001 along with Texas Instruments' inductive sensors and Hall-Effect switches map onto common smartwatch requirements, and why those features make the TMAG3001 device an option for wearable applications such as fitness trackers, medical trackers, smart trackers, and smartwatches.

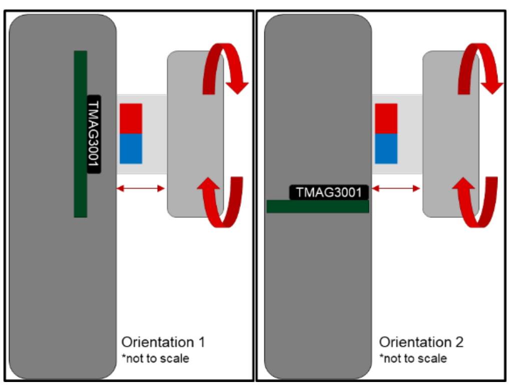

Figure 1. Digital Crown Orientations

Operation of Digital Crowns

Digital crowns in smartwatches act as rotary buttons that can be used to interact with the smartwatch. By rotating the digital crown, users are able to scroll, zoom, adjust settings, and so on. Some digital crowns can even act as buttons to allow for even more functionality. With linear 3D Hall-effect sensors, a single sensor can be used to detect both the rotation of the digital crown and any button press functionality of the digital crown.

The TMAG3001 is one of Texas Instruments' three-axis linear Hall-effect sensors that offers a variety of functionalities that make the device an option for digital crown applications. The TMAG3001 not only comes in an ultra-small package, but it also offers low power consumption through wake-up and sleep mode. Additionally, the TMAG3001 offers a variety of programmable options that can be enabled such as angle calculations and various interrupt functionalities.

Saves Power and PCB Space

When it comes to wearable applications, an important factor to consider is the battery life. By reducing power consumption, the usage time of these wearables can be extended, which is crucial for fitness, medical, and smart trackers that need to stay on for extended periods of time.

With wakeup and sleep mode, devices such as the TMAG3001 can be configured to only sample the magnetic field when required.

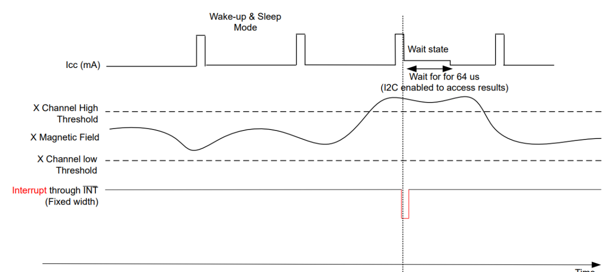

Figure 2. Wakeup and Sleep Sampling

As shown in Figure 2, to save power, depending on the device's configuration, the TMAG3001 spends most of the time in a low power state. Then, based on the timing interval that is selected, the device wakes up and takes a measurement. From here, depending on what interrupt method is implemented, the device can signal an interrupt if the selected conditions are met (such as a threshold being crossed or a result being ready to be read).

In addition to keeping power consumption low, another key factor to consider is size, which is why keeping smartwatches as compact as possible is important. With the ultra-small wafer chip scale package (WCSP) package offered by the TMAG3001, which is shown in Figure 3, users are able to save space on PCBs. By being able to reduce the size of the PCB, lighter and more compact smartwatch designs can be considered allowing for a more comfortable feel without sacrificing functionality.

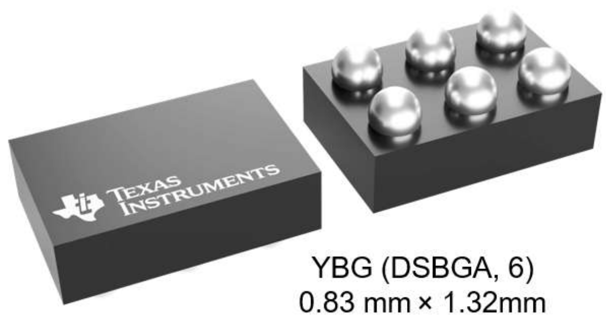

Figure 3. TMAG3001 Package

Programmability

One of the key features of the TMAG3001 is programmability. With this device, users can make a selection from a wide variety of interrupt functionalities.

One of these interrupt functionalities includes wake-on-change (WOC) mode. With WOC, the device can either be configured to monitor changes in angle or changes in a single magnetic field axis (either X, Y, or Z). When the device detects a change in magnetic field or angle, an interrupt gets triggered and the new measurement is used as a reference for successive measurements. Figure 4 shows the device response where the TMAG3001 is configured to monitor the x-axis for changes in the magnetic field. Figure 5 shows how the device responds when the device is configured to respond to changes in angle measurements.

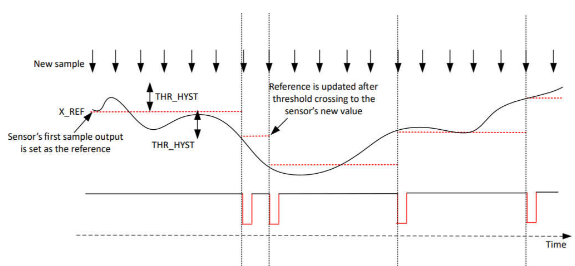

Figure 4. Magnetic Field WOC Example

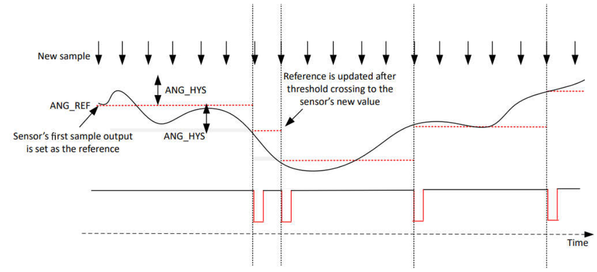

Figure 5. Angle WOC Example

The TMAG3001 can also be configured to send an interrupt response based on a set threshold value. Unlike with WOC mode, instead of monitoring a reference value that gets updated when a change is detected, a specific threshold value can be used to determine when an interrupt must occur if implementing angle, magnetic, or magnitude limit checks. This interrupt response can either look like a brief pulse or a latch that is cleared by I2C communication. Alternately, the device also offers switch mode functionalities which would configure the device's interrupt pin to act as an on/off switch based on a set threshold.

Instead of sending an interrupt when a threshold is crossed, an interrupt can be configured to occur when a conversion measurement is completed and data is ready to be read.

Inductive Button Press

The second way that position sensors can be used in smartwatches is to detect when a button is pressed. Button press detection can be done with Texas Instruments' inductive sensors, such as the LDC2112 and the LDC2114. Typically, a button press is detected using mechanical switches; however, there are many advantages when using inductive sensing for this application. First, inductive sensing is a contactless method which makes inductive sensing more reliable and enables a longer effective life of the product. Due to the nature of mechanical switches which require physical contact, over time they can suffer from mechanical stress leading to degradation of the switch as the result of constant use. Additionally, inductive sensors can be used to detect the amount of force used to press down on the button which is a feature that mechanical switches lack. Another benefit to using inductive sensors to detect a button press is that these sensors are more immune to environmental factors such as dust, dirt, water, and debris. This helps to increase the long-term use for these inductive buttons as opposed to mechanical switches which are exposed to those elements and tend to corrode and wear out over time.

The way that an inductive sensor is used to detect a button press is highlighted by Figure 6. As shown in Figure 6, the inductive sensor is used to measure the deflection of the metal plate as the button gets pressed. As the metal plate deflects, eddy currents are generated on the metal plate which increases sensor frequency. As this metal plate moves closer to the sensor, the sensor frequency continues to increase and the inductive device converts this sensing frequency to a digital value for the user to see. Additionally, inductive sensors such as the LDC2112 and the LDC2114 have digital output pins that can output an interrupt when the button is pressed and a preset threshold is reached.

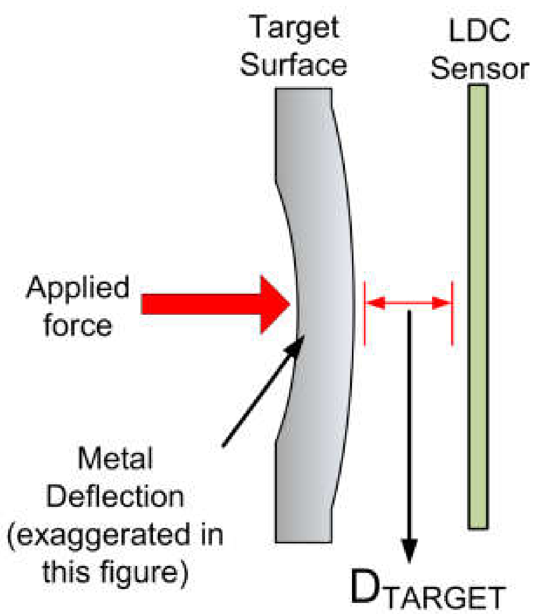

Figure 6. Inductive Touch Components

The reason LDC2112 and LDC2114 are recommended for touch button applications over other inductive sensors is that they have a baseline tracking algorithm that accounts for temperature drift and button surface deformation to help re-calibrate the deflected material and keep its digital thresholds consistent. Additionally, another key feature of the LDC2112 and the LDC2114 is that they offer a WCSP package which has a size of 1.6mm × 1.6mm. For smartwatch applications, space constraints are an important consideration which is why small package options are beneficial.

Removable Screen Detection

Another application for position sensors in smartwatches is the ability to detect when the screen is removed. Removable screens are a feature that is seen in watches designed for children, especially as many children enjoy having the ability to remove the screen from their watches. The device from Texas Instruments that is commonly used for this application is the DRV5032DUDMRR. This device is a dual-unipolar hall-effect switch which means that the device has two output pins where one output detects magnetic fields from the north pole of the magnet and the other output detects magnetic fields from the south pole of the magnet. Alternatively, another Hall-Effect switch from Texas Instruments' portfolio that can be used for this application is the TMAG5231 which is an ultra-low-cost device with multiple sensitivity and current consumption options that comes in a small X2SON package (1.4mm x 1.1mm).

Conclusion

As smartwatches become more commonplace, especially in fitness and medical trackers, designers are constantly looking for ways to improve and optimize smartwatch designs. Low-power linear 3D Hall-effect sensors such as the TMAG3001 provides many beneficial functionalities while still saving space. With the ability to keep the device in a low-powered state until a change in magnetic field is detected, the energy efficiency of digital crowns is able to be optimized to help extend battery life. Furthermore, inductive sensors such as the LDC2112 and LDC2114 are able to help reduce damage seen with mechanical switches in button press applications. By implementing unique features such as removable screens (which can be done with Hall-effect switches such as the DRV5032 and TMAG5231) these wearables can extend the reach into younger generations who enjoy having a smartwatch just as much as an adult counterpart.

Table 1. Recommended Position Sensing Devices

	Characteristics	Design Considerations
TMAG3001	Low power, cost-optimized 3D Linear Hall Effect sensor with configurable low power modes, WCSP package (0.83mm × 1.32mm), I2C interface, and programmable switch functionality.	Great for space constrained applications due to WCSP package. Internal CORDIC algorithm allows device to calculate angle and detect exact position of an object. Can measure magnetic field strength in 3 axes.
LDC2112	2 channel inductive sensor with WCSP package (1.6mm × 1.6mm) and baseline tracking algorithm.	Great for space constrained applications due to WCSP package. More immune to temperature drift and deformation of button surface.
LDC2114	4 channel inductive sensor with WCSP package (1.6mm × 1.6mm) and baseline tracking algorithm.	Great for space constrained applications due to WCSP package. More immune to temperature drift and deformation of button surface. Able to implement more buttons due to additional channels.
DRV5032	Low power Hall-Effect switch with dual-unipolar magnetic response variants. Has SOT-23, TO-92, and X2SON package options.	Dual-Unipolar magnetic response (DU, DG, and FD variants) allows device to detect which pole of the magnet the magnetic fields are coming from.
TMAG5231	Cost-optimized, Hall-Effect switch offered in SOT-23 and X2SON packages.	General purpose Hall-Effect switch for consumer applications.

Table 2. Related Technical Resources

Name	Description
Angle Measurement With Multi-Axis Hall-Effect Sensors	A guide to monitoring absolute angle position using a 3D Hall-effect sensor
Low Power Design Using Hall-Effect Sensors	A discussion on how to optimize power consumption with Texas Instruments' Hall-effect sensors
Inductive Touch Buttons for Wearables	A discussion on the benefits of using inductive touch buttons for wearables
TMAG3001EVM	GUI and attachments incorporate angle measurement using a precise three-dimensional linear Hall-effect sensor

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