Rotation detection has to be done in several applications. Such end-equipments are a bike computer, motor control applications, general flow-sensors, water meters, and many others. An integrated solution in such applications has the advantages of a reduction of external components and a small form factor. Especially if the integrated solution is designed for low-power consumption the capacity of the battery can be reduced or the system can be optimized for longest lifetimes using only one battery.

The power consumption of such a system can also be optimized by choosing the measurement principle. There are different ways to realize rotation detection. For example it is possible to use:

- optical sensor,
- hall sensors,
- GMR (=Giant Magnetic Resistor) sensors or
- LC-sensors.

The disadvantage of a solution using an optical sensor is for instance the high current consumption. However, using a LC sensor (resonant circuitry) reduces the current consumption. This article describes the solution for rotation detection using an LC sensor.

The microcontroller MSP430FW42x from Texas Instruments has an integrated “Scan Interface Module” (peripheral module) that takes over the excitation of a connected LC circuitry and measures the damping ratio. The Scan Interface consists of the Analog Front-End, the Timing State Machine, and the Processing State Machine. The programming of Timing State Machine defines the single measurement steps. Each single step for the measurement like activation of comparator, its reference voltage, selection of the input channel, measurement start, and more can be programmed. The Processing State Machine is used for the evaluation of the measurement results. It
detects rotation and increments or decrements the integrated counter if a complete rotation happened. The CPU is only needed to do the initialization of the Scan Interface module. After that the CPU can be switched off, because the Scan Interface module takes over the complete rotation detection. By reducing the time the CPU has to be activated the current consumption of the system is reduced.

The schematic for a rotation detection system is shown in figure 1. In this example two LC-sensors are used. The microcontroller was designed to support the usage of up to four LC-sensors. Using only one LC-sensor allows detecting rotation, but not the direction of the rotation. A second LC-sensor makes it possible also to detect the direction of the rotation. Further LC-sensors can be used for redundancy.

Figure 2 shows the LC sensor. The inductor of the LC-circuitry is placed above a plate that is half covered with conductive material. One side of the LC circuitry is connected to Vcc/2. The other side is floating in the idle state. The electronic stimulates the resonant circuitry by connecting one inductor to ground (SIFCH.0 or SIFCH1 in figure 1). This charges the resonant circuitry. As soon as the ground level is switched off again the resonant circuitry starts to oscillate. The frequency of this damped oscillation is around the resonance frequency of the LC resonant circuitry. Because of the damped oscillation there is also an alternating magnetic field generated by the inductor. As soon as conductive material is placed in the alternating magnetic field, the decay time will be shorter. This is the case because eddy current is generated in the conductive material. This means that energy is taken away from the resonant circuitry, which causes the shorter decay time.

Before the Scan Interface module can process the measurement results a digitization of the coil position has to be done. The previous described measurement delivers an analog value (decay time). For processing a digital value is needed. For rotation detection it is necessary to know if the coils are place above the conductive material or not. By knowing the previous position and the actual position the rotation and the direction of the rotation can be detected. The digitization of the coil position is done with a simple method. This method is shown in figure 3. After a certain time (tdelay) a time window is opened (tgate). Within this window it is checked if the oscillation reaches a defined amplitude. If this is the case a latch is set. Otherwise the latch is reset. So when
the coil is placed above metal, the decay time is shorter. This cause that there are no half waves of the oscillation above the reference voltage. The latch will be reset (= coil above metal). When the coil is place above the non-conductive area of the plate the amplitude of the decaying oscillation will be above the reference voltage. This causes that the latch will be set (= coil above non-conductive material). These digital values for the coil positions are used for the processing. The Scan Interface of the MSP430 controller realizes the digitization by using an analog comparator and a 10-bit DAC for the reference voltage generation. All these parts are integrated in the Scan Interface. The single measurement steps like activation of comparator and DAC, delay time generation, and measurement time are programmable via the Timing State Machine. The programmability of the single measurement steps allows to adjust the measurement timing to different types of sensors.

After the digitization of the coil position the measurement results has to be processed. A simple algorithm to do the processing is doing it with a state machine (see figure 4). The state machine is used to store the previous positions of the coils and calculate the new state by using the actual measurement. The movements of the plate can be detected. If two sensors are used in the application the number of rotations and also the direction of the rotation can be detected. A counter can now be incremented for a clockwise rotation and the counter can be decremented for anti-clockwise rotation.

The Processing State Machine is programmable and can be adjusted to different application needs. Beside the state machine there are also two 8-bit counters available that can be triggered as soon as a certain state of the state machine is reached. After a complete rotation the Processing State Machine increments the counter. If the direction has changed and a complete rotation was done in the opposite direction the counter is decremented.

The complete rotation detection is done by the Scan Interface module. No CPU activity is needed for rotation detection and counting of rotations. The CPU can be activated by interrupts at certain counter values. As soon as such an interrupt occurs the CPU reads out the counter value, calculate the rotation speed or calculates the fluid-flow volume, and display the result on a LCD.
Of course, this measurement principle can also be realized by using a standard microcontroller. Texas Instruments provide an application note that describes how to realize rotation detection with an MSP430F41x device. However, the advantage of the MSP430FW42x solution is that no CPU activity is needed for the rotation detection. The CPU can be used to do other measurements, calculations, or communication. It can also be switched off to reduce the current consumption of the system. The current consumption of the measurement system is another big advantage of the MSP430FW42x solution. In a system with a sample rate of around 512 samples per second the current consumption of the MSP430FW427 is around 10uA. The software solution using an MSP430F413 consumes around 50uA. By using the integrated hardware module the current consumption can be reduce five times in this case. Further advantages of the integrated solution are the possibility to use higher sample rates that cannot be realized with the software solution.

The new module of the MSP430FW42x also offers features to recalibrate the reference voltage for the comparator. Because of altering, temperature drift, and tolerances of the used components the reference voltage for the digitization of the sensor position has to be recalibrated. The integrated Scan Interface allows detecting these changes and correcting the settings of the DAC that generates the reference voltage.

In this article one measurement principle for rotation detection was described. The flexibility of the integrated Scan Interface module in the MSP430FW42x allows to use different types of sensors. The adjustment of the settings and timing by programming offers the needed flexibility to use this chip in different types of application. The flexibility even allows to use the Scan Interface module for communication, analog measurements, or hardware supported state machine handling.

Further information about the measurement principle and the MSP430FW42x can be found on the MSP430 internet page http://www.msp430.com/
Figure 1  Inductive Rotation-Detection using MSP430FW427

Figure 2  Inductive Measurement Principle
Figure 3  Digitization of Inductor Position

Figure 4  Processing of the Measurement Results