White paper: Interfacing a 2.4GHz Transceiver to a Philips Twin-Eye Laser Sensor

1. Introduction

This document describes how to interface the Philips PLN2020 twin-eye laser sensor to the Nordic Semiconductor nRF24L01 2.4GHz transceiver. This chipset offers PC peripheral manufacturers a complete integrated, high-precision, ultra-fast, wireless and low power solution for human interface devices. The user can enjoy the freedom of a wireless radio link and the high precision of a laser sensor. Both devices have very low power consumption, which ensures long battery lifetime.

2. The PLN2020 twin-eye laser sensor

Utilizing interferometry techniques normally applied only in high-performance professional applications, Philips Laser Sensors' twin-eye laser technology leverages the latest developments in solid-state lasers, digital signal processing and System in Package (SiP) technology to achieve unparalleled resolution and accuracy for position/velocity sensing in consumer-product applications *(see figure 1)*.

A solid-state laser in the sensor generates an 850-nm wavelength infrared laser beam that is focused by a lens onto the surface of the target object whose position/velocity is being measured. The laser light is scattered by the target surface, resulting in some of the light returning to the sensor and re-entering the laser source, where it optically mixes with the light being generated by the laser (*see figure 2*).

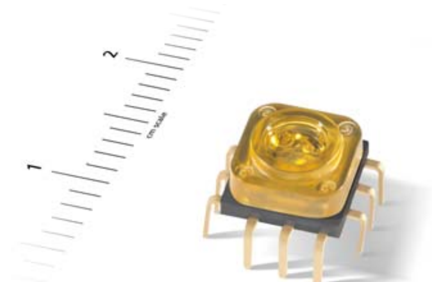

Figure 1 – PLN2020 twin-eye laser sensor

Motion of the target towards or away from the laser source causes a Doppler shift in the frequency of the returning laser light. This Doppler shift is proportional to the speed of the motion. Optical mixing between the returning light and that being generated in the laser source therefore results in fluctuations in the laser power at a frequency proportional to the speed of the target. These power fluctuations are sensed by a photo-diode that is optically coupled to the laser.

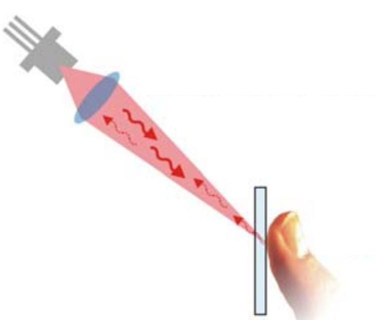

Figure 2 – Philips Laser Sensors' self-mixing laser technology

Although this self-mixing in the laser allows measurement of the Doppler shift frequency and subsequent calculation of the target surface velocity, it does not yield information about whether the target is moving towards or away from the laser source. To identify this direction, the laser power is modulated with a low-frequency triangular waveform, resulting in corresponding changes in laser temperature and consequent modulation of the laser frequency. This frequency modulation of the emitted laser light simulates small forward and backward movements, respectively on the rising and falling slope of the laser power. This decreases the observed Doppler shift if the simulated source movement and the target surface movement are in the same direction, and increasing the observed Doppler shift if the simulated movement and target surface movement are in opposite directions. Comparison of the measured Doppler shift on the rising and falling slopes of the triangular modulation waveform therefore reveals the direction of target surface motion (*see figure 3*).

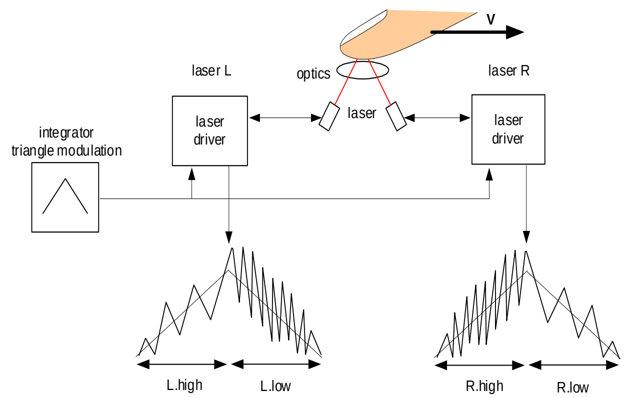

Figure 3 – Direction measurement in Philips Laser Sensors' twin-eye technology. Each laser detects direction independently

The output from the photo-diode, that senses fluctuations in the laser power, is processed in a software programmable Application-Specific Integrated Circuit (ASIC). This ASIC conditions the signal, digitizes it and then analyses it using advanced digital signal processing techniques. These include digital filters that extract the signal from background noise and Fourier Transforms that analyze the signal in the frequency domain to obtain the Doppler shift frequencies. Based on these frequencies, the ASIC then computes the velocity of the target object along the axis of the laser beam. By combining two laser sources in a single sensor, which focuses its laser onto the target from two orthogonal directions, it is possible for the ASIC to combine the two axial velocities into a single velocity vector in the movement plane of the target surface. Integrating velocity over time then derives positional information.

Unlike conventional laser sensors that use a separate source and detector, the use of a solid-state laser as both the source and self-mixing detector offers significant advantages. Firstly, because the optical pathways from the source to the target surface and from the target surface back to the source are identical, there are no critical alignment problems in the positioning of the optical components. Secondly, it means that the wavelength sensitivity of the self-mixing detector is inherently aligned to the laser wavelength, eliminating many of the drift problems associated with separate sources and detectors. Lastly, it reduces system cost.

Laser power is dynamically controlled by circuitry in the ASIC and continuously monitored by independent protection circuitry that automatically short-circuits the laser if an over-power condition is detected. This dual-redundant active protection system protects against both internal and external circuit faults, insuring that the laser power always stays within Class 1M eye-safety limits as set out in International Electrotechnical Commission document IEC 60825-1, Edition 1.2, 2001-08.

2. The nRF24L01

The nRF24L01 is a single chip radio transceiver for the global, license-free 2.4 GHz ISM band. The low cost nRF24L01 is designed to merge very high speed communications (up to 2Mbit/s) with extremely low power (the RX current is just 12.5mA). Indeed, compared to competing 2.4GHz technologies, typical battery life time improvement ratios are between 15 to 600x (or more).

The transceiver consists of a fully integrated frequency synthesizer, a power amplifier, crystal oscillator, demodulator, modulator and Enhanced ShockBurst™ protocol engine. In addition, the nRF24L01 also offers an innovative on-chip hardware solution – called MultiCeiver™ – that can support up to six simultaneously communicating wireless devices. This makes it ideal for building wireless Personal Area Networks in a wide range of applications including wireless PC desktops (see below) and wristwatch-based intelligent sports instruments (e.g. wireless pulse monitoring).

Output power, frequency channels, and protocol set-up are easily programmable through an SPI-bus. Current consumption is very low, only 8.5mA at an output power of -6dBm and 12.5mA in RX mode. Built-in modes such as Power Down (400nA current) and Standby (32µA at 130µs wakeup) makes significant power savings easily realizable. The data rate can be chosen between 1 and 2Mbit/s. This allows for a short time-on-air, and therefore a low power consumption.

Figure 4 – Size of nRF24L01 with 0402 SMD components

The nRF24L01 is equipped with Enhanced Shockburst™. This offers address decoding and packet validation on up to 6 individual data pipes, making bi-directional link protocol implementation easier and more efficient. In a typical bi-directional link, the terminating part will acknowledge received packets from the originating part in order to make it possible to detect data loss.

Data loss can then be recovered by retransmission. The idea with Enhanced Shockburst™ is to let nRF24L01 handle both acknowledgement of received packets and retransmissions of lost packets, without involvement from the microcontroller. As a result, the only external components required in a typical nRF24L01 implementation are a crystal, some supporting RC components, and an application MCU that can be extremely low cost because the majority of complexity is intentionally designed to reside within the on-chip nRF24L01. Even the required crystal spec has been relaxed with inputs that are 5V tolerant. This allows direct connection to an external USB controller, for example, without need of any additional "glue" logic. Everything else – entire radio, MCU for protocol, peripherals, inductors, and filters, are all pre-integrated into this 4x4mm single chip solution.

The 2.4GHz ISM band is used by many systems, like W-LAN and Bluetooth. This makes it a rather noisy environment. But the disturbances is often of a short duration, meaning that a channel might be blocked by a transmission for very short time. To handle this, the transceiver must either choose another channel, or wait until the channel is clear again. Normally, one will re-transmit a few times so see if the disturbance has disappeared. The nRF24L01 is made with this in mind. If the transmission fails for some reason, the nRF24L01 will automatically send the last packet again. Changing channel is considered a last resort if communication can't be established within a reasonable time.

A SPI-bus is used to configure and communicate with the nRF24L01. This interface is common on most microcontrollers. The maximum speed on the nRF24L01 SPI-bus is 10MHZ, which allows for very fast data transmission.

3. Interfacing the PLN2020 sensor to an RF-link / nRF24L01

Both the PLN2020 and the nRF24L01 communicate via SPI-bus. A microcontroller with a relatively low pin-count can then be chosen. Due to the relatively fast data transmission to and from the PLN2020 and nRF24L01, a hardware SPI-bus is recommended. Software SPI with bit-banging will consume too much processor-time and increase power consumption.

Figure 4 shows how to connect the two devises to the SPI-bus. A separate chip enable, CE, is used for each device. This is normally a general purpose I/O port. This enables the MCI to switch the SPI-bus to the selected device.

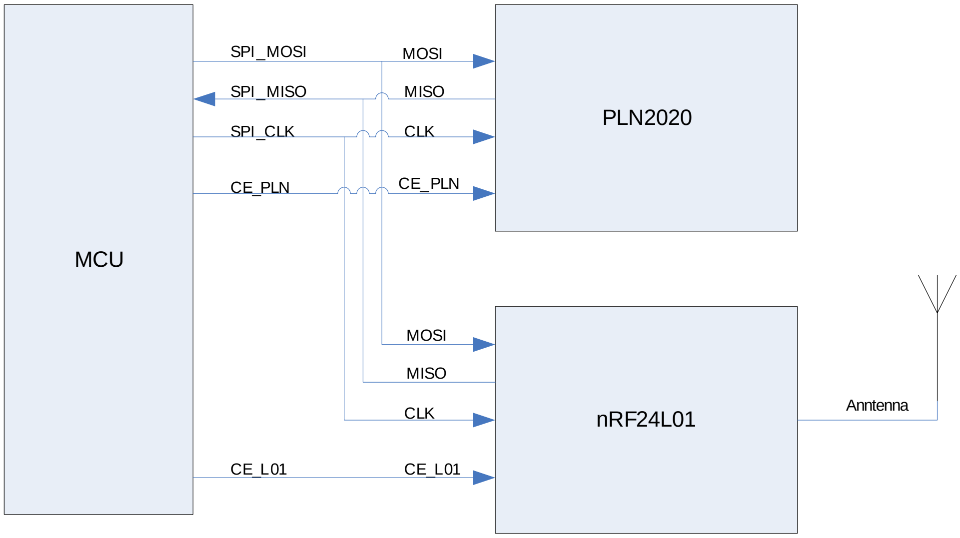

Figure 5 - SPI-bus connection

4. RF-protocol

The PLN2020 sensor will typically be used in a mouse or pointer application. The communication to the host, normally a PC, follows a rather simple low-level protocol. The frequency agility protocol is built on a series of assumptions regarding mouse / keyboard applications and the traffic in the 2.4GHz band.

The traffic in the 2.4GHz band is mainly consistent of frequency stationary systems like WLAN and frequency-hopping systems like Bluetooth. While frequency stationary systems operate in a specific part of the band, frequency-hopping systems will generate traffic in the whole band. All traffic generated by systems operating in the 2.4GHz band is packet based. At a given channel in the 2.4GHz band, if a frequency hopping system is present, the likelihood of a collision with traffic from that system is the same in every channel. It is therefore no use in changing the operating channel if disturbed by a frequency hopping system. If the disturbance comes from a frequency stationary system, it is possible to move in such manner that the likelihood for a collision with the same system on the new channel is minimal.

A mouse will require a much higher update rate than a keyboard. It is assumed that when a mouse is used, it should be updated every 8th millisecond. The mouse will therefore have priority in front of the keyboard regarding updates.

Based on the previous assumptions the definition of the frequency agility protocol emerges:

"A protocol that will move own traffic to another channel in the 2.4GHz band if a stationary disturbance occurs at the currently used frequency."

The main functionality of the frequency agility protocol will be to:

- Detect stationary disturbance.
- Move in such manner that new disturbance from the same source will not occur.
- Do not move if disturbed by a frequency-hopping source.
- Give priority to mouse traffic.

It is important to notice that this protocol will only force a change in operating frequency if a stationary disturbance occurs. After it has changed the operating frequency, it will be on the new channel for a relative long time.

The frequency agility protocol functionality is based on the communication between the mouse and the dongle. When the mouse is in use, it will send a packet to the dongle every 8th millisecond and wait for acknowledge. The mouse will re-send a packet up to two times if no acknowledgement has been received. Bluetooth will stay up to 650 microseconds on one channel before hopping. This means that if a Bluetooth system is knocking out the mouse' first attempt to send a packet, the next two should get trough since each packet-acknowledgement cycle takes about one millisecond. It is therefore not likely that a frequency hopping system will cause a change in frequency.

If all three attempts to send a packet fail, the mouse and dongle will change channel according to a table. The table is built up to take care of the functionality that avoids disturbance from the same source at the new channel. Specially the high bandwidth of WLAN

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YOUR NOTES

Philips Laser Sensors

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