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APPLICATION NOTE 4153

Using the MAXQ3210 in a Light-Beam Alarm System

Abstract: This application note demonstrates an alarm system that uses the MAXQ3210 RISC microcontroller and an external photoelectric sensor as the alarm trigger. When the light beam is interrupted, a loud audio alarm sounds. Various photoelectric sensing modes and performance parameters are discussed. The assembly language source code and PCB Gerber files are available.

Overview

One can imagine numerous interesting applications where interrupting a beam of light causes an audible alarm. This application note describes such a system. By using the MAXQ3210 microcontroller and its built-in piezoelectric horn/transducer driver, a system is implemented with a minimal component count.

A commercially available, photoelectric light-sensor module is the input to the alarm system. There are numerous types of light sensors available; some issues relevant to selecting the best sensor for an application are discussed in this document. A small, commercially available wall-transformer power supply powers this system.

The MAXQ3210 RISC microcontroller is the heart of the system, and there are very few additional components required. A small 3-pin piezoelectric audio transducer produces the audible alarm; a linear voltage regulator powers all electronics, other than the photoelectric module which is powered directly from the external power supply. The schematic for this system is shown in **Figure 2** below. A two-sided printed circuit board (PCB) provides the interconnect for the prototype. The Gerber files for manufacturing this PCB are available for download (ZIP). This file also contains the source code, related project file, and loadable hex file for this application.

The software for this demonstration system was written in MAXQ® assembly language. The tool used in developing this application was the MAX-IDE version 1.0. The MAX-IDE is a free, easy-to-use Windows®-based development environment that provides a complete suite of tools for the MAXQ family of processors.

The hardware used in the firmware development for this application was the MAXQ3210 Evaluation Kit board. This board provided a convenient, proven platform for testing the firmware. With this board and the MAX-IDE tool set, a complete development and debug environment is provided.

Possible Applications

A burglar alarm is a familiar application for the light-beam alarm system described in this document. When an intruder passes through an entryway protected by a light sensor, they interrupt the beam of light and cause the alarm to sound. In environments where there is little debris in the air to reflect light, the light beam remains invisible and is interrupted before the intruder knows that the sensor is present. This type of system can notify a shop owner that someone has entered their establishment. The sensor could also be used to monitor that someone, or something like a pet, remains inside an area. By placing the sensor outside an area's entryway, it remains unseen until the beam is interrupted when someone exits. By strategically placing the sensor on a kitchen countertop, this alarm could be used to deter the family pet from jumping on the counter.

In a commercial setting, this alarm system can detect items on a moving conveyor belt. By placing the receiver or reflector opposite the emitter, the alarm sounds when a passing object interrupts the beam. If the objects on the belt differ in size, the sensor could be placed so that only the largest items interrupt the beam. In a more complex system, multiple sensors are mounted at different heights above the belt to differentiate the size of the passing objects. If the objects have a sufficient profile and reflectivity, they can reflect sufficient light back to a receiver to activate the sensor. With a slight change in the software, the alarm system could be modified to activate if the belt stops or even to count objects.

The potential applications for this light-beam alarm system are wide and varied, and limited only by the user's imagination. The alarm system implemented here demonstrates a generalized design that can be applied to numerous applications or can be used as the basis for a unique system more targeted to a specific application.

Photoelectric Sensor

In a photoelectric sensor a light source, an emitter, generates a beam that is detected by a light-sensitive device, a receiver. The beam's source is typically a modulated LED packaged with drive electronics and optics. The receiver contains amplifying and demodulating electronics along with related receiving optics. Commercially available units are produced in many configurations intended for a variety of specific applications. Sensors, for example, can be designed to be active when an object is present or not present. They can be designed to be reflected by specific types of surfaces and not others. They can be focused and targeted at very fine objects such as a fine thread, or they can be defocused to cover larger areas and larger objects. With such a range of applications, one must take care to choose the correct photoelectric sensor. The discussion below reviews some factors that influence sensor selection.

Sensing Modes

Generally, photoelectric sensors can be divided into three broad categories of sensing modes: opposed, retroreflective, and diffuse. In opposed-mode sensing, also called "through-beam" mode, the light emitter and receiver are contained in separate packages and are arranged opposite each other. The light from the emitter shines directly on the receiver; an object is detected when it interrupts the beam. In retroreflective mode, the object is also sensed when the beam is interrupted. In this mode, however, the emitter and receiver are enclosed in the same package. A special reflector (retroreflective) returns the light from the emitter to the receiver. Unlike a mirror, which reflects light back to the source only if it is perpendicular to the beam, a retroreflective device reflects light back to its source, regardless of the angle of incidence (within certain constraints, of course). This single package arrangement consolidates the electronics of a retroreflective sensor in a single location, and eliminates one package and its associated cabling. In diffuse-mode sensing, also called proximity mode, both the emitter and receiver are contained in the same package, but the light beam is reflected by the object being detected. This mode is common in applications where the target's reflectivity and profile are sufficient to return a significant percentage of the emitted light back to the sensor.

Optics

The optics used in a particular sensor greatly influence its effectiveness for a given application. In typical diffuse-mode sensing, minimal optics are used to give the emitter a broad pattern and the receiver a wide field of view. In a special case called convergent-mode sensing, different optics are used to produce a tight beam and a well-defined sensing area. This approach allows objects to be detected that would otherwise have insufficient reflectivity for standard diffused-mode sensing. When available space is restricted, fiber optic strands or bundles of strands can channel light energy from the emitter to the receiver. Fiber optics can also be used when it is necessary to detect objects in an extremely caustic environment. This is because glass, frequently used as fiber optic material, can withstand very high temperatures and corrosive environments well beyond the capabilities of a standard photoelectric sensor module.

Sensor Output

Another distinguishing characteristic of a photoelectric sensor is its output type. Depending on the device's configuration, the receiver can generate an active output when the light beam is detected ("Light On" operation), or when it ceases being detected ("Light Off" operation). The receiver's output can also be pulled high to its supply voltage (sourcing) which is referred to as "PNP Output," or pulled low to ground (sinking) which is referred to as "NPN Output" when it is active. Some devices offer user-selectable Light On or Dark On operation, and have both PNP and NPN outputs available.

Wavelength

The color, or wavelength, of the light emitted from a sensor can also be a distinguishing characteristic. One can choose a sensor for a particular application based on the wavelength of its emitted light, because the reflectivity or absorptivity of the object being detected may be greater for that particular wavelength. Most standard sensors use a wavelength in the high end of the visible spectrum (red = 650nm) or the low end of the infrared spectrum (infrared = 880nm).

Modulation

To minimize the possibility of detecting unwanted light sources, it is common to modulate the light source. This modulated signal is then used at the receiver to filter out unwanted signals. The modulation frequency is typically in the range of a few kilohertz, and this frequency directly affects the system's response time.

Distance

Photoelectric sensors can function at distances from several centimeters up to hundreds of meters. Opposed-mode systems generally operate up to 10x the distances of retroreflective or diffuse-mode designs. Some emitters use lenses to collimate the light, i.e., make its rays parallel and improve beam intensity and, therefore, the operating distance. Other emitters use the natural diffusion properties of light to cover a larger area. Because of this dispersion, however, these emitters typically have a much shorter sensing distance. On average, the sensing distance for a retroreflective device is approximately 4x that of a simple reflective device. In specialized applications requiring sensing at great distances, laser light sources can be used. Since laser light can be created with minimal beam divergence, most of the emitter's energy is returned to the receiver. In some applications where the object being detected has a highly reflective surface, a polarizing reflector is used. In this situation, any nonpolarized light returned to the sensor is reflected from the detected object.

Excess Gain

A key specification for any photoelectric sensor is excess gain, which predicts the reliability of a sensor operating in a given environment. Specifically, this parameter is a measure of the receiver's ability to detect an amount of light above the minimum required for detection and to produce an active output. Excess gain values can range from 1.5 for clean air environments with no dirt buildup on lenses or reflectors, up to 50 or more for dirty environments with heavy contamination from fog, mist, or dust.

Example System Sensor

The specific photoelectric sensor used in this example system is the Keyence™ PZ-G61B shown with the PCB and reflector in the photograph of **Figure 1**. This sensor is a retroreflective device designed to fit a wide variety of applications. The sensor provides a user-adjustable gain and offers both PNP and NPN output signals. In this example system, the PNP output switches the module's power supply (+12V DC in this case) to this output when active. The sensor also offers a two-position, user-selectable switch that causes the device to operate as a Dark On or a Light On device. The sensor is set for Dark On operation in this application. The Keyence PZ-G61B is specified to operate over a distance of 0.3 feet to 13.8 feet (0.1m to 4.2m) when the specified reflector is used. The reflector in this example system is a Keyence OP-84219 R-2L, 2in x 2in square retroreflective device.

Figure 1. PCB, sensor, and reflector.

Circuit Diagram

The circuit diagram for this design is shown in Figure 2. As can be seen, very few components are necessary to implement a system using the PZ-G61B sensor and the MAXQ3210 microcontroller. A 12V wall-transformer power supply powered the system. A single supply was chosen because of the difference in power supply requirements for the sensor and the microcontroller. The photoelectric sensor is specified to operate from 10V to 30V DC ±10%. The maximum supply voltage for the MAXQ3210 is specified as 9.5V. Using a single power supply for both devices would push the limits of the specifications and would leave little margin for variation. Consequently, a regulator was used on the PCB to generate the microcontroller's 5V supply. A linear 5V regulator (7805) was used to reduce the 12V main power input from the external power supply to the 5V needed for the microcontroller. By shorting the MAXQ3210's digital supply input (V_{DD}, pin 17) to its regulator output (REGOUT, pin 18), the internal regulator was effectively deactivated.

While testing the prototype system, it was noted that the voltage output from the specific, unregulated power supply used for this implementation and listed in the bill of materials was significantly higher than the rated 12V. With no load, the output measured nearly 16V. While this was well within the maximum ratings of the 5V regulator, it did cause the regulator to heat slightly when fully loaded. The heating was not a problem for this specific implementation, because the regulator was not enclosed and was in an open-air environment. However, it may be necessary to account for this power dissipation in a different environment. This can easily be accomplished by adding a heatsink to the TO-220 regulator package. Alternately, a slightly more expensive 12V regulated-output power supply can be used. Either method should keep the 5V regulator's temperature under control since the board requires very little power.

In this design, the photoelectric sensor's output was buffered into the microcontroller's input pin by using an n-channel FET. This approach isolates the microcontroller from potential ESD events entering the board through the remote sensor's cable. If a damaging ESD event did occur, then the FET and not the microcontroller would probably need to be replaced. This buffered protection represents a minimal cost, and has the additional advantage of isolating the 12V sensor output signal from the 5V signal levels expected on the microcontroller's input pin.

To produce the system's audible alarm, a CUI CEP-1172 piezoelectric audio transducer was used. This device has a minimum sound pressure level of 81db at 30cm and 12V DC, and a resonant frequency of approximately 3.3kHz. While the MAXQ3210 produces horn-drive signals of nearly 5V in this system, the transducer produces a significantly loud alarm, certainly more than adequate to draw someone's attention. A few passive components (two resistors and a capacitor) allowed the MAXQ3210 to produce this impressive sound level.

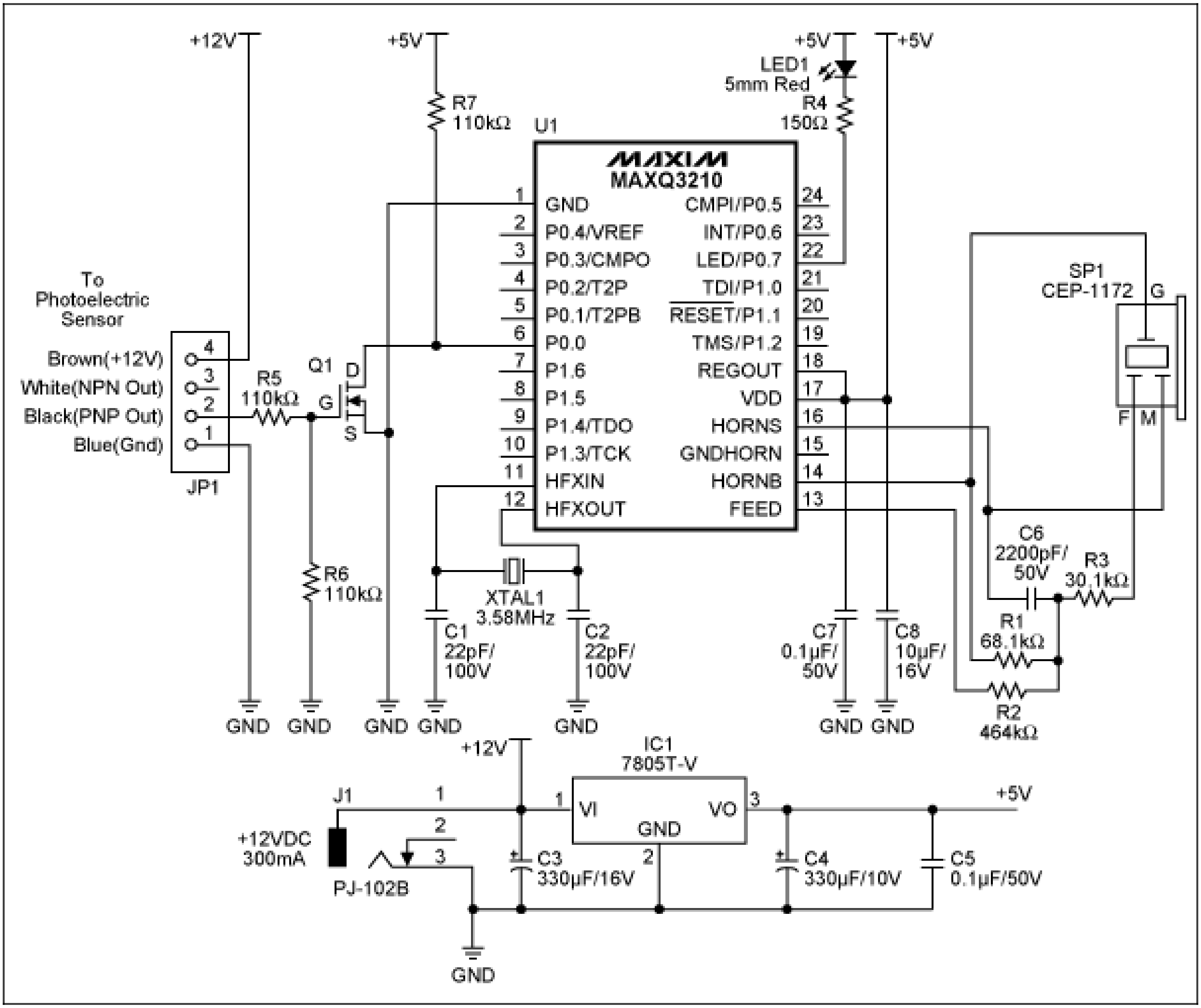

Figure 2. Board schematic.

Firmware Details

The firmware for this application is straight-forward. It consists of one assembly language source file (LightBeamAlarm.asm) that contains the hardware initialization, the main program loop, and several subroutines. The light-sensor's PNP output is connected to the processor's P0.0 port pin through the FET, and the signal level is read by the software. If the sensor's output is active, the alarm sounds.

To create the audible alarm, a subroutine causes the piezoelectric transducer to "chirp." Each chirp consists of a fixed on-time and a fixed off-time. These on- and off-times were determined experimentally, and were subjectively chosen to make the audible alarm as noticeable as possible. Regardless of how briefly the light sensor's output is activated, the transducer will chirp five times. If the sensor's output is active longer than the five-chirp period, it will continue producing multiples of five chirps until the output becomes inactive again.

As a "system operational" indicator, a LED is flashed on and off. The high-current capability designed into the processor's P0.7 pin is used to directly sink the current from the attached LED. The processor's Timer2 times out every 0.5s, and generates an interrupt when it does so. The interrupt service routine toggles the port pin connected to the LED (P0.7) every time that it is executed. This action causes the LED to flash once a second.

A generalized time delay created with software timing loops is provided to create variable delay intervals. Parameters establishing the delay period are passed to the subroutine in otherwise unused accumulators. These delay periods are used to generate the chirping on- and off-times mentioned above.

Conclusion

The system described in this application note implements an alarm system that is triggered when a light-beam is interrupted. The system uses a commercially available light emitter-receiver pair that employs a reflector to return the light from the emitter to the receiver. The system requires a minimal component count because it takes advantage of the MAXQ3210 microcontroller's built-in resources, such as a piezoelectric horn driver and direct LED-drive port pin. The software is easily contained in the processor's 2kB on-board EEPROM memory, and an external wall-transformer power supply powers the board's 5V regulator.

Application Note 4153: www.maxim-ic.com/an4153

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