Night and Day Application

A light sensor is essentially a transistor whose base (B) is photosensitive. Photons of light are converted to electrons when they hit the transistor base which partially turns on the transistor allowing electrons to flow between the collector and emitter. The more light that hits the base the more the transistor will turn ON by lowering the resistance between the emitter and collector.

Light density is measured in Lux. Table 1 is a chart to illustrate the relationship between actual ambient light scenarios, the equivalent value in lux, and a couple of signal levels to expect given a standard VCC voltage and load resistor placed on the collector.

For the experiments in this paper – we are using Vishay Semiconductor’s TEMT6202FX01L part as pictured. This is a very small part, which comes in a 0805 package – so the technician has soldered leads onto the part for easier experimentation. It’s tough to tell from the photograph but there is a small wire inside sensor that indicates the emitter on the two pin part.

There are a couple of items to note right away in Table 1.

First, there is a huge ratio difference in lux between a bright sunny day and night 1 to 120,000. Thus it is pretty easy to design a circuit with GreenPAK (PAK), part number SLG46200, that is able to distinguish night from day. The easiest method of detecting bright light from dark is simply by connecting to a digital input. The low voltage digital input has a relatively flat VIH (1.7V) and VIL (0.52V) levels even across temperature, process, and voltage. Thus in our example a 75kΩ load resistor will easily trip a low voltage PAK digital input with its extremely high impedance CMOS input.

Table 1. Ambient Light Scenario Table

<table>
<thead>
<tr>
<th>Ambient Light Scenario</th>
<th>Lux</th>
<th>Ambient light sensor with VCC=5V, RL=1kΩ</th>
<th>Ambient light sensor with VCC=5V, RL=22kΩ</th>
<th>Ambient light sensor with VCC=5V, RL=75kΩ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brightest sunlight</td>
<td>120,000</td>
<td>0V</td>
<td>0V</td>
<td>0V</td>
</tr>
<tr>
<td>Shade on a sunny day</td>
<td>20,000</td>
<td>0V</td>
<td>0V</td>
<td>0V</td>
</tr>
<tr>
<td>Overcast day</td>
<td>10,000</td>
<td>0V</td>
<td>0V</td>
<td>0V</td>
</tr>
<tr>
<td>Sunrise or sunset on a clear day</td>
<td>400</td>
<td>4.95 V</td>
<td>0V</td>
<td>0V</td>
</tr>
<tr>
<td>Office Lighting</td>
<td>200-500</td>
<td>3.3V</td>
<td>4.8 V</td>
<td>4.998 V</td>
</tr>
<tr>
<td>Dark Stormy Day</td>
<td>40</td>
<td>4.994 V</td>
<td>4.8 V</td>
<td>4.998 V</td>
</tr>
<tr>
<td>Moonlight</td>
<td>1</td>
<td>4.9999990 V</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

© 2022 Renesas Electronics Corporation
However, PAK inputs are pretty quick, with a 20MHz to 25MHz response. So hooking up a sensor like this will likely generate digital chatter as the signal transitions from low to high and high to low.

In our testing on a nominal part we see the chatter right around the light equivalent of a 1V input.

To reduce chatter a standard digital input can be selected with the Schmitt trigger enabled. However, with this selection the variation in VIH AND VIL is much greater so this application is most certainly limited to only non-precise applications.

More Precise Sensing

GreenPAK1 and GreenPAK2’s analog comparators are accurate to around +/-5% so they’ll do a reasonable job for most applications and are certainly more accurate over temperature, process, and voltage as compared to purely digital inputs.

Next, the load resistor RL alters the signal level for the same amount of lux – see Table 1 as an example. Depending on what light level your application is trying to distinguish you need to set the proper load resistor. The light sensor datasheet gives the gain curves associated with one or more load resistors.

If the RL value is set above 1 MΩ then board noise and thermal noise starts to become a limiting issue. A filter capacitor will help knock down the noise. The penalty of this filter capacitor is delayed response to a light signal. The capacitor value should be selected according to the response time of the
application following the standard $f = 1/(2\pi RC)$ formula.

If the light sensor is placed some distance from the PAK IC then it is possible that common-mode noise will be applied to the input of the PAK. Common-mode noise is noise that is present on the ground pin and signal pin. In the case of common-mode noise we cannot assume that the intended ground at the sensor emitter is exactly the same voltage as the PAK ground. The PAK IC in single-ended comparator mode will output using common-mode noise + real signal possibly giving a wrong output. The way to solve this issue is with differential measurement with the PGA located in the ADC block. A future paper will cover PAK differential measurements.

In our application day light will result in near zero volts applied to the PAK IC and moonlight will result in about 5V applied to the PAK IC. The GPAK2 (SLG46400) comparator supports a signal range from 0 to 1V or 0 to 1.5V. If you overdrive the input on the comparator there is no application or reliability issue up to a diode drop above VDD.
Saving Power

To detect various levels of daylight brightness will require a lower value for RL. A low value of RL results in higher current consumption. One simple method to reduce the power consumption is by taking samples periodically.

The PAK ICs support this capability through a number of methods. One simple method is to set a counter. The PAK counter sends out a pulse equivalent to a single count when it rolls over.

Simply by setting the counter value and clocking it duty cycled pulses can be generated at a fixed ratio. Next, apply the counter to an output pin and connect to the top of the RL resistor as shown in the diagram. The overall power consumption will drop roughly by the duty cycle of the counter. So if the counter is set to 10, then the power consumption will drop by 11x (Counter Data+1). This assumes the power consumption is dominated by the load resistor.

The diagram shows a PAK Latch connected to the output of the comparator. This latch is necessary in our application to “capture” the sample. The comparator’s output will reflect the right value but will return immediately to OFF condition when the counter pulse returns low. So the Latch is placed to capture the change in the output of the comparator. The latch will need to reset at the start of each new sample.

Well that is the theory anyways, let’s look at a real life example.

In our real life example we first need to generate a sampling clock. Ambient light sensors are not designed to be particularly fast. In fact ours with a 22kΩ load resistors settles in about 0.5 ms. So our sampling clock needs to go slow. First we select the slowest speed in our RC Oscillator or 29 kHz with the /12 option this yields a 2.4 kHz frequency. This is still too fast so we divide with a DFF by 2 yielding a frequency of 1.2 kHz or ~0.8 ms.

*Picture 3 – Scope photo from GreenPAK Oscilloscope of the ambient light sensor being turned on and settling as measured on Pin 3. Settled level at around 0.7V is equivalent to office fluorescent lighting.*
This is just about right, but we elect to divide one more time just to ensure we have enough margin for temperature and tolerance variation. Our final sample clock is ~600Hz or ~1.65ms.

The sample clock is a square wave. Now remember our goal is to produce a pulse that turns on for 1.65 ms but NOT with a 50% duty cycle. So we run our sample clock into a counter CNT0. The counter will count the pulses up to a programmed value and when the final value is reached the counter outputs one pulse equal to the sample clock pulse. We put 10 into the counter for this demo. Thus it is easy to get 1 pulse period ON 10 (Counter Data+1) pulse periods OFF. Much larger values can be programmed into the counter if samples only need to be taken once in a great while saving even more power.

The output of CNT0 turns ON Pin 4 that is connected to the sensor and RL. Picture 2 shows the voltage that is applied to our input sense pin 3. The initial pulse should be ignored and the sensor only sampled after settling for a few 10’s of milliseconds. Thus we apply the output of our sample pulse stream to DLY1. DLY1 is a rising edge only ~0.79 ms delay. When CNT0 outputs a rising edge, DLY1 tracks these 0.79 ms later. When CNT0 outputs a falling edge DLY1 tracks this with no delay. Therefore the sensor turns ON and begins to settle in 0.5 to 0.7ms, just as the sensor signal finishes settling the comparator turns on and takes a sample and then both the sensor and comparator shut OFF at the same time.

The final DLY2 is used as a glitch filter. When the comparator turns on a small glitch can be output as

![Graph](image.png)

**Picture 4 – Scope photo of the sensor input under bright light. Note the Pin 10 output is now high and free of glitches and remains high when the sample is not being taken.**
the comparator settles. Normally the comparator takes about 100µs to settle. Since we are not concerned about ultrafast response we set the DLY2 glitch filter to delay on both edges and for a period of much longer than 100µs. Remember if the Delay period is longer than the input signal then the pulse is swallowed by the DLY2 circuit.

More sophisticated light sensing designs can also be accomplished with the PAK IC. In the example below a simple 4 level light detector is shown. This example can easily be turned into a 4 bit level (16 levels) detector by changing each resistor value to be ½ of the previous resistor value. Logic can be added to the PAK IC to detect the level and output a signal that indicates that screen brightness should be increased or a light to be turned on.

*Happy PAKing.*
IMPORTANT NOTICE AND DISCLAIMER

RENESAS ELECTRONICS CORPORATION AND ITS SUBSIDIARIES (“RENESAS”) PROVIDES TECHNICAL SPECIFICATIONS AND RELIABILITY DATA (INCLUDING Datasheets), design resources (including reference designs), application or other design advice, web tools, safety information, and other resources “AS IS” AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS OR IMPLIED, INCLUDING, WITHOUT LIMITATION, ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for developers skilled in the art designing with Renesas products. You are solely responsible for (1) selecting the appropriate products for your application, (2) designing, validating, and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, or other requirements. These resources are subject to change without notice. Renesas grants you permission to use these resources only for development of an application that uses Renesas products. Other reproduction or use of these resources is strictly prohibited. No license is granted to any other Renesas intellectual property or to any third party intellectual property. Renesas disclaims responsibility for, and you will fully indemnify Renesas and its representatives against, any claims, damages, costs, losses, or liabilities arising out of your use of these resources. Renesas' products are provided only subject to Renesas' Terms and Conditions of Sale or other applicable terms agreed to in writing. No use of any Renesas resources expands or otherwise alters any applicable warranties or warranty disclaimers for these products.

(Rev.1.0 Mar 2020)

Corporate Headquarters
TOYOSU FORESIA, 3-2-24 Toyosu,
Koto-ku, Tokyo 135-0061, Japan
www.renesas.com

Contact Information
For further information on a product, technology, the most up-to-date version of a document, or your nearest sales office, please visit:
www.renesas.com/contact/

Trademarks
Renesas and the Renesas logo are trademarks of Renesas Electronics Corporation. All trademarks and registered trademarks are the property of their respective owners.

© 2021 Renesas Electronics Corporation. All rights reserved.