Ambient Light Sensing Using GPAK

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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.

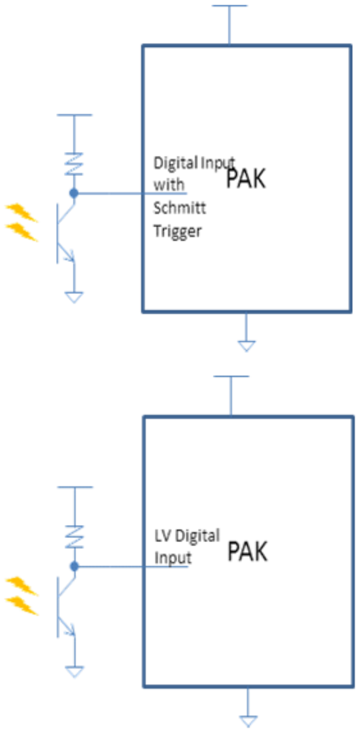
First, there is a huge ratio difference in lux between a bright sunny day and night 1 to 120,000. Thus it is pretty easy to design a circuit with Silego's GreenPAK (PAK), part number SLG46200, that is able to distinguish night from day. The easiest method of detecting bright light from dark is simply 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.

Picture 1. Picture of Ambient Light Sensor

Table 1. Ambient Light Scenario Table

Ambient Light Scenario	Lux	Ambient light sensor with VCC=5V, RL=1kΩ	Ambient light sensor with VCC=5V, RL=22kΩ	Ambient light sensor with VCC=5V, RL=75kΩ
Brightest sunlight	120,000	0V		0V
Shade on a sunny day	20,000	0V		0V
Overcast day	10,000	0V		0V
Sunrise or sunset on a clear day	400	4.95 V		0V
Office Lighting	200-500		3.3V	
Dark Stormy Day	40	4.994 V		4.8 V
Moonlight	1	4.999990 V		4.998 V

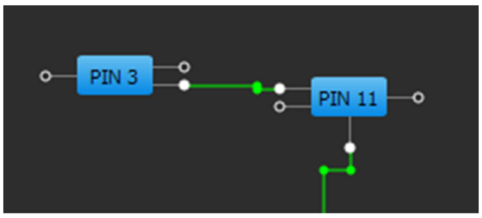
However, PAK inputs are pretty quick, with a 20MHz to 25MHz response. So hooking up a sensor like this will likely generate digital chatter as the signal transitions from low to high and high to low.



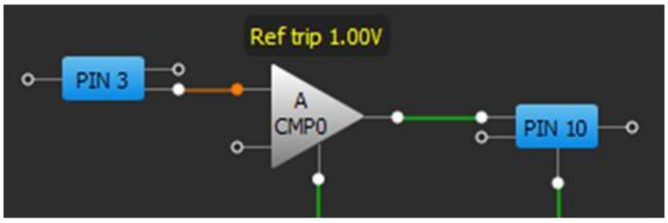
Circuit 1. Digital Low Voltage Input and Digital Input with Schmitt trigger

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.



Software Screen Shot 1 . PAK2 Software showing a LV digital input driving an output

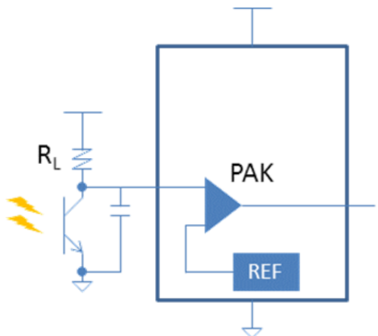


Software Screen Shot 2 . PAK2 Software showing the proper sensing of a light sensor with a PAK comparator

More Precise Sensing

PAK1 and PAK2'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.

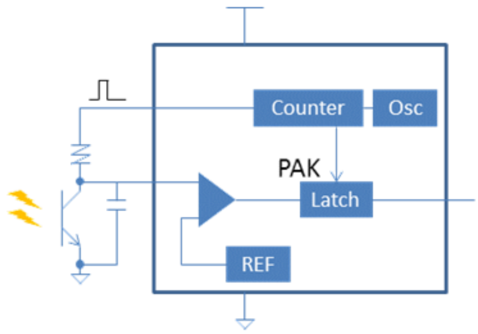


Circuit 2. PAK in Light Sensor application with sensing comparator

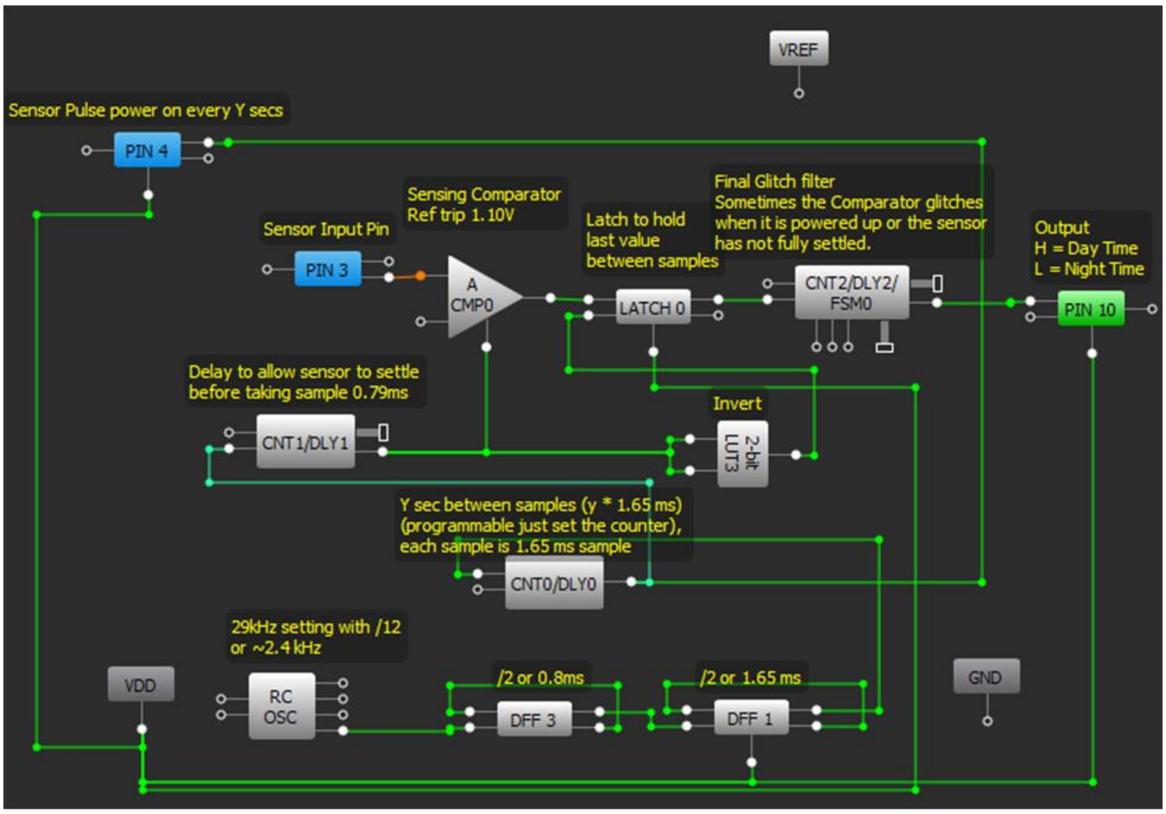
If the RL value is set above 1 MΩ then board noise and thermal noise starts to become a limiting issue. A filter capacitor will help knock down the noise. The penalty of this filter capacitor is delayed response to a light signal. The capacitor value should be selected according to the response time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



Circuit 3. PAK with a periodic sampling scheme to reduce power consumption



Circuit 4. Actual PAK implementation of the concept circuit illustrated in Circuit 3 to reduce power consumption

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.

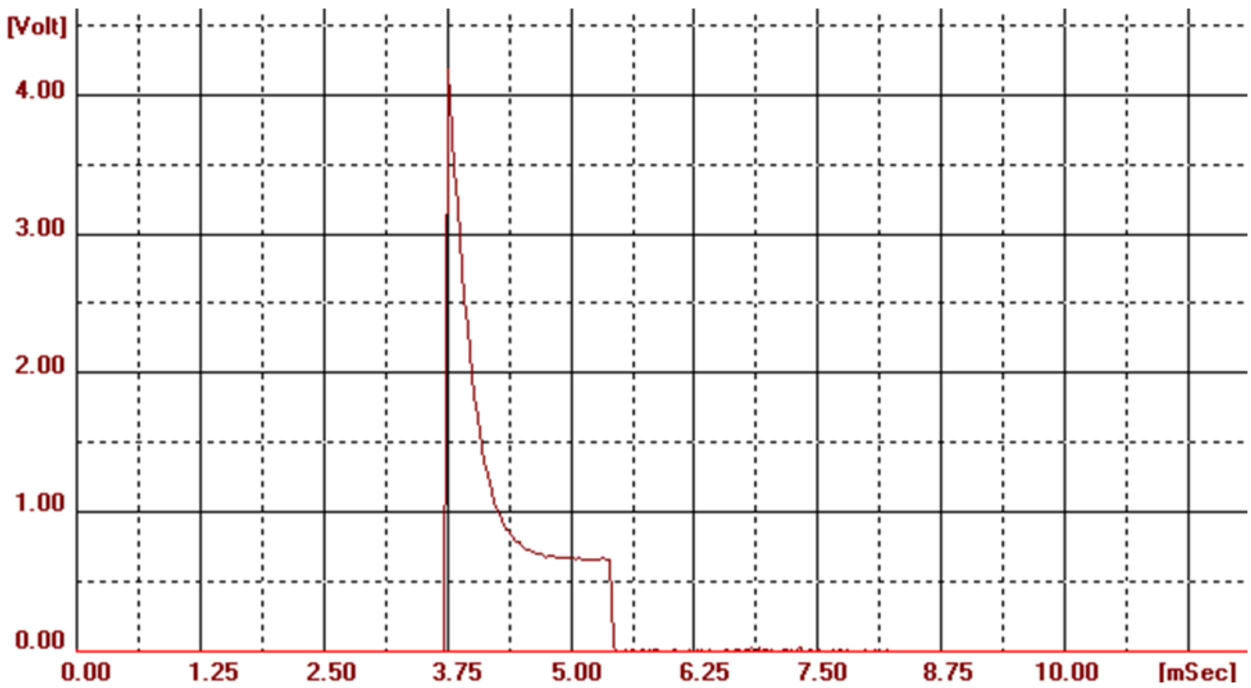
The PAK ICs support this capability through a number of methods. One simple method is to set a counter. The PAK counter sends out a pulse equivalent to a single count when it rolls over.

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 current.

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.



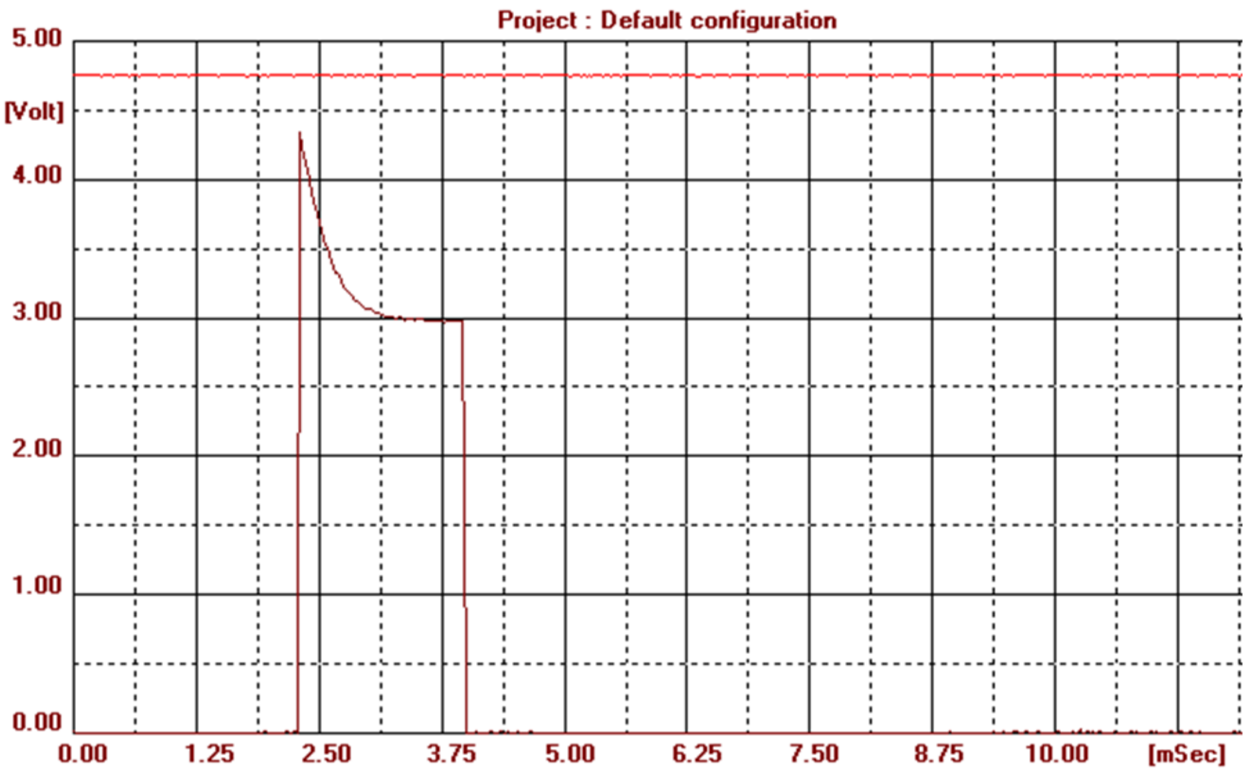
Picture 3 – Scope photo from Silego's PAK Oscilloscope of the ambient light sensor being turned on and settling as measured on Pin 3. Settled level at around 0.7V is equivalent to office fluorescent lighting.

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.

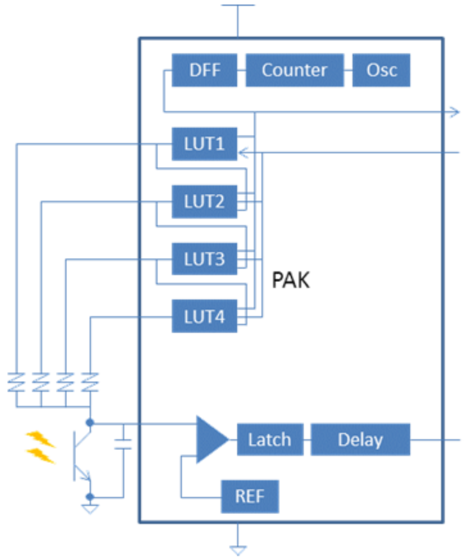
The output of CNT0 turns ON Pin 4 that is connected to the sensor and RL. Picture 2 shows the voltage that is applied to our input sense pin 3. The initial pulse should be ignored and the sensor only sampled after settling for a few 10's of milliseconds. Thus we apply the output of our sample pulse stream 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



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



Circuit 5. PAK with a simple 4 level light detector

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.

About the Author

Name: John McDonald

Background: John McDonald came to Silego from SiTime ('05 – '08), a MEMS resonator start up. As VP of Sales and Marketing, the SiTime team introduced the world's first and only production MEMS oscillators, achieved numerous design wins shipping 100's K of units in the first production quarter. Prior to SiTime, John was working for Cypress MicroSystems (CMS), a Cypress Semiconductor funded startup and makers of the popular PSoC microcontroller family. As VP of Marketing ('01 to '05), he led a great worldwide marketing and applications team that grew the PSoC product family to be the fast growing and high margin success it is today. Prior to CMS, Mr. McDonald worked for Cypress Semiconductor and was part of the general purpose and programmable clock marketing group ('98 - '01) during a period in which non acquisition sales grew by more than 5x of which more than 50% was Japan designed in revenue.

Mr. McDonald has also worked for Analog Devices in the Precision Op Amp group and as an advanced analog design engineer for 6 years in Washington State. John has his BSEE from the University of Washington, and has authored numerous technical articles.

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A	John McDonald	08/23/2013	New application note

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