Auto Calibration of Optoelectronics: Manufacturing Variations, Temperature Changes, and LED Degradation Cause Unreliability and Low Life Expectancy

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Taking the product variances out of your optoelectronics designs has the potential to dramatically improve the reliability, performance and life expectancy of the end use equipment. Optimum optoelectronic manufacturing has a 2:1 variance in the min / max output of a device, but today's optoelectronic manufacturing process operations cannot economically put into practice this precise control for producing devices in such an exact and narrow specification. The designer must take into consideration all possible product variations including minimum to maximum electrical characteristics as well as variations in performance over time and temperature.

Optical switching occurs when the LED radiates light on the phototransistor and a current begins to flow. This load current (IL) can be changed to a voltage and easily measured by adding a resistor to either the collector or emitter (see figure 1). The forward current of the LED (ID) is used to control the amount of light being radiated. This current is controlled using a limiting resistor (RD) and typically ranges from 5mA to 20mA. The equations to calculate the resistor values are noted in figure 1 with a typical load resistance value noted.

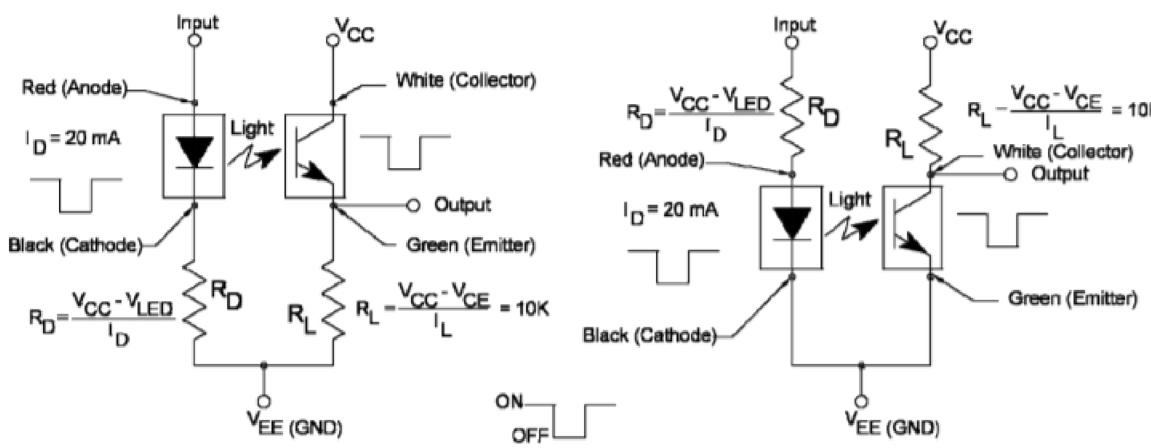

Figure 1

As mentioned, manufacturing variances in the devices themselves can create output current variations. When slotted or reflective switches are manufactured, they are built with an LED and photosensor (photodiode, phototransistor, or Photologic®) and are tested and categorized into groups. These subsequent groupings are then used to provide the desired input and output electrical characteristics. Typical variation for the electrical output IC(ON) has a ratio (maximum IL / minimum IL) from 3 to 7 (i.e. IL maximum = 5mA / IL minimum = 1mA provides a ratio of 5 / 1 = 5). The design engineer must take into consideration these variations during the equipment design cycle.

Another design consideration is inherent degradation of the LED. As LEDs age, they all have a tendency to lose efficiency with respect to optical power. Typical degradation is referenced at 25°C with a known LED current (ID, typically 20mA). As shown in figure 2, the output typically degrades between 5% and 20% over 100,000 hours or 11.4 years. This might seem to be a long time, but a lot of equipment is expected to operate for more than10 years, thus the design engineer needs to take this into consideration.

In addition to manufacturing variation and LED degradation, the ultimate use for the application must also be taken into consideration. Temperature changes have a significant affect on the product – a variation in temperature changes both the

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amount of light emitted by the LED as well as the sensitivity of the photosensor. When temperature increases, the light emitted by the LED decreases, while the sensitivity of the phototransistor increases. This offset helps, but doesn't totally fix the problem. Figure 3 shows a typical LED and phototransistor output current relative to temperature. The actual amount of change in output current versus temperature may increase or decrease, depending on the characteristics of the LED and phototransistor. For those applications where temperature variation is a design factor, this must also be considered.

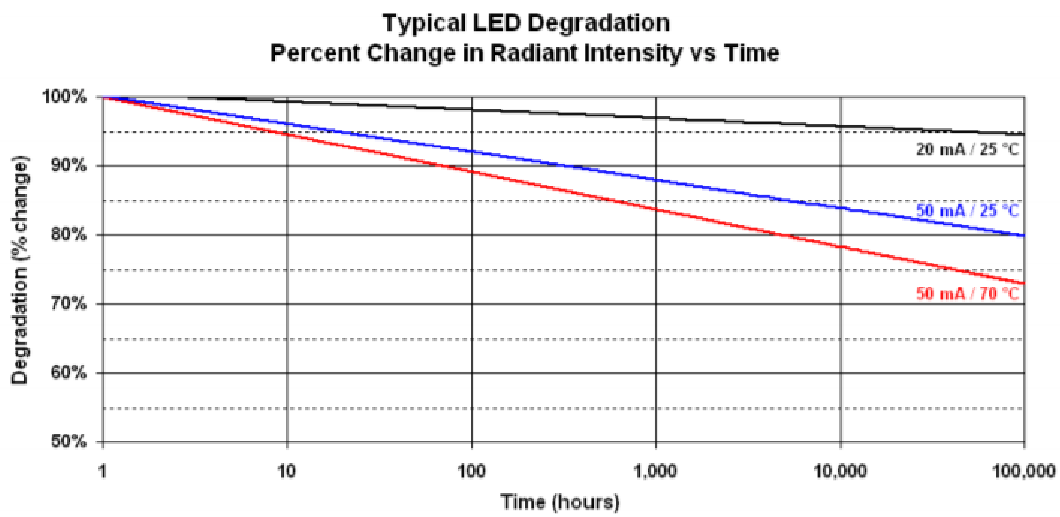
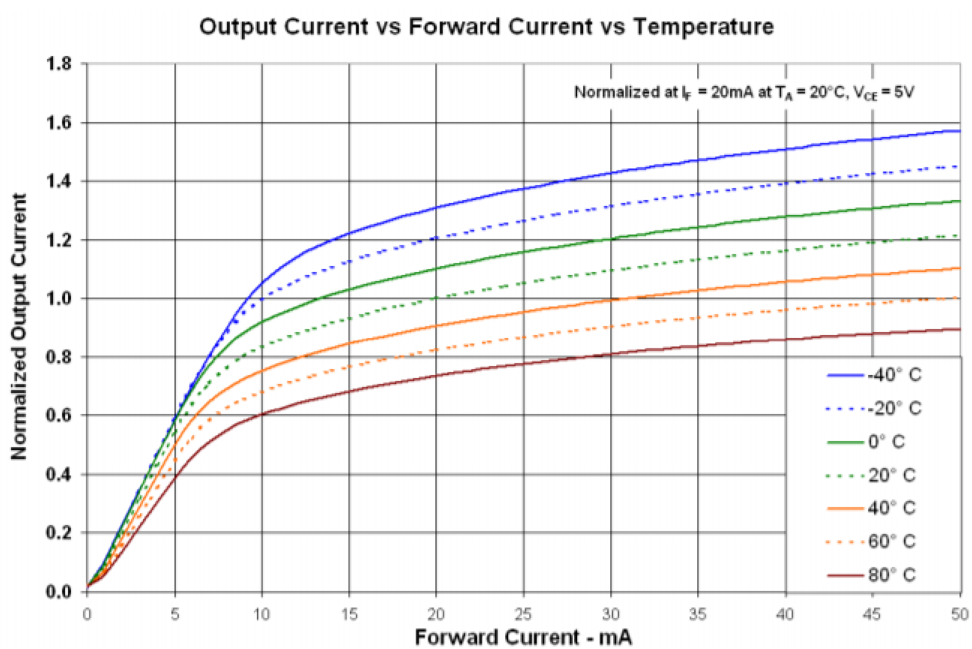


Figure 2



Variation in the power supply may also occur. As the power source varies due to temperature, load and aging factors, the drive current for the LED may change as well as the output current of the phototransistor. Because this is typically a small change (unless the power source is on the verge of failure), the designer can expect a change in the 0% to 2% range.

So now we know that an optical switch has an LED and photosensor that can have an output current maximum / minimum ratio in the 3 to 7 range at room temperature. Adding LED degradation at 5% changes this ratio to 3.15 to 7.35. Adding temperature variation from –40°C to + 85°C can change this ratio to 5.53 to 12.90 or more. Fortunately, with simple designs like the ones in figure 1, the minimum amount of output current becomes the most important design factor. First, one must take into consideration the specified electrical characteristic variation, temperature fluctuation, LED degradation and finally the change in the power source. Designing with these characteristics in mind will provide a more robust and stable solution.

How is it possible to take into consideration all these effects without spending hours of calculations and computer simulations? What if there was a device with a feature that would allow the system to be calibrated at any time, and would remember the final set-up information? Products with automatic calibration circuitry do just that, enabling the engineer to design a robust solution for most optical devices in a matter of minutes. By providing the flexibility of either calibrating before or after being assembled in the equipment, automatic calibration will extend the LED life by compensating for degradation of its output over time, since it "remembers" the calibration settings.

With a simple triggering mechanism, such as momentarily grounding the calibration pin, the device can be programmed to begin the automatic calibration cycle at any time during the life of the equipment, extending LED life by compensating for degradation. A technician would be able to recalibrate a customer's sensors remotely to correct a performance problem caused by any of the mentioned variances.

An auto-calibration circuit in this type of application is designed to compensate for the change of optical devices due to manufacturing variance. The system could be used to calibrate either reflective or interruptive devices ,providing a consistent output and eliminating the requirement to confirm either the LED drive resistance or phototransistor load resistor to maintain a consistent output steady state condition. The design engineer can narrow the expected startup output state while providing a device that will operate with that same startup state for years, thus enhancing the reliability and consistency of the system. Degradation of the LED or phototransistor is compensated for each time the system is calibrated, enabling the system to provide a known, consistent output level resulting in years of consistent quality. The circuit could maintain the calibrated setting even if power is lost, allowing faster startup without the need for calibration every time the device is initiated.

Mounted on a small PC board, an auto calibration unit would consist of a set of shorting pins, allowing the user to change the phototransistor load resistor. By arranging the shorting bar to the appropriate location, the load resistance could be changed from approximately 2.5KΩ to 27K Increasing the load resistor increases the sensitivity of the device.

When the calibration pin is momentarily grounded, the system would begin its calibration process and raise the current through the LED from 0mA to 14mA, until the phototransistor reached the preset output level, causing a green calibration light to blink 3 times . At this time, the LED drive current is locked and maintained until the Reset/Clear pin is grounded. If the LED drive current reaches the maximum allowable value, a RED warning light can be programmed to turn on. During this calibration process, remote monitoring of the analog output pin would allow the designer to ensure the system is calibrated (a nominal setting for this preset calibrated output level is ½ VCC, when the calibration procedure is completed). Adjusting the phototransistor load resistor may be required to allow the system to calibrate properly.

The analog output allows the design engineer to set any reference point to recognize an optical change for the device being monitored. The analog output can be used with reflective devices to monitor small changes in the distance from the device.

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The further the target is away from the device, the lower the reflected signal.

The logical output will change state once the preset optical light condition is reached. The “Logic Out A” switches when the optical signal increases above approximately 2/3 of VCC while “Logic Out B” switches when the optical signal decreases below approximately 1/3 of VCC.

As with all optical devices, switching conditions are consistent with the phototransistor receiving a preset light level. This switching position and light level may vary depending on several possible factors such as:

- Ambient light variation (reduced or eliminated with periodic recalibration)
- LED and phototransistor pair degradation (eliminated with periodic recalibration)
- Contamination in front of either the LED or phototransistor (reduced or eliminated with periodic cleaning)
- System power variation (reduced or eliminated with periodic recalibration)
- Temperature changes (reduced or eliminated with periodic recalibration)

The autocalibration PC board can be wired directly to any optical device with an LED and phototransistor.

- Interruptive devices / slotted switches / interruptive encoders
- Reflective devices / reflective switches / reflective encoders
- Specialty devices / fluid sensors

A simple autocalibration circuit can thus eliminate or reduce the effects of most manufacturing, temperature variation, and LED degradation. This gives design engineers the ability to tighten up the expected output requirements for optoelectronic phototransistor output devices, providing more reliable products.

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