Application Report
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Self-Powered, Ambient Light Sensor Using bq25504

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Battery Charge Management

ABSTRACT

Ambient light sensors have become very common in portable electronics to adjust the brightness of the screen. These sensors automatically increase the screen brightness when a portable device, such as a cell phone, is used in sunlight and dims or turns off the display when the cell phone is placed next to the ear. In this application report, a proof-of-concept, self-powered, ambient light sensor is described which is powered by a solar cell. The solar cell is used to power the device and as a light sensor. The output of the described circuit is a square-wave pulse whose frequency is proportional to the light intensity. The circuit does not require a battery to operate and automatically starts itself when sufficient ambient light is on the sensor.

1 Introduction

The bq25504 is an ultralow-power charger integrated circuit (IC) intended for interfacing to dc sources like solar cells, thermal harvesters, and high-impedance batteries. Its industry-leading, low-quiescent current and high charger efficiency makes it an ideal choice for charging batteries and super-capacitors from a variety of energy harvesting sources. The IC has internal circuitry to manage the voltage across the storage element and to optimize the charging of the storage element.

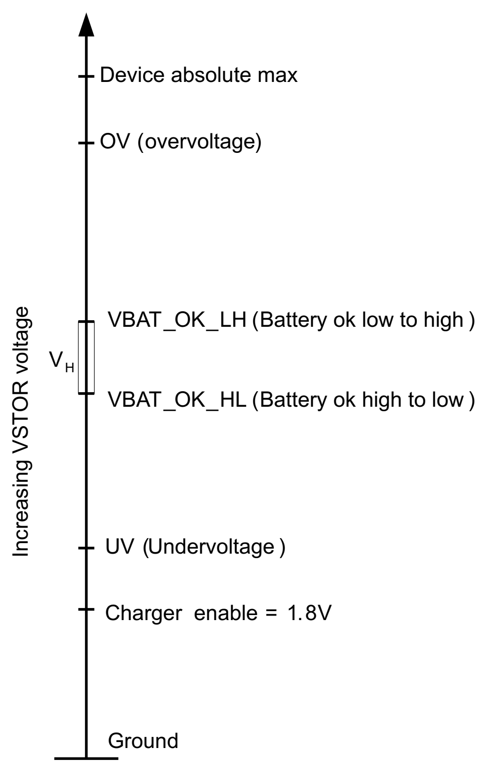

Figure 1. Critical Threshold Voltages and Their Relative Magnitudes

For successfully extracting energy from the source, three different threshold voltages must be programmed using external resistors, namely the undervoltage (UV) threshold, battery-good threshold (VBAT_OK) and overvoltage (OV) threshold. The three threshold voltages determine the region of operation of the IC. Figure 1 shows a plot of the voltage at the VSTOR pin (pin 15) and the various threshold voltages. Initially, the CSTOR capacitor is charged by the low-efficiency, cold-start circuitry. When the CSTOR capacitor is charged to 1.8 V, the main capacitor turns on. The CSTOR capacitor voltage keeps rising and crosses the UV threshold at which point an internal switch between (VSTOR) pin 11 and (VBAT) pin 14 is turned on. For the application under consideration, this feature is not used. As charging continues, the C_{STOR} capacitor reaches the $VBAT\_OK_{LH}$ threshold, and the VBAT_OK signal goes high. Finally, when the C_{STOR} capacitor reaches the overvoltage threshold, charging stops.

In the application, the $VBAT\_OK_{LH}$ and $VBAT\_OK_{HL}$ thresholds are designed to turn on and off an LED. The frequency of the LED turning on and off depends on the input power. Figure 2 shows a schematic of the circuit. It consists of the bq25504 IC, resistors to program the various thresholds, and the VBAT_OK signal (pin 11) connected to a switch which can turn on and off an LED. The detailed operation of the circuit is discussed next.

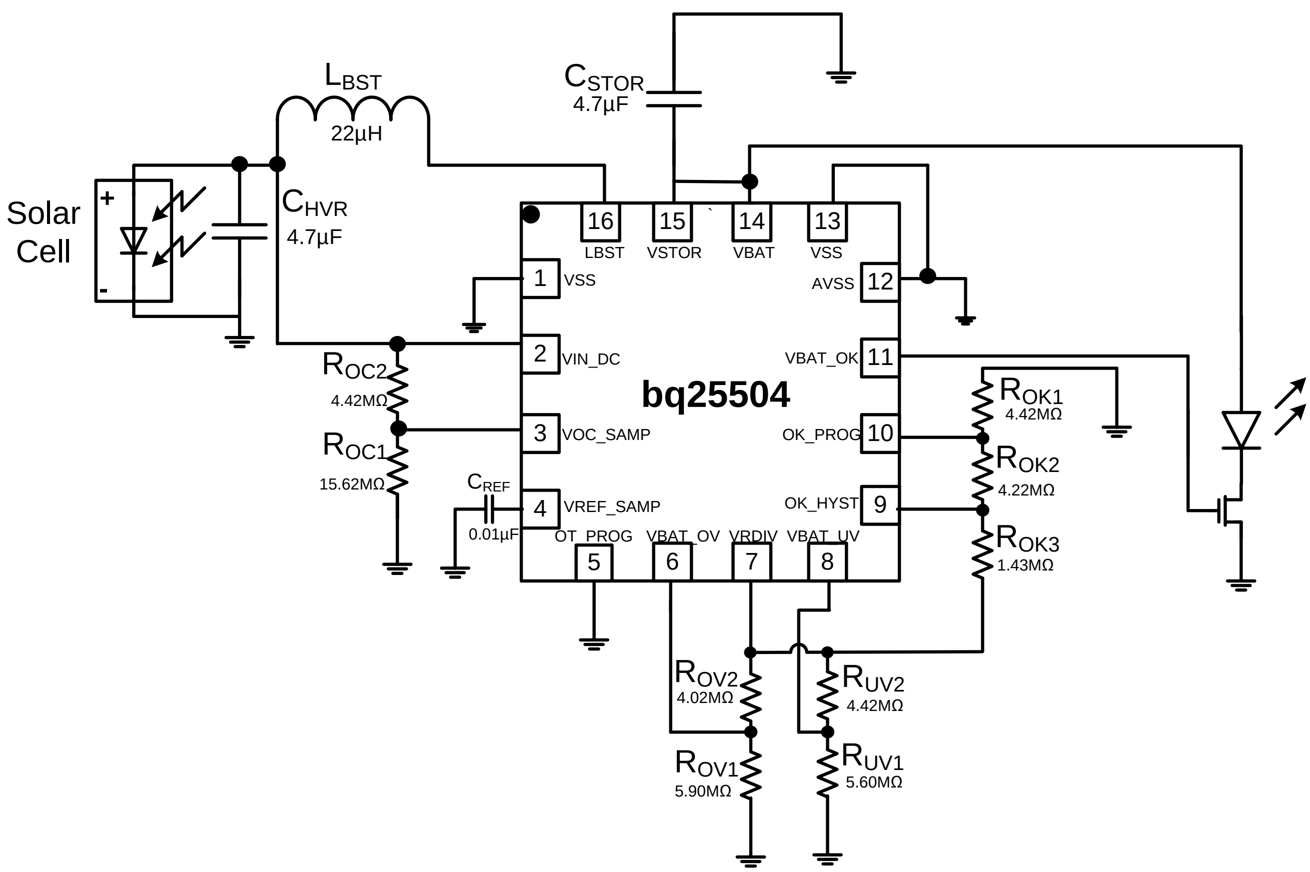

Figure 2. Schematic of bq25504 Circuit showing LED and External Switch

2 Principle of Operation

The working of the circuit is as follows. When sufficient light is on the solar panel, the circuit begins operation and charges the C_{STOR} capacitor. When the C_{STOR} capacitor reaches the VBAT_OK (low to high) threshold, the VBAT_OK signal goes high and the LED turns on. This applies a load on the C_{STOR} capacitor, and the capacitor starts discharging. When the C_{STOR} node reaches the VBAT_OK (high to low) threshold, the VBAT_OK signal goes low and the LED turns off. This removes the load on the C_{STOR}

capacitor. At this time, C_{STOR} starts charging again and the process repeats. Figure 3 and Figure 4 show a theoretical plot of the voltage at the CSTOR and VBAT_OK nodes for two different input light conditions. To determine the frequency of oscillation, the on-time and off-time of the VBAT_OK signal are determined. The on-time, t_{on}, is determined by the charging current, I_{CHG}, which is a function of the input power. It is given by the expression

$$t_{ON} = \frac{C_{STOR} V_H}{I_{CHG}} \quad (1)$$

V_H represents the hysteresis voltage and is the difference between the VBAT_OK (low to high) and VBAT_OK (high to low) voltage.

The off-time t_{OFF} is determined by the LED current, I_{LED}, and is given by the expression

$$t_{OFF} = \frac{C_{STOR} V_H}{I_{LED}} \quad (2)$$

The frequency of oscillation is given by the expression

$$f = \frac{1}{t_{ON} + t_{OFF}} \quad (3)$$

For a typical input source, such as a single solar cell, the charging current is much lower than the LED current, i.e.,

$$I_{CHG} << I_{LED} \quad (4)$$

Using the preceding equations, it can be shown that

$$f = \frac{I_{CHG}}{C_{STOR} V_H} \quad (5)$$

The charging current is directly proportional to the input power (i.e., $I_{CHG} \propto P_{in}$). Thus, $f \propto P_{in}$.

From the preceding expression, it can be seen that as the input power increases, the frequency of oscillation increases, thus providing a measure of the light intensity.

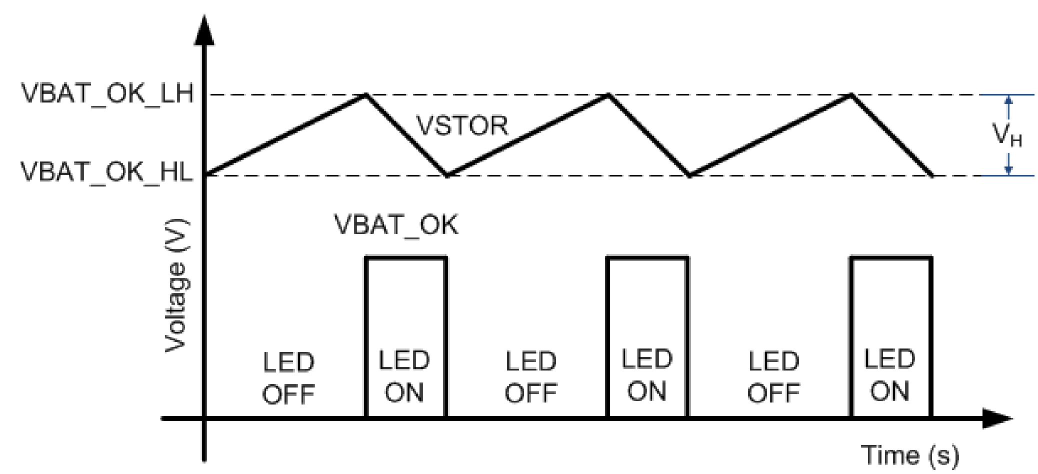

Figure 3. Theoretical Plot of VSTOR and VBAT_OK in Low-Power (Low-Light) Conditions

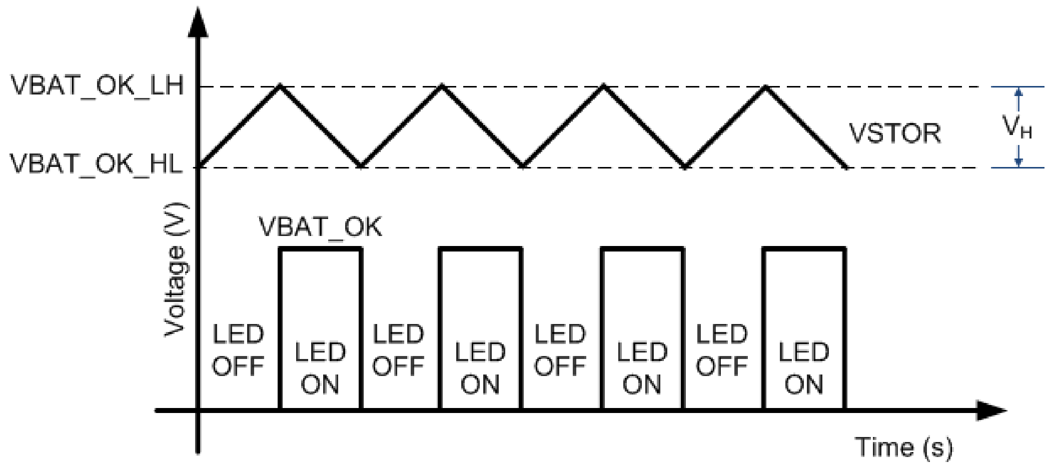

Figure 4. Theoretical Plot of VSTOR and VBAT_OK in High-Power (Bright-Light) Conditions

3 Design Considerations

The main design consideration in this solution is the selection of the LED, hysteresis voltage, and C_{STOR} capacitance. From the data sheet, the minimum CSTOR is 4.7 µF. The hysteresis voltage (VH) is set by the resistors R_{OK1}, R_{OK2}, and R_{OK3}. The VBAT_OK (low to high), $VBAT\_OK_{LH}$, and $VBAT\_OK_{HL}$ voltages which represent the higher and lower thresholds of the hysteresis voltage are given by the expressions

$$VBAT\_OK_{LH} = 1.23\left(1 + \frac{R_{OK2} + R_{OK3}}{R_{OK1}}\right) \tag{6}$$

and

$$VBAT\_OK_{HL} = 1.23\left(1 + \frac{R_{OK2}}{R_{OK1}}\right) \tag{7}$$

respectively. By choosing the appropriate resistor values, various ranges of frequencies can be obtained.

4 Experimental Results

The circuit shown in Figure 2 was designed and tested. For this test, a fluorescent light was chosen as the light source. An IXYS solar panel (XOB17-12x) was chosen to harvest the light energy. The key waveforms are shown in Figure 5. The VSTOR node has a saw-tooth waveform corresponding to the charging and discharging of the CSTOR capacitor, and the VBAT_OK node has a square with a frequency that is proportional to the input light. The frequency of oscillation is 1.25 Hz, corresponding to a measured input light intensity of 300 lux.

5 Summary

By using the circuit shown in Figure 2, designers can quickly evaluate the ambient light conditions and response of different photovoltaic panels to varying ambient conditions. Other applications of the circuit include demonstration of the effect of shading, maximum power point tracking, and different light sources on system performance. Lastly, the circuit demonstrate flexibility and can serve as a platform to evaluate other energy sources.

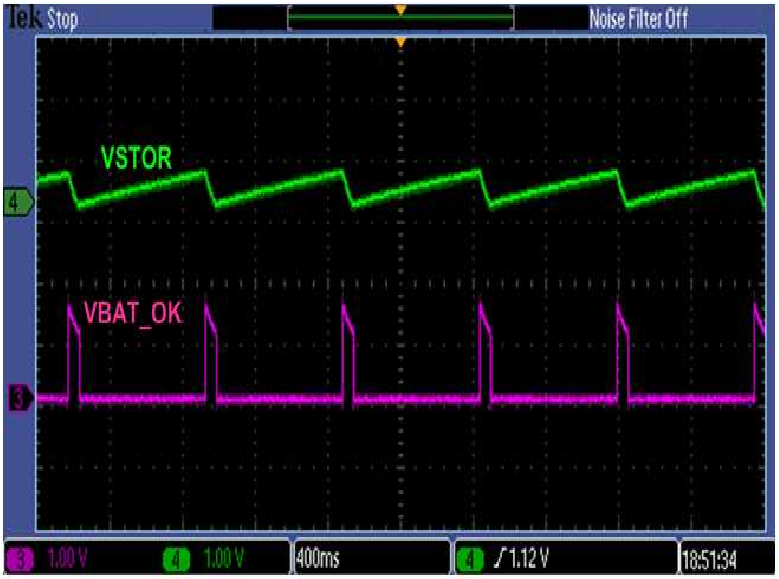

Figure 5. Scope Plot

6 References

1. *bq25504, Ultra Low Power Boost Converter with Battery Management for Energy Harvester Applications* data sheet (SLUSAH0)
2. *bq25504 EVM - Ultra Low Power Boost Converter with Battery Management for Energy Harvester Applications* user's guide (SLUU654)

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