BH66F2560 Integrated Pulse Oximeter AFE Application Description

D/N: AN0654EN

Introduction

The Holtek MCU BH66F2560 can be specifically used in the development of Pulse Oximeter applications. This MCU integrates a sink current generator and a Pulse Oximeter AFE module and can be directly connected to sensors. In this application note, how to setup the integrated sink current generator and Pulse Oximeter AFE is introduced to help users with their rapid product development.

Operating Principle

The Pulse Oximeter is a medical device that can be used to measure human oxygen saturation (SpO2) levels. Blood oxygen saturation is calculated by measuring the content of oxyhemoglobin (HbO2) in the hemoglobin because the absorption of a specific spectrum by hemoglobin (Hb) varies with the oxygen content. A common practice way of measuring this is to illuminate a finger using two light sources, a red light having a wavelength of about 660nm and an infrared light having a wavelength from 880nm to 940nm. Then using a photodiode, located on the other side of the finger, these two transmitted light sources are received. Finally, the amount of light absorption is calculated.

Figure 1 shows the Pulse Oximeter application circuit diagram. In this diagram, the emitting diode, LED, and the receiving diode, PD, are directly connected to the MCU. The MCU integrated sink current generator can output a constant current to illuminate the emitting LED. The two different illumination types transmitted by the LED will be received by the receiving diode PD after passing through the finger. At this moment, the receiving diode PD will generate a current signal, which will be converted into a voltage signal, amplified and then filtered by the Pulse Oximeter AFE. Finally this analog signal will be sampled and converted by the ADC.

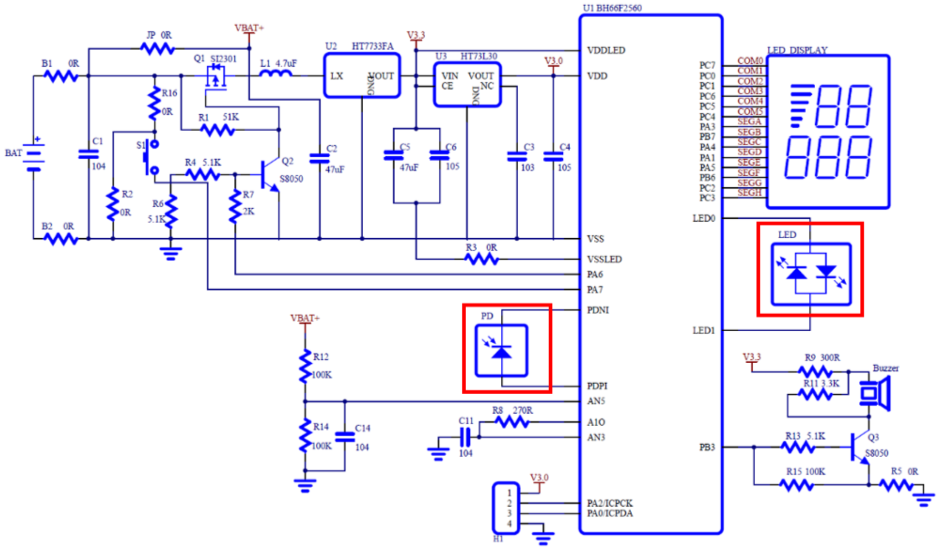

Figure 1. Pulse Oximeter Circuit Diagram

Functional Description

Sink Current Generator

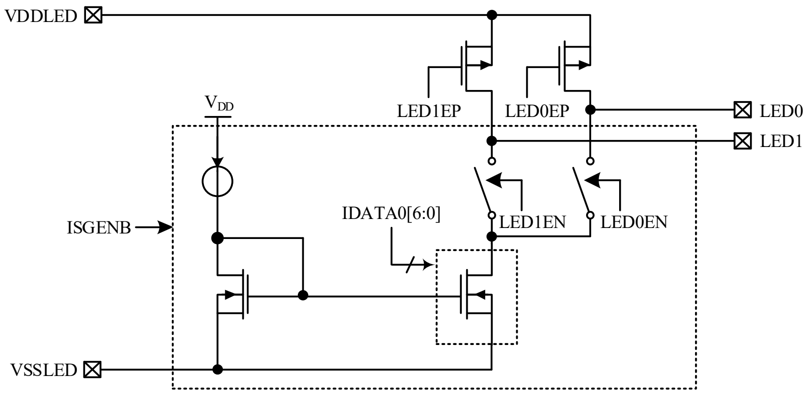

Figure 2. Sink Current Generator Block Diagram

- When the sink current generator is used a voltage needs to be supplied to the VDDLED pin. This voltage ranges from $1.4+V_{LED}+V_{CABLE}$ to 5.5V. Here, V_{LED} refers to the maximum voltage drop across the external LED and V_{CABLE} refers to the voltage drop across any cable, connector or any other component in series with the LED. It is not recommended to use V_{DD} as the input voltage for the sink current generator. This is because V_{DD} is the ADC reference voltage and any noise generated when the sink current generator changes its output current will cause fluctuations in the input voltage.
- The sink current generator enable control bit is active low. When Bit 7, ISGENB, in the IDATA0 register is set low, the sink current generator will be enabled. Otherwise, it will be disabled.
- Users can change the values of LED1EP, LED0EP, LED1EN and LED0EN to change the LED0 and LED1 current level. This can also change the direction of the current through the emitting diode and therefore control whether the emitting diode is to emit red light or infrared light.

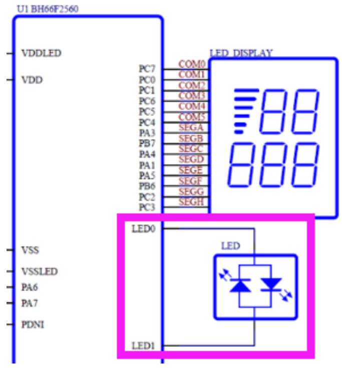

Figure 3. Emitting Diode LED Driving Circuit

When LED0EP and LED1EN are set high, LED0 will be the positive pole and LED1 will be the negative pole. When LED1EP and LED0EN are set high, LED1 will be the positive pole and LED0 will be the negative pole. Setting LED1EP and LED1EN high at the same time or LED0EP and LED0EN high at the same time should be avoided.

- Modifying the D6~D0 values in the IDATA0 register can change the sink current generator output current, thereby changing the illumination intensity of the emitting diode. The current value (mA) can be set by the IDATA0[6:0] bits. For example, when IDATA0 is set to 00111100B, the current value will be 60mA. Here the sink current output value ranges from 0mA to 75mA and the step size is 1mA. As the current value is set according to the emitting diode characteristics, users should refer to the emitting diode specification.

Pulse Oximeter AFE

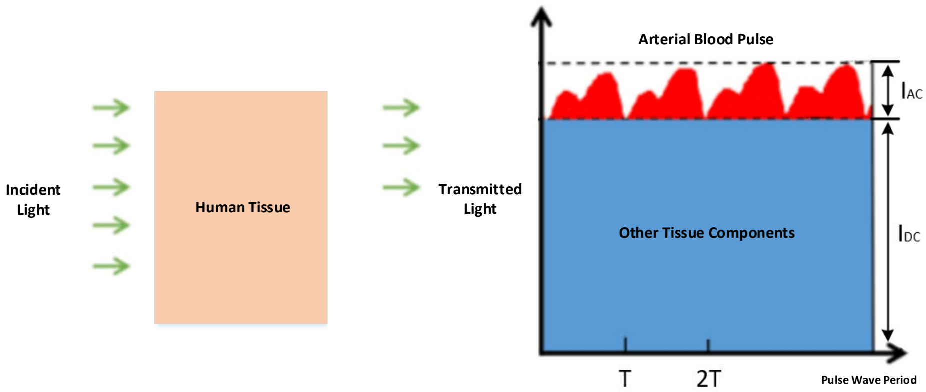

Figure 4. Receiving Diode Current Signal

Red and infrared light will be absorbed by the various different human tissue components. The light absorption by muscles, bones, veins and other connective tissues is almost constant. However, when arterial blood is flowing, its light absorption naturally changes. When the received optical signal is converted into an electrical signal, because the light absorption by arteries changes but the light absorption by other tissue components remains nearly constant, the obtained electrical signal appears as an AC signal superimposed upon a DC signal

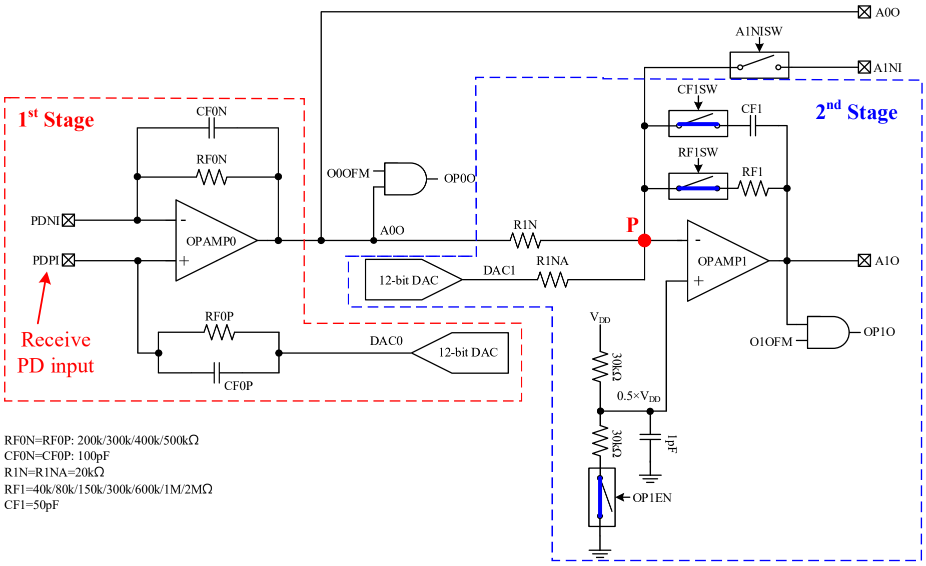

Figure 5. Pulse Oximeter AFE Block Diagram

The Pulse Oximeter AFE is mainly composed of two 12-bit D/A converters and two operational amplifiers. It is used to process the current which is produced by the receiving diode after being illuminated. This current includes both DC and AC signal components. In figure 5, Stage 1 is used to process the DC signal and Stage 2 is used to process the AC signal.

- Stage 1

  OPAMP0 and RF0N form an I-V conversion circuit to convert the current signal of the receiving diode into a voltage signal. This voltage signal is output by the A0O and sampled by the ADC. Note that this sampled signal is the DC part. At the same time, DAC0 should output a bias voltage, whose empirical value is 0.15V, to suppress the weak dark current generated by the receiving diode under no-light conditions.

  $$V_{A0O}=V_{DAC0}+I_{PD}\times(RF0N+RF0P)$$

  The resistance values of RF0N and RF0P can be changed by programming the OPRCS[4:3] bits. When selecting these values, users should ensure that the maximum value of V_{A0O} is not greater than V_{DD}, which is the upper limit of the ADC sampling.

- Stage 2

  Based on the ADC value of the sampled DC signal, DAC1 needs to output a voltage, V_{DD}-V_{A0O}, to cancel out the DC signal output from OPAMP0. The voltage at point P shown in Figure 5,V_P, is equal to 0.5V_{DD} and R1N is equal to R1NA. This results in equal and opposite currents through R1N and R1NA. Therefore, theoretically there should be no current flowing between the P point and the RF1 resistor. In fact, the AC signal of V_{A0O} would cause small fluctuations on the V_{A0O} and there is also hysteresis at the DAC1 output. Therefore, the currents flowing through R1N and R1NA are not equal. There will be a tiny current I_{AC} between the P point and RF1. After amplification by OPAMP1, this tiny current will be sampled by the ADC.

  $$V_{A1O}=V_P+I_{AC}\times RF1$$

  The RF1 resistance value can be changed by programming the OPRCS[2:0] bits. Users should ensure that the maximum value of V_{A1O} is not greater than V_{DD}, which is the upper limit of the ADC sampling.

- The Pulse Oximeter periodically emits infrared light, turns off the emitting diode and then emits red light, sampling both the DC and AC signals at every stage. These signals are marked as IR_DC, IR_AC, AMB_DC, AMB_AC, RED_DC and RED_AC. The sampled red and infrared light DC signals should both subtract AMB_DC and the sampled red and infrared light AC signals both should subtract AMB_AC. This operation can cancel out not only the effect of ambient light but also the DAC0 output bias voltage V_{DAC0} and the OPAMP offset voltage.
- Consideration 1: The turn on condition for the operational amplifiers is to set the OPnEN bit high.
- Consideration 2: The turn on condition for the DACs is to set the DACnEN bit high. The DAnH[3:0] and DAnL[7:0] bits are used to store the 12-bit conversion data. The reference voltage is V_{DD} and V_{DACn} is equal to $(V_{DD}/2^{12}) \times D[11:0]$.
- Consideration 3: The ADC input signal is controlled by the SADC1 register. When the SADC1[7:4] bits are equal to 1001B, the input signal is sourced from the internal A0O. When the SADC1[7:4] bits are equal to 1000B, the input signal is sourced from the internal A1O.

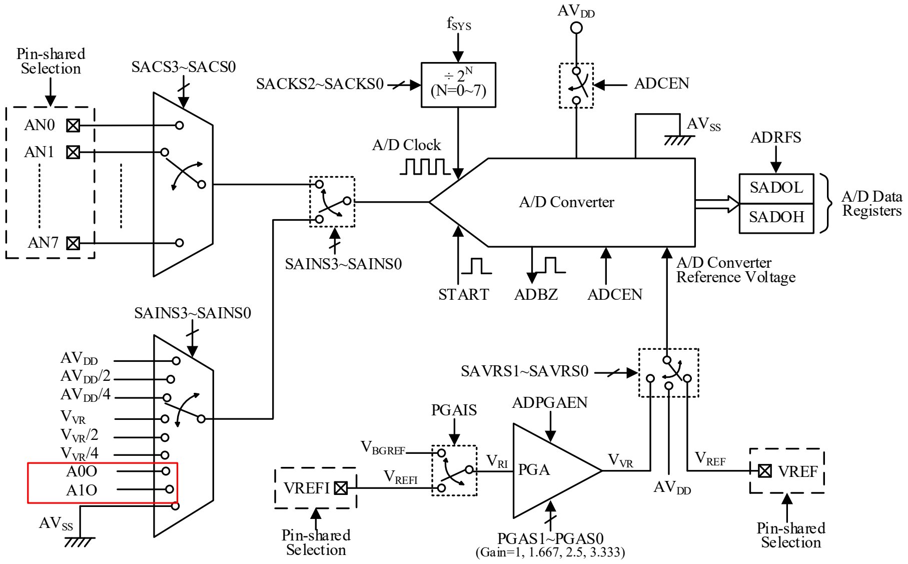

Figure 6

Conclusion

To assist users to get started more rapidly in actual applications, this application note has provided information on how to use the BH66F2560 sink current generator and Pulse Oximeter AFE module.

Reference Material

Reference file: BH66F2560 Datasheet.

For more details, refer to the Holtek website: www.holtek.com.

Versions and Modification Information

Date	Author	Release	Description
2023.05.18	杨子彬	V1.00	First version

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