

Cost-Optimized Opamp Window Comparator for Ultra-low Power PIR Motion Detectors

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A window comparator is a combination of a noninverting and an inverting comparators along with two reference voltages, Vref_A and Vref_B as shown in Figure 1. When the signal at the input of the window comparator crosses either thresholds, the corresponding output changes state to an opposite voltage level at the output.

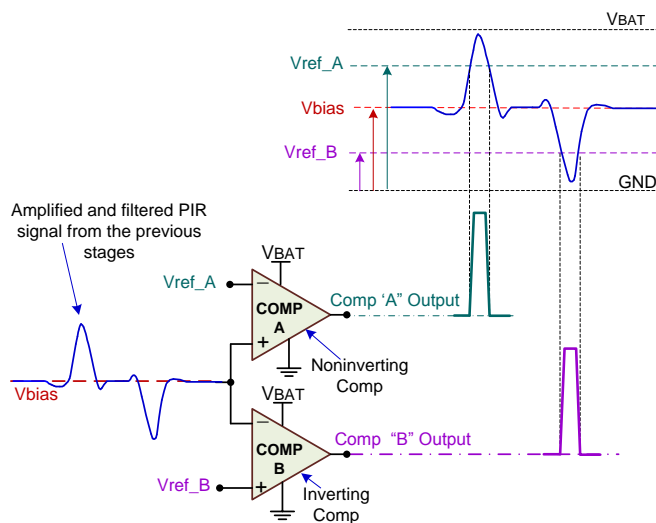


Figure 1. A Window Comparator Including a Noninverting and an Inverting Comparator and the Corresponding Inputs and Outputs

Passive Infrared (PIR) Motion Detector

An example of a system using a window comparator is a PIR motion detector shown in the block diagram of Figure 2.

Battery-powered wireless PIR motion detector sensor nodes are used in industrial, commercial and residential [Smart Building Monitoring](#) systems. They require ultra-low power analog-front-end (AFE) interface to amplify and filter small and noisy output signal of the sensor. The AFE includes a window comparator which signals a microcontroller unit (MCU) in the system the presence of motion in the sensor's field of view.

In the "gain/bandpass" stages, the PIR signal amplifies by about 96 dB in two similar sections, each having a bandpass filter with cut-off frequencies of 0.7 Hz and 10 Hz respectively.

Event-driven Sampling of PIR Sensor Signal

In some detectors, the MCU digitizes the signal for post processing and having a window comparator in the AFE circuit seems unnecessary. However, it must cycle on and off while the AFE maintains "on" continuously to save power. In this case, the comparator can be used to implement event-driven sampling. That is, the MCU starts sampling only when it receives wake-up signals from the comparator at the beginning of changes in the signal due to crossing of objects in the field of view.

A Cost-optimized Opamp Window Comparator

Normally a wireless motion monitoring network includes many sensor nodes and it is essential to design the nodes with minimal cost-optimized electronic components.

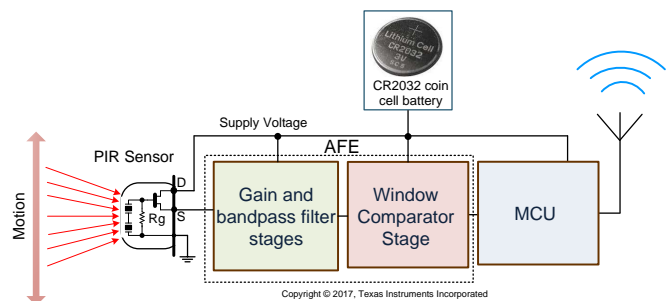


Figure 2. Block Diagram of a Typical Wireless Battery Operated PIR Motion Detector

Traditionally, the AFE is designed with a dual opamp amplifier, two individual comparator ICs and some additional passive components. However, considering PIR's low frequency signal, it is feasible to design the entire analog interface with a new 4 channel nanopower amplifier such as TLV8544— see application note [SNAA301](#).

The TLV8544 has 4 channels, two opamps in the package can be used in the "gain/bandpass" stages of the AFE circuit, the remaining two (spares) can replace the individual comparator devices in the window comparator circuit as shown in Figure 3.

It should be mentioned that an amplifier cannot be used as a comparator interchangeably in all applications because of amplifier's relatively long recovery time from output saturation and relatively long propagation delay due to internal

compensation. Particularly, nanopower opamps have very slow slew rate, limiting their usage as a comparator in only applications with very low frequency input signal such as PIR motion detector application.

The new nanopower TLV8544 opamp performance, namely; rail-to-rail input/output operation, nanopower per channel current consumption (500 nA typ), very low input offset voltage (500 μ V typ), very low offset voltage drift with temperature (1.5 μ V/ $^{\circ}$ C), ultra-low input bias current (100 fA typ), ultra-low input offset current (100 fA) and optimal cost, makes it a suitable choice for the application. The input signal is biased at mid-rail to allow input signal to swing up or down from the center.

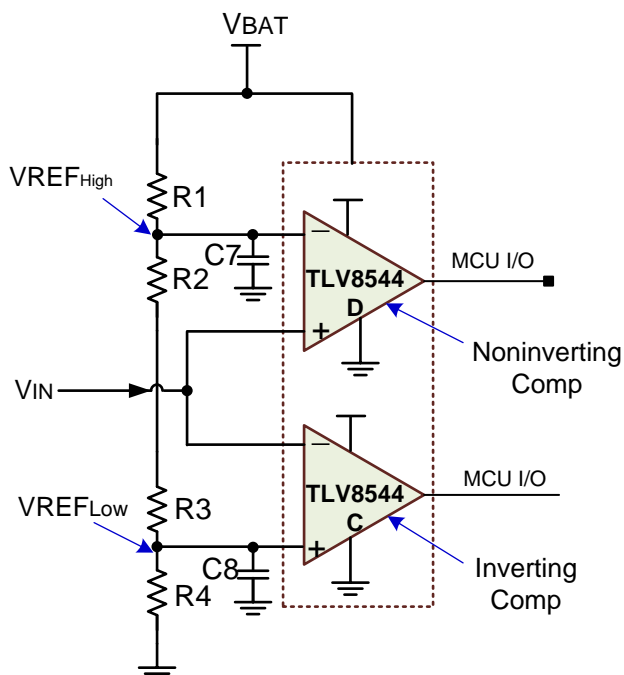


Figure 3. The Window Comparator Stage Implemented by the TLV8544 "C" and "D" Opamps

Reference Voltage Generator

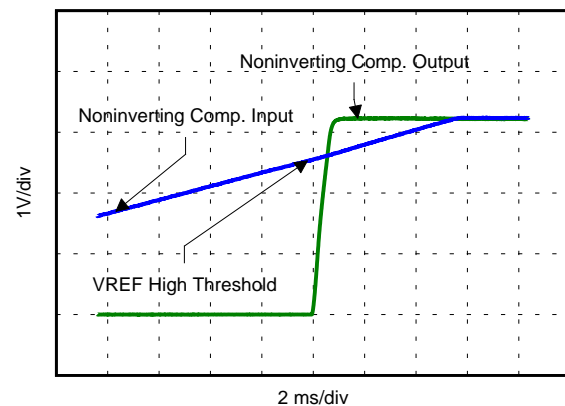
Referring to Figure 3, the reference voltages "VREF_{High}" and "VREF_{Low}" are generated by the divider network R1, R2, R3, and R4, where $R_x = 15\text{ M}\Omega$. The ultra-low input bias and offset current of the TLV8544 enables choice of very large resistor values in the circuit, reducing static current consumption in the reference voltage generator circuit.

The equations for calculating the reference threshold voltages are:

$$VREF_{High} = \left(\frac{R2+R3+R4}{R1+R2+R3+R4} \right) V_{BAT}$$

$$VREF_{Low} = \left(\frac{R4}{R1+R2+R3+R4} \right) V_{BAT}$$

A PIR motion detector board, [BOOSTXL-TLV8544PIR](#), is available from TI website for hands on experiment. The plots of Figure 4 and Figure 5 were generated using data captured from the booster board.



SNA4

Figure 4. Scope Plot of the Upper Cycle of the PIR Signal and the Output of the Noninverting Comparator

In Figure 4, the upper cycle of the PIR signal and the output of the noninverting comparator are shown. In the circuit, the "VREF_{High}" is fixed at about $0.75 \times V_{BAT}$ (~2.48V). As the input signal crosses the 2.48V threshold, the output of the opamp comparator changes from cutoff (slightly above ground) to saturation (slightly below V_{BAT}) in about 637 μ S,

The lower cycle of the PIR signal and the output of the inverting comparator are given in Figure 5. In the circuit, the "VREF_{Low}" is fixed at about $0.25 \times V_{BAT}$ (about 0.83V). As the signal crosses the 0.83V threshold, the output of the opamp comparator changes from cutoff to saturation in about the same amount time as the noninverting comparator.

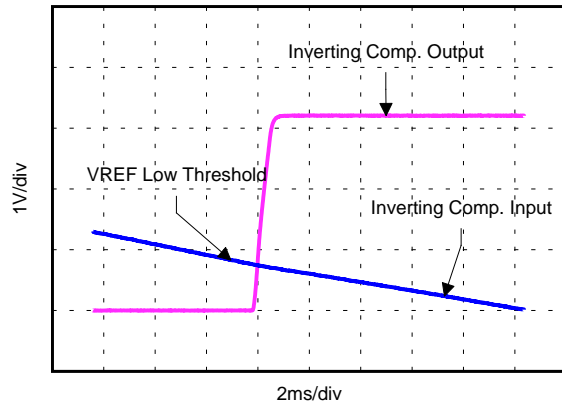


Figure 5. Scope Plot of the Lower Cycle of the PIR Signal and the Output of the Inverting Comparator

Table 1. Nanopower Amplifiers Family

Family	Channel Count	IQ/Ch	Vos (max)	Vsupply
TLV8544	4	500 nA	3.1 mV	1.7 to 3.6 V
TLV880x	1, 2	320 nA	4.5 mV	1.7 to 5.5 V
LPV81x	1, 2	425 nA	0.3 mV	1.6 to 5.5 V

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