ZSBI010

PASSIVE INFRARED AMPLIFIER

PRELIMINARY PRODUCT SPECIFICATION

PS002301-SEC1099

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1. ARCHITECTURAL OVERVIEW

The ZSBI010 Passive InfraRed (PIR) Amplifier is a low-power monolithic eight-pin CMOS mixed-signal integrated circuit. The PIR Amplifier is designed to be a front-end gain component for PIR motion sensors, and is composed of three major blocks:

- A High-Gain Operational Amplifier (120-dB Open Loop Gain)
- An *Auto-Zero Feedback Loop* consisting of a First Order Sigma-Delta Modulator and Digital Integrator, and a 1-Bit D/A Converter and Output Buffer
- An RC Oscillator

NOTE: Gain and bandwidth are user-configurable using external components.

The ZSBI010 Passive InfraRed Amplifier device is used for motion detection in security systems and control (both Commercial and Home) applications.

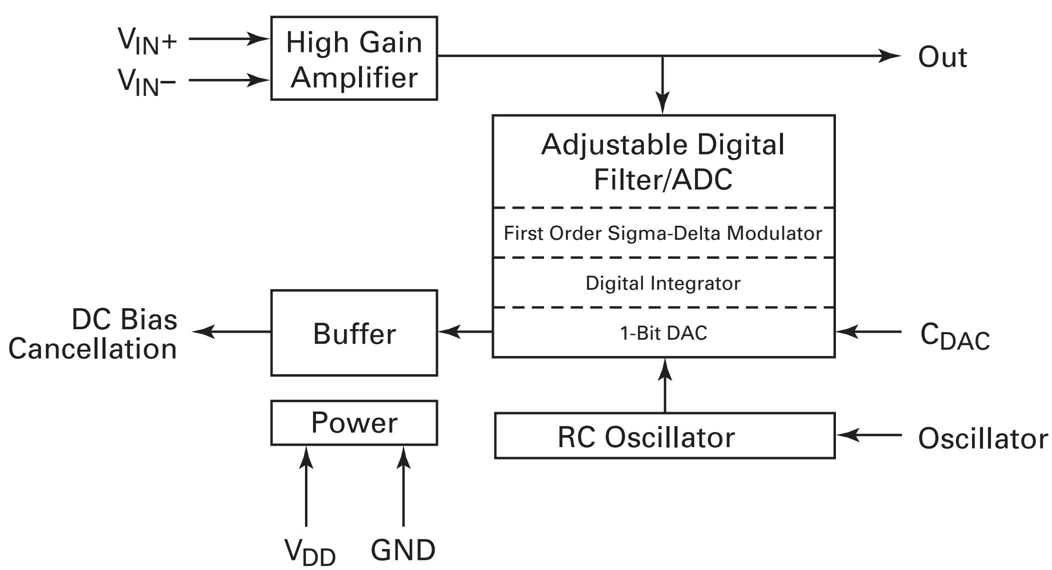
1.1 ZSBI010 FEATURES

- Highly integrated mixed-signal solution
- User-configurable High-Gain Amplifier
- Built-in Adjustable Digital Filter
- Auto-Zero Feedback
- Low-Power CMOS
- Internal Bandgap

Figure 1 illustrates a block diagram.

1.2 BLOCK DIAGRAM

FIGURE 1. ZSBI010 FUNCTIONAL BLOCK DIAGRAM



2. PIN DESCRIPTIONS

FIGURE 2. 8-PIN DIP AND SOIC DEVICES

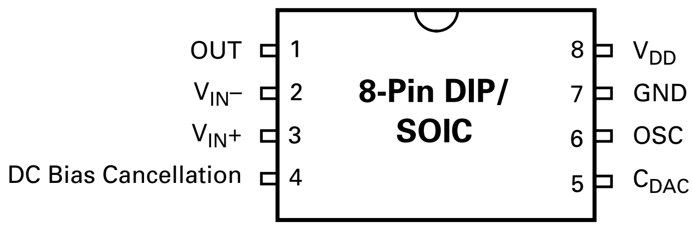


TABLE 1. PIN DESCRIPTION SUMMARY

Symbol	Pin #	Direction	Description
OUT	1	Output	PIR Amplifier Output
V_{IN}–	2	Input	PIR Amplifier Inverting Input
V_{IN}+	3	Input	PIR Amplifier Noninverting Input
DC Bias Cancellation	4	Output	Output a DC Bias to cancel the bias from the PIR sensor
C_{DAC}	5	Input	Filter Capacitor (0.001–0.1 μF)
OSC	6	Input	Oscillator Frequency Control Resistor
GND	7	Input	Ground
V_{DD}	8	Input	+5 V Power Input

3. OPERATIONAL DESCRIPTION

The motion detection function of a PIR sensor operates in a frequency band of 0.1–10 Hz, and requires a typical gain 0–60 dB or greater. A simple conceptual model of the PIR Amplifier circuit can consist of an amplifier and a bandpass filter. A digital integrator is connected in a negative feedback loop with the amplifier to provide a lower-frequency corner of 0.1 Hz. If the system gain requirement is 60 dB at 0.1 Hz, then the location of the feedback pole is measured in fractional millihertz. This measurement is difficult to achieve with analog ASICs, discrete components, or operational amplifiers. The higher-frequency corner is easily achieved with a reasonably-valued discrete resistor and capacitor at the amplifier output.

The PIR Amplifier features a simple single-bit system: a first order sigma-delta modulator, an up/down counter, and a D/A converter. The required low-frequency corner, F_{LOW}, is controlled by the length of the ADC counter and the gain of the amplifier. The single bit D/A provides an analog output. This analog output is filtered, and it connects to the amplifier's inverting input, which completes the negative feedback loop.

This closed-loop system forms an Auto-Zero Feedback system to refer PIR signals to the analog-to-digital converter reference voltage, V_{REF}, which provides a baseline for an external window comparator or other detection circuitry. As a result, the system automatically amplifies the PIR signal, refers it to a known baseline, and sets the low-frequency corner at 0.1 Hz or less.

3.1 HIGH-GAIN OPERATIONAL AMPLIFIER

The differential high-gain operational amplifier allows the user to configure the overall PIR system-gain bandwidth and to complete the negative feedback loop with external components. Typically, the gain is configured in the range 60–70 dB. A 120-dB open-loop gain provides the user with sufficiently low gain error, which can be less than 5% for gains up to 72 dB.

3.2 ADJUSTABLE DIGITAL FILTER/DAC

The Adjustable Digital Filter/DAC is composed of the following two functional blocks:

1. A First Order Sigma-Delta Modulator and Digital Integrator
2. A 1-Bit DAC Converter

3.2.1 First Order Sigma-Delta Modulator and Digital Integrator

A First Order Sigma-Delta Modulator digitizes the input signal for the digital integrator. An up/down counter is the digital integrator. A *Fast mode* feature activates after power-on reset, or if the amplifier output remains saturated for longer than 10 seconds (RC_{OSC} = 10 MHz). The integration rate in Fast mode is 28 times faster, allowing the system to reacquire and cancel the DC PIR bias level quickly.

3.2.2 1-Bit D/A Converter

The D/A converter transforms a value into a single bit pulse train at the RC clock frequency. The average value of this pulse train corresponds to the DC bias of the PIR sensor. The output of the D/A converter is filtered, buffered, and connected to the inverting input of the operational amplifier via external components. It then subtracts the DC bias of the PIR from the amplifier output. The D/A full-scale output is V_{REF}, at 2.5 VDC.

3.3 AUTO-ZERO FEEDBACK

Auto-Zero Feedback refers to the technique in which the amplifier output baseline is controlled via negative feedback. In the PIR Amplifier, the A/D converter functions as the control loop error amplifier, referenced to the analog-to-digital reference voltage, V_{REF}. With the low-frequency pole provided by the digital integrator, the negative feedback precisely biases amplifier output at V_{REF}, thereby canceling the DC bias of the PIR sensor, and referring PIR signals above 0.1 Hz to V_{REF}.

3.4 RC OSCILLATOR

The RC oscillator sets the internal clock frequency for the digital signal. The frequency is set by the external resistor when connected to the OSC pin. The frequency range of the oscillator is 1–10 Mhz.

4. ELECTRICAL CHARACTERISTICS

4.1 ABSOLUTE MAXIMUM RATINGS

TABLE 2. ABSOLUTE MAXIMUM RATINGS

Parameter	Min	Max	Units	Notes
Ambient Temperature under Bias	–20	+70	°C	
Storage Temperature	–65	+150	°C	
Voltage on V_{DD} pin with respect to GND	–0.3	+5.5	V	
Total Power Dissipation			mW	
Maximum Current out of GND			mA	
Maximum Current into V_{DD}			mA	
Input Voltage	V_{SS}–0.6V	V_{DD}+0.6V	V	
Maximum Current into an Input Pin	–10	+10	µA	
Output Short Circuit Duration		3	sec	
Supply Voltage		5.25		
Supply Current		1.5	mA	
ESD Protection		2	kV	1

NOTE:
1. Mil. Std. 883C, Method 3015.7.

4.2 DC CHARACTERISTICS

TABLE 3. DC CHARACTERISTICS, TEMPERATURE RANGE T_A = 0°C to +70°C

Symbol	Parameter	V_{DD}	Min	Typical @ 25°C	Max	Units	Conditions
A_{VOL}	Open Loop Voltage Gain	5.0V			120	dB	R_L = 100 KΩ V_O = 0.2–4.8 V
C_{DA}	Filter Capacitor	5.0V	0.0001		0.01	µF	
E_N	Input Referred Noise	5.0V			5.5	µA rms	A_V = 72 dB 0.05–10 Hz
E_{ON}	Output Noise	5.0V			200	pk-pk mV	Gain = 68 dB 0.05–10Hz; sensor offset = 800 mV
F_{LOW}	Low Frequency cutoff	5.0V		0.058		Hz	F_{OSC} = 10 MHz Gain = 68 dB
F_{OSC}	RC Oscillator Frequency Range	5.0V	1		10	MHz	Set by the resistor on the OSC pin

Notes:
1. The normal operating voltage (V_{DD}) range is: 4.75V–5.25V.
2. GND = 0V.

TABLE 3. DC CHARACTERISTICS, TEMPERATURE RANGE T_A = 0°C to +70°C (CONTINUED)

Symbol	Parameter	V_{DD}	Min	Typical @ 25°C	Max	Units	Conditions
GBW	Gain–Bandwidth Product	5.0V	100			kHz	$T_A = 25^oC$ C_L = 100 pF
GBW_{DAC}	DAC Gain/Bandwidth Product	5.0V	100			kHz	$T_A = 25^oC$ C_L = 100 pF
I_{CC}	Supply Current	5.0V			1.5	mA	
I_{IN}	Input Current	5.0V			400	pA	
I_O	Output Current	5.0V	50			µA	V_{REF} ±1.5 V
I_{ODCB}	DC Bias Cancellation Output Current (pin 4)	5.0V	50			µA	
I_{REF}	Reference Current ($V_{REF} \div R_{OSC}$)	5.0V			20	µA	30 kΩ < R_{OSC} < 1 MΩ
K_{OSC}	Transfer Function	5.0V		0.5		MHz-µA	
P_M	Phase Margin	5.0V		45		Degrees	$T_A = 55^oC$ C_L = 100 pF
R_{OUT}	Output Impedance	5.0V			1000	Ω	0–100 Hz
SR	Slew Rate	5.0V	0.01			V ÷ µs	$T_A = 25^oC$ C_L = 100 pF
T_D	Temp Drift	5.0V	–5		5	%	
TK_{OSC}	K_{OSC} Absolute Accuracy	5.0V	–20		+20	%	
T_{OPR_DLY}	OPR: Overload/ Power-On Recovery Delay: Time period that V_{OUT} remains either > V_{SHI} or < V_{SLO} before the loop activates Fast mode to reacquire the baseline, V_{REF} (Figure 3)	5.0V		$2^{20} \div F_{OSC}$ x 96		sec	Scales as OSC modifies the operating frequency
T_{OPR_REC}	OPR Recovery Period (For a 1.2-volt change in DC operating point) Recovery Period begins after above T_{OPR_DLY}. $T = T_{fast} + T_{normal}$	5.0V	12		120	sec	Time that circuit stays in Fast mode and recovers within 200 mV of V_{REF}

Notes:
1. The normal operating voltage (V_{DD}) range is: 4.75V–5.25V.
2. GND = 0V.

TABLE 3. DC CHARACTERISTICS, TEMPERATURE RANGE T_A = 0°C to +70°C (CONTINUED)

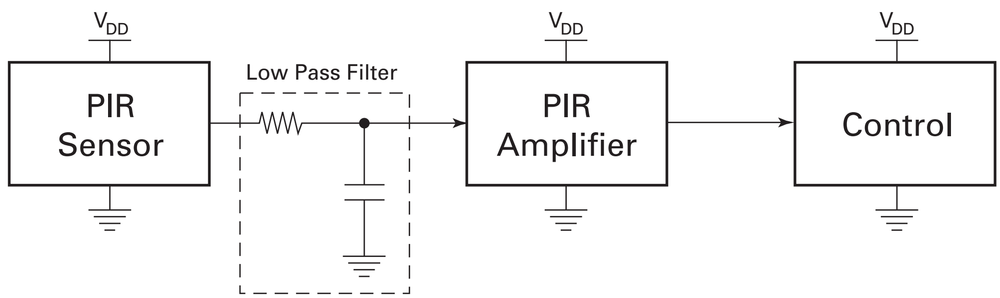
Symbol	Parameter	V_{DD}	Min	Typical @ 25°C	Max	Units	Conditions
VAZ_{OS}	Auto-Zero System Offset Voltage (voltage difference between OUT and OSC for DC input)	5.0V	–30		30	mV	System Bandwidth = 0–0.1Hz
V_{IN}	Input Voltage Range (Direct Couple)	5.0V	0.1		1.6	V	
V_{REF}	Reference Voltage	5.0V	2.2		2.4	V	

Notes:
1. The normal operating voltage (V_{DD}) range is: 4.75V–5.25V.
2. GND = 0V.

5. SYSTEM DESIGN CONSIDERATIONS

A PIR Motion Detection system can be separated into three major blocks: a PIR Sensor Block, a PIR Amplifier Block, and a Control Block. The system block diagram is illustrated in Figure 3.

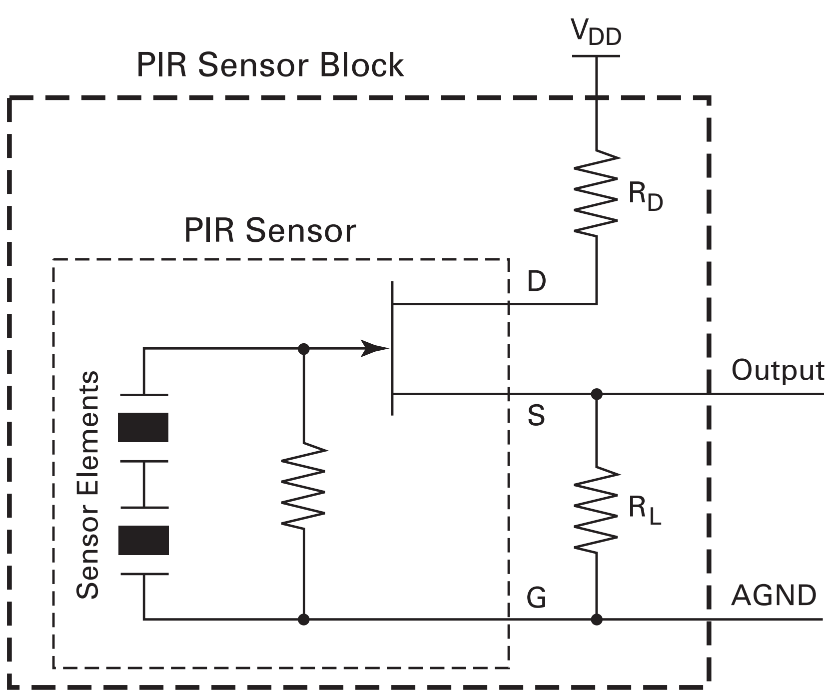
FIGURE 3. SYSTEM BLOCK DIAGRAM OF PIR MOTION DETECTION



5.1 PIR SENSOR BLOCK

A typical PIR sensor features sensor elements and a built-in Field Effect Transistor (FET). The connectivity of the PIR Sensor Block is illustrated in Figure 4. The PIR sensor manufacturer provides the specification of the *Voltage Responsivity* with the load resistance R_L (usually 47 kΩ). In this block, 500 Ω is recommended for R_D; 47 kΩ is recommended for R_L.

FIGURE 4. CONNECTIVITY OF PIR SENSOR BLOCK



5.2 PIR AMPLIFIER BLOCK

A ZSBI010, as used in the PIR Amplifier Block, yields the following benefits:

1. High performance in a simple design
2. Less external components required
3. Reliability and stability

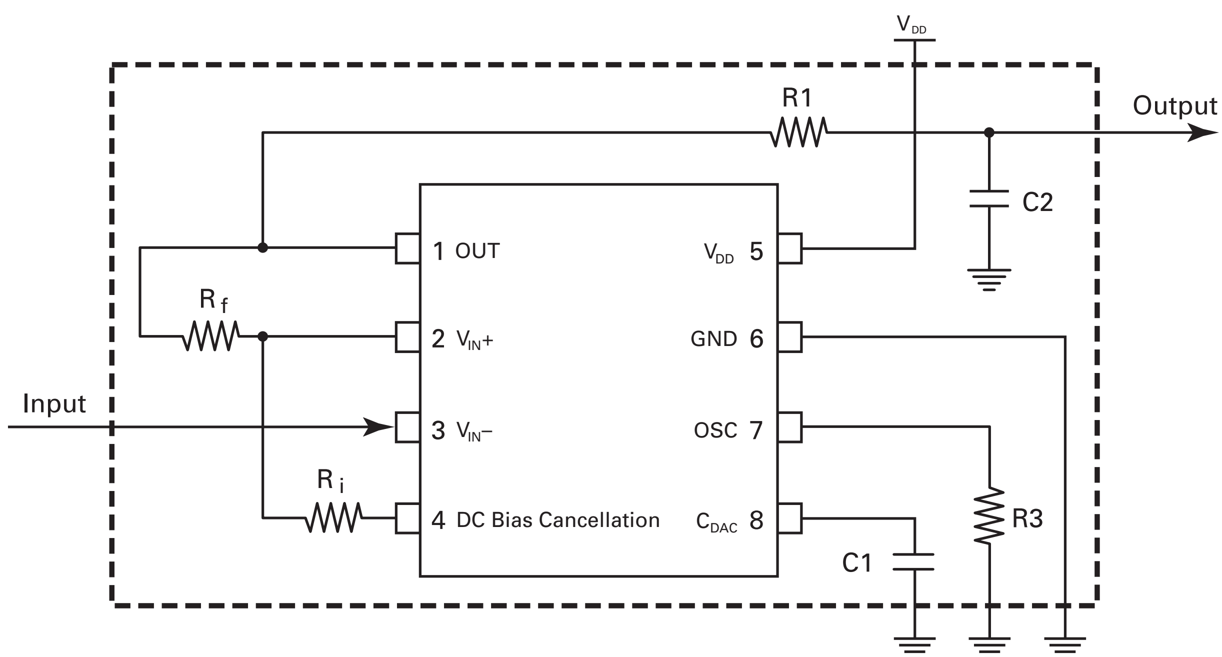
The PIR Amplifier Block can also be directly connected to the output of the PIR Sensor Block without an AC-coupling capacitor. Figure 5 illustrates the connectivity of the PIR Amplifier block. The gain of the amplifier is calculated as:

$$Gain = 1 + (R_f \div R_i)$$

$$|Gain|\ (dB) = 20 \log |Gain|$$

The recommended value for R_f is 1 MΩ; the recommended value for R_i is 470 Ω. The gain is 66.6 dB.

FIGURE 5. CONNECTIVITY OF PIR AMPLIFIER BLOCK



The ZSBI010 also features an Adjustable Digital Filter (a low-pass filter), which is used for filtering out the DC bias from the PIR sensor. This filter returns the DC signal, in the range 0–0.1 Hz, as feedback from the amplifier output to the V_{IN}– pin to cancel the DC bias from the PIR sensor. The cutoff frequency (F_C) of the low-pass filter is calculated as:

$$F_{LOW} = ([R_f \div R_i] \times [0.5 \times R3 \div 2.5]) \div (4 \times 2\pi \times 2^{34})$$
$$= (0.2 \times R3 \times R_f) \div (4 \times 2\pi \times 2^{34} \times R_i)$$

For an F_{LOW} value close to DC, the value of R3 is recommended to be 50 kΩ.

An RC low-pass filter at the PIR amplifier output filters the 10- to 15-Hz signal. The cutoff frequency (F_C) of the RC filter is calculated as follows:

$$F_C \sim 1 \div (2\pi R1C2)$$

With a cutoff frequency approximately equal to 16 Hz, the values of R1 and C2 are recommended to be 100 kΩ and 0.1 µF, respectively.

5.3 CONTROL BLOCK

The output of the PIR amplifier is connected to the Control Block for motion detection control. Because the output from the PIR amplifier is an analog signal, analog-to-digital signal conversion is required. The analog-to-digital conversion is achieved either by using simple comparators (converted to `0` or `1` only) or an ADC. The output from the ADC connects to the control circuitry, which can be one or more switches, or a microcontroller.

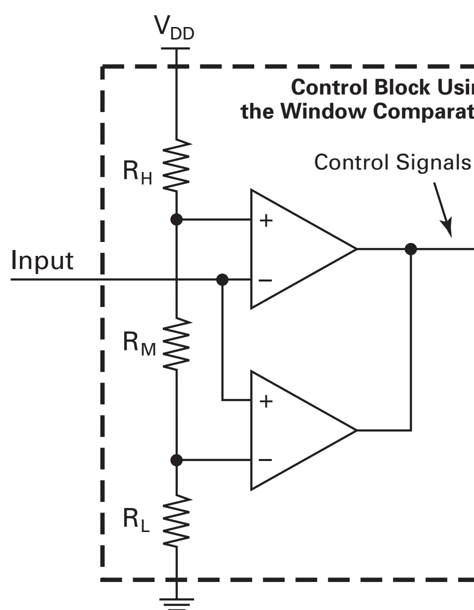
5.3.1 Using the Window Comparator for the Control Circuitry

Figure 6 illustrates the control circuitry using window comparators. Resistors R_H, R_M, and R_L are used to setup the *Upper Threshold* and *Lower Threshold* for motion detection. The comparator output is used for switches or other control circuitry. Upper and Lower Threshold are calculated as follows:

$$\text{Upper Threshold Voltage} = \frac{R_M + R_L}{R_H + R_M + R_L} \times V_{DD}$$

$$\text{Lower Threshold Voltage} = \frac{R_L}{R_H + R_M + R_L} \times V_{DD}$$

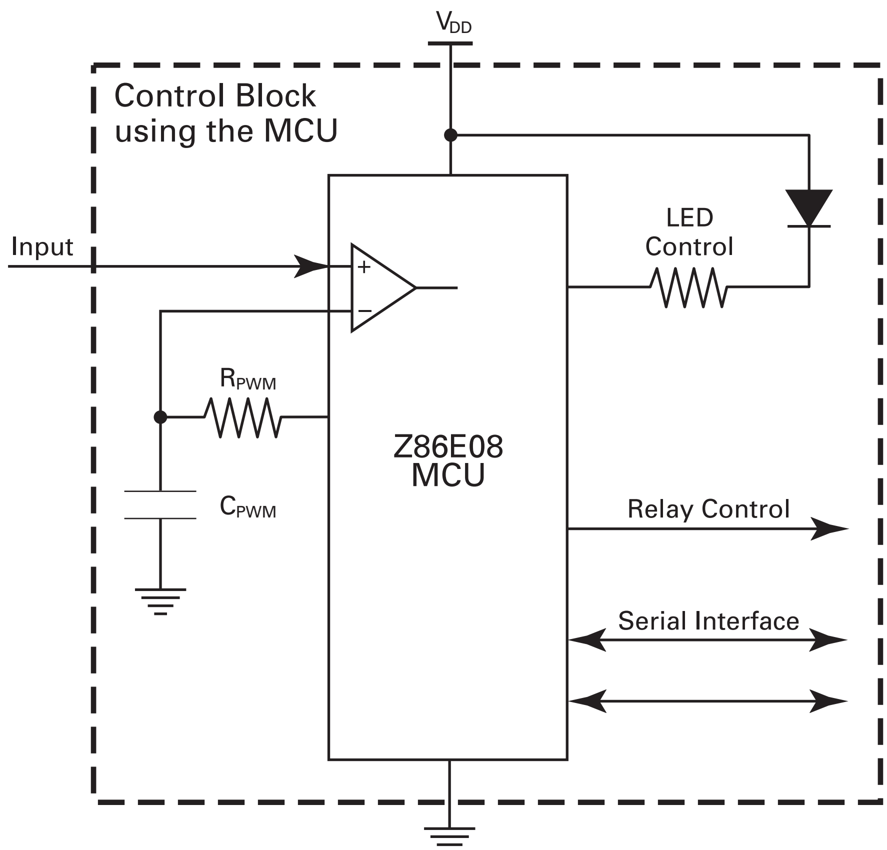
FIGURE 6. COMPARATOR CONTROL CIRCUITRY



5.3.2 Using an MCU for the Control Circuitry

Figure 7 illustrates MCU control circuitry, for which ZiLOG recommends its Z86E08 or Z86C08 MCUs. The output signal from the PIR Amplifier Block connects to the MCU's noninverted comparator input. A software-controlled analog-to-digital conversion processes the analog signal to control the processing of the user's application. The Upper and Lower Thresholds are also set under software control. The MCU communicates with the host system via the serial interface. A relay is connected as an open- and closed-loop control.

FIGURE 7. MCU CONTROL CIRCUITRY



6. APPLICATION INFORMATION

As described in the previous section, the application design of ZSBI010 is very simple. The PIR sensor features different specifications for different manufacturers. As a result, the gain may require alteration by adjusting the values of R_f and R_i (see Section 4.2, DC Characteristics). Otherwise, most of the recommended values are used on the system design.

6.1 APPLICATION NOTES

Refer to the ZSBI010 Application Note titled *ZSBI010 Passive InfraRed System Design*.

6.2 REFERENCE DESIGNS

Figures 8 through 10 provide different reference designs for the ZSBI010.

FIGURE 8. REFERENCE DESIGN OF ZSBI010 WITH PIR SENSOR INPUT

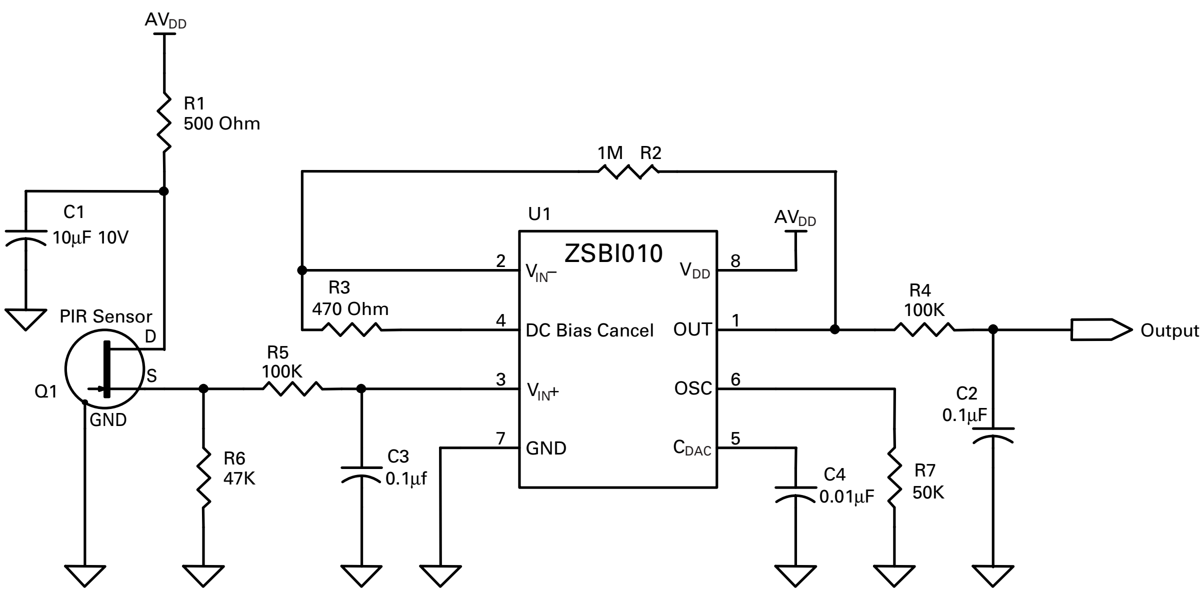


FIGURE 9. REFERENCE DESIGN OF ZSBI010 CONNECTING TO THE WINDOW COMPARATOR CONTROL CIRCUITRY

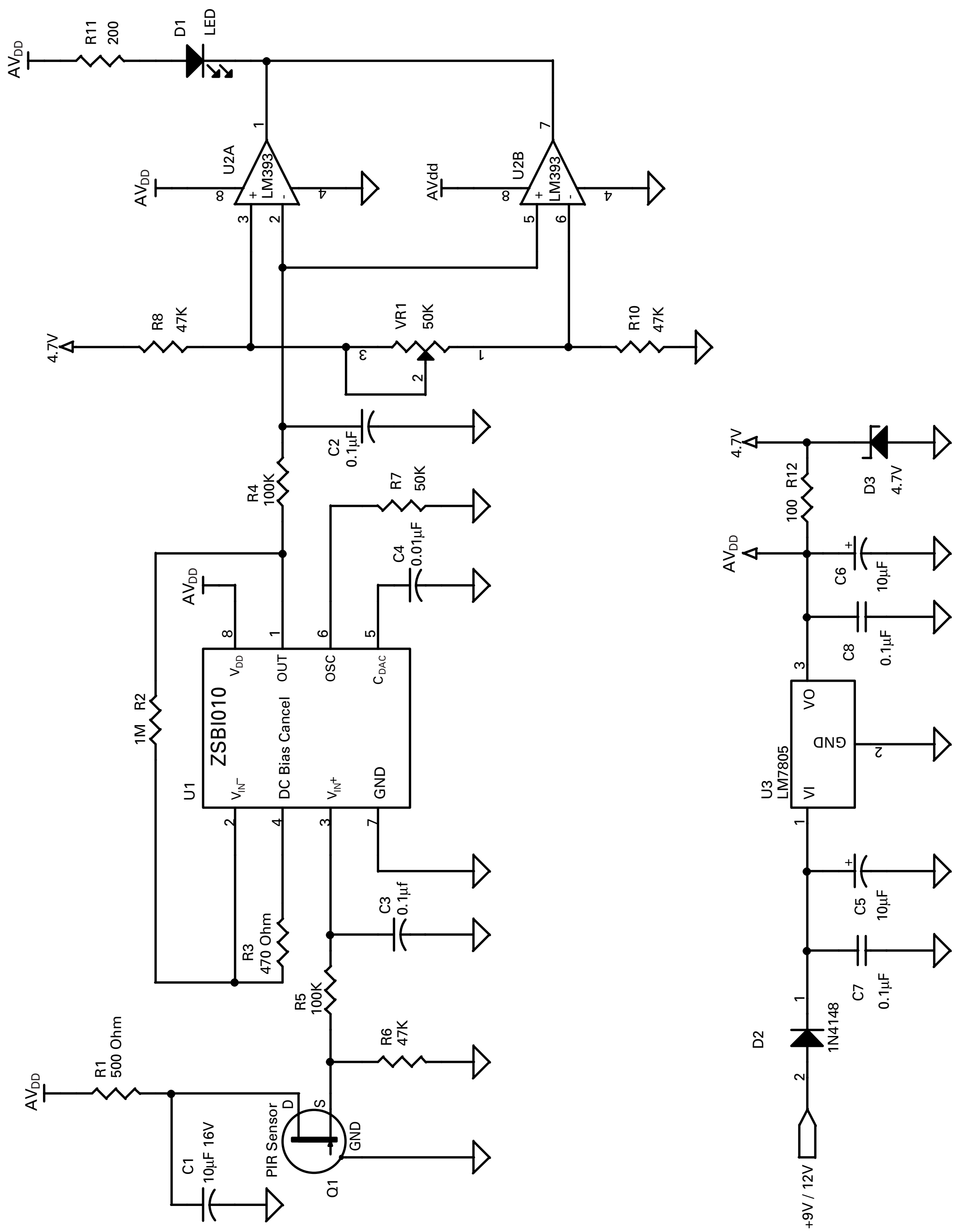
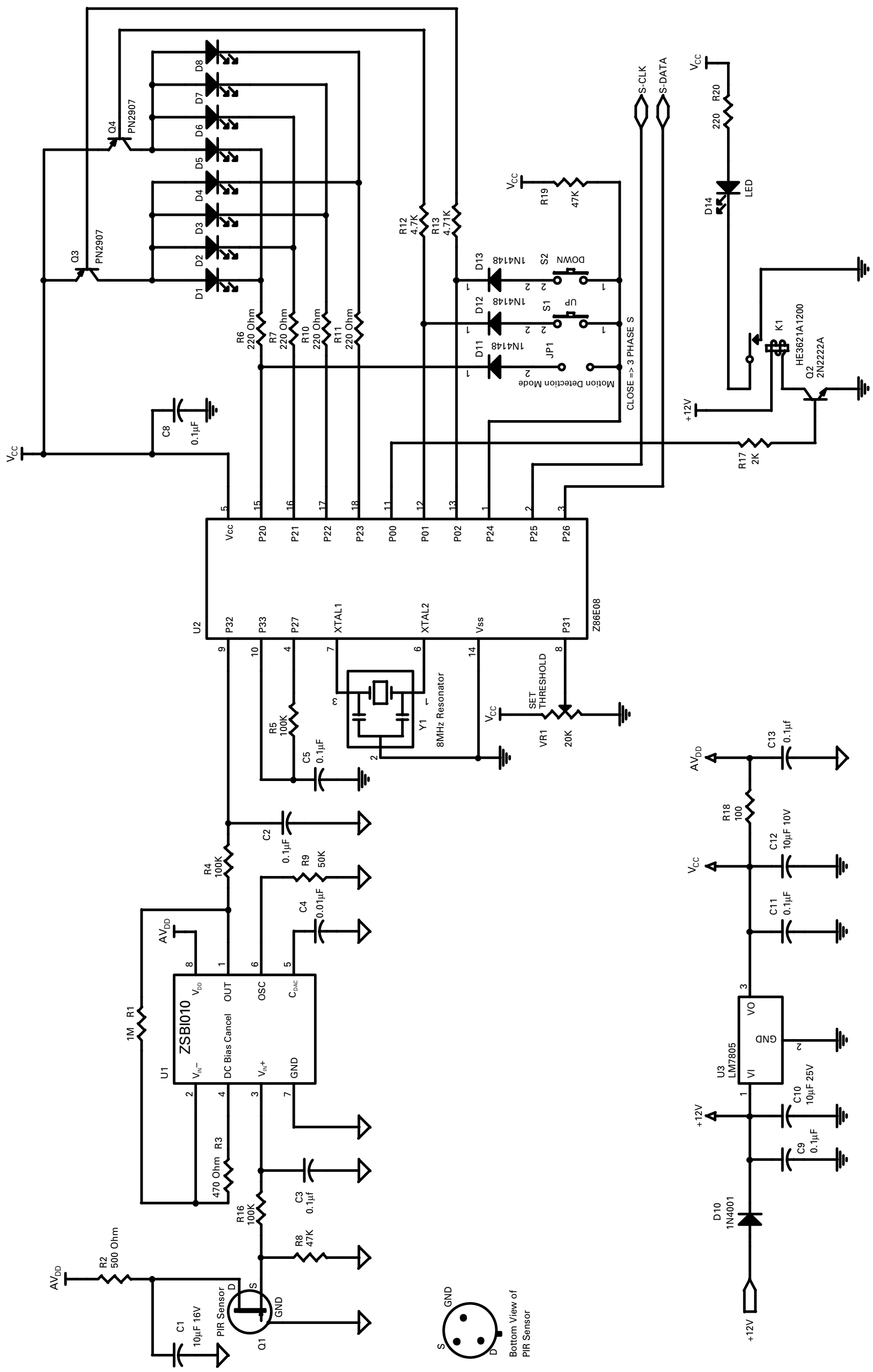


FIGURE 10. ZSBI010 REFERENCE DESIGN CONNECTING TO ZILOG'S Z86E08 MCU



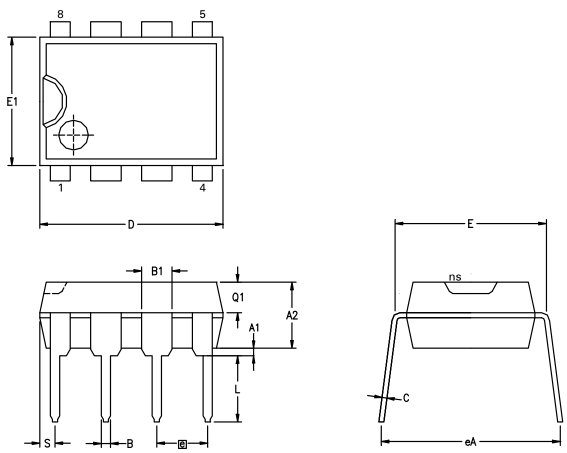
7. PRECHARACTERIZATION PRODUCT

The product represented by this document is newly introduced and ZiLOG has not completed the full characterization of the product. The document states what ZiLOG knows about this product at this time, but additional features or nonconformance with some aspects of the document may be found, either by ZiLOG or its customers in the course of further application and characterization work. In addition, ZiLOG cautions that delivery may be uncertain at times, due to start-up yield issues.

8. PACKAGING

The ZSBI010 PIR Amplifier is available in 8-pin PDIP and 8-pin SOIC packages.

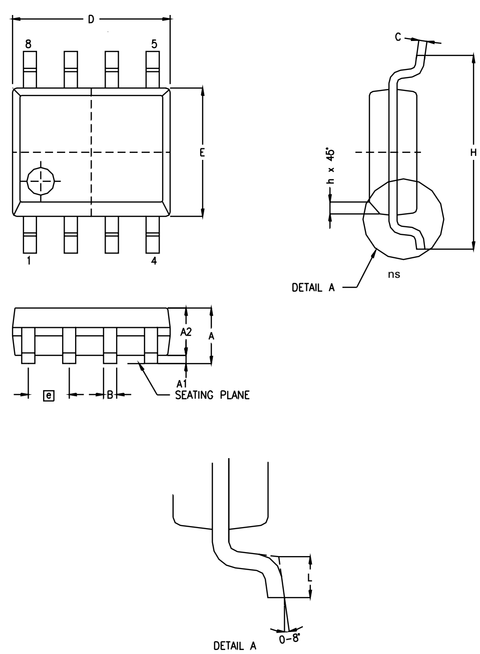
FIGURE 11. 8-PIN PDIP PACKAGE



SYMBOL	MILLIMETER		INCH	
	MIN	MAX	MIN	MAX
A1	0.38	0.81	0.015	0.032
A2	3.25	3.43	0.128	0.135
B	0.38	0.53	0.015	0.021
B1	1.40	1.65	0.055	0.065
C	0.20	0.30	0.008	0.012
D	9.02	9.27	0.355	0.365
E	7.62	8.26	0.300	0.325
E1	6.20	6.58	0.244	0.259
e	2.54 BSC		0.100 BSC	
eA	7.87	9.14	0.310	0.360
L	3.18	3.43	0.125	0.135
Q1	1.40	1.65	0.055	0.065
S	0.64	0.89	0.025	0.035

CONTROLLING DIMENSIONS: MM.

FIGURE 12. 8-PIN SOIC PACKAGE



SYMBOL	MILLIMETER		INCH	
	MIN	MAX	MIN	MAX
A	1.55	1.73	0.061	0.068
A1	0.10	0.25	0.004	0.010
A2	1.40	1.55	0.055	0.061
B	0.36	0.48	0.014	0.019
C	0.18	0.25	0.007	0.010
D	4.80	4.98	0.189	0.196
E	3.81	3.99	0.150	0.157
e	1.27 BSC		.050 BSC	
H	5.84	6.15	0.230	0.242
h	0.25	0.40	0.010	0.016
L	0.46	0.81	0.018	0.032

CONTROLLING DIMENSIONS : MM
LEADS ARE COPLANAR WITHIN .004 INCH.

9. ORDERING INFORMATION

ZSBI010 Available Packages	
Standard Temperature	
8-Pin DIP	ZSBI010PZ000SC
8-Pin SOIC	ZSBI010SZ000SC

For fast results, contact your local ZiLOG sale offices for assistance in ordering the part(s) required.

Code Example	
Preferred Package	Plastic Dual Inline Package
Longer Lead Time	Small Outline Integrated Circuit
Speed	Not Applicable
Standard Temperature	S = 0°C to +70°C
Environmental Flow	C = Plastic Standard

9.1 PART NUMBER DESCRIPTION

ZiLOG part numbers consist of a number of components. For example, part number ZSBI010PZ000SC is a ZSBI010 DIP that operates in the 0ºC to +70ºC temperature range, with Plastic Standard Flow. The ZSBI010PZ000SC part number corresponds to the code segments indicated in the following table.

Z	ZiLOG Prefix
SB	Security/Building Control
I	Interface
010	Product Number
PZ	Package
000	Analog Device
S	Temperature
C	Environmental Flow

10. DISCLAIMER

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