

# Low-Noise and Long-Range PIR Sensor Conditioner Circuit

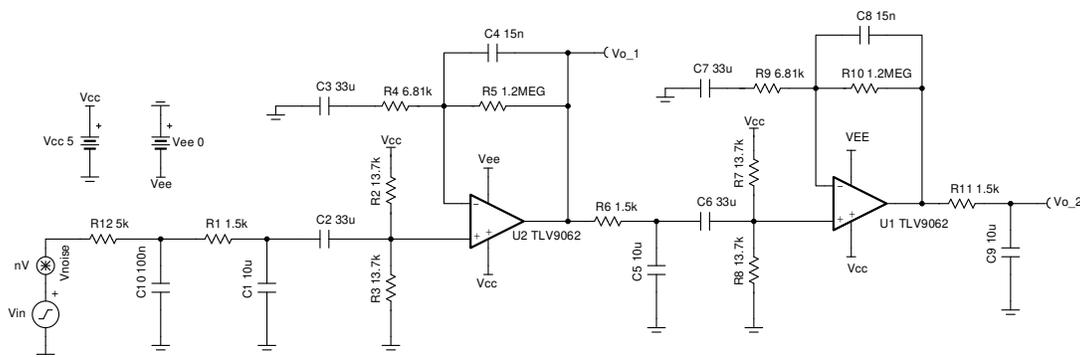


## Design Goals

AC Gain	Filter Cut Off Frequency		Supply	
90 dB	$f_L$	$f_H$	$V_{CC}$	$V_{EE}$
	0.7 Hz	10 Hz	5 V	0 V

## Design Description

This two stage amplifier design amplifies and filters the signal from a passive infrared (PIR) sensor. The circuit includes multiple low-pass and high-pass filters to reduce noise at the output of the circuit to be able to detect motion at long distances and reduce false triggers. This circuit can be followed by a window comparator circuit to create a digital output or connect directly to an analog-to-digital converter (ADC) input.



## Design Notes

1. The common mode voltage and output bias voltage are set using the resistor dividers between  $R_2$  and  $R_3$  (and  $R_7$  and  $R_8$ ).
2. Two or more amplifier stages must be used to allow for sufficient loop gain.
3. Additional low-pass and high-pass filters can be added to further reduce noise.
4. Capacitors  $C_4$  and  $C_8$  filter noise by decreasing the bandwidth of the circuit and help stabilize the amplifiers.
5. RC filters on the output of the amplifiers (for example,  $R_6$  and  $C_5$ ) are required to reduce the total integrated noise of the amplifier.
6. The maximum gain of the circuit can be affected by the cutoff frequencies of the filters. The cutoff frequencies may need to be adjusted to achieve the desired gain.

## Design Steps

1. Choose large-valued capacitors  $C_1$ ,  $C_5$ , and  $C_9$  for the low-pass filters. These capacitors should be selected first since large-valued capacitors have limited standard values to select from compared to standard resistor values.

$$C_1 = C_5 = C_9 = 10\mu\text{F}$$

2. Calculate resistor values for  $R_1$ ,  $R_6$ , and  $R_{11}$  to form the low-pass filters.

$$R_1 = R_6 = R_{11} = \frac{1}{2\pi \times f_H \times C_1} = \frac{1}{2\pi \times 10\text{Hz} \times 10\mu\text{F}} = 1.592\text{k}\Omega$$

$$\text{Choose } R_1 = R_6 = R_{11} = 1.5\text{k}\Omega \quad (\text{Standard value})$$

3. Select capacitor values for  $C_2$ ,  $C_3$ ,  $C_6$ , and  $C_7$  for the high-pass filters.

$$C_2 = C_3 = C_6 = C_7 = 33\mu\text{F}$$

4. Calculate the resistor values for  $R_4$  and  $R_9$  for the high-pass filters.

$$R_4 = R_9 = \frac{1}{2\pi \times f_L \times C_2} = \frac{1}{2\pi \times 0.7\text{Hz} \times 33\mu\text{F}} = 6.89\text{k}\Omega$$

$$\text{Choose } R_4 = R_9 = 6.81\text{k}\Omega \quad (\text{Standard value})$$

5. Set the common-mode voltage of the amplifier to mid-supply using a voltage divider. The equivalent resistance of the voltage divider should be equal to  $R_4$  to properly set the corner frequency of the high-pass filter.

$$R_2 = R_3 = R_7 = R_8 = 2 \times R_4 = 2 \times 6.81\text{k}\Omega = 13.62\text{k}\Omega$$

$$\text{Choose } R_2 = R_3 = R_7 = R_8 = 13.7\text{k}\Omega \quad (\text{Standard value})$$

6. Calculate the gain required by each gain stage to achieve the total gain requirement. Distribute the total gain target of the circuit evenly between both gain stages.

$$\text{Gain} = \frac{90\text{dB}}{2} = 45\text{dB} = 177.828\frac{\text{V}}{\text{V}}$$

7. Calculate  $R_5$  to set the gain of the first stage.

$$R_5 = (\text{Gain} - 1) \times R_4 = (177.828\frac{\text{V}}{\text{V}} - 1) \times 6.81\text{k}\Omega = 1.204\text{M}\Omega$$

$$\text{Choose } 1.2\text{M}\Omega$$

8. Calculate  $C_4$  to set the low-pass filter cut off frequency.

$$C_4 = \frac{1}{2\pi \times R_5 \times f_H} = \frac{1}{2\pi \times 1.2\text{M}\Omega \times 10\text{Hz}} = 13.263\text{nF}$$

$$\text{Choose } C_4 = 15\text{nF}$$

9. Since the gain and cut off frequency of the first gain stage is equal to the second gain stage, set all component values of both stages equal to each other.

$$R_1 = R_6 = 1.5\text{k}\Omega$$

$$R_7 = R_8 = 13.7\text{k}\Omega$$

$$R_9 = R_4 = 6.81\text{k}\Omega$$

$$R_{10} = R_5 = 1.2\text{M}\Omega$$

$$C_8 = C_4 = 15\text{nF}$$

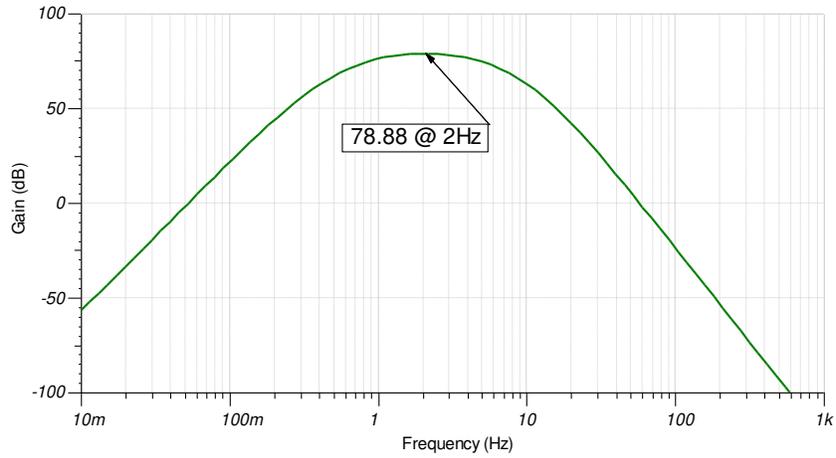
10. Calculate  $R_{11}$  to set the cut off frequency of the low-pass filter at the output of the circuit.

$$R_{11} = \frac{1}{2\pi \times C_9 \times f_H} = \frac{1}{2\pi \times 10\mu\text{F} \times 10\text{Hz}} = 1.592\text{k}\Omega$$

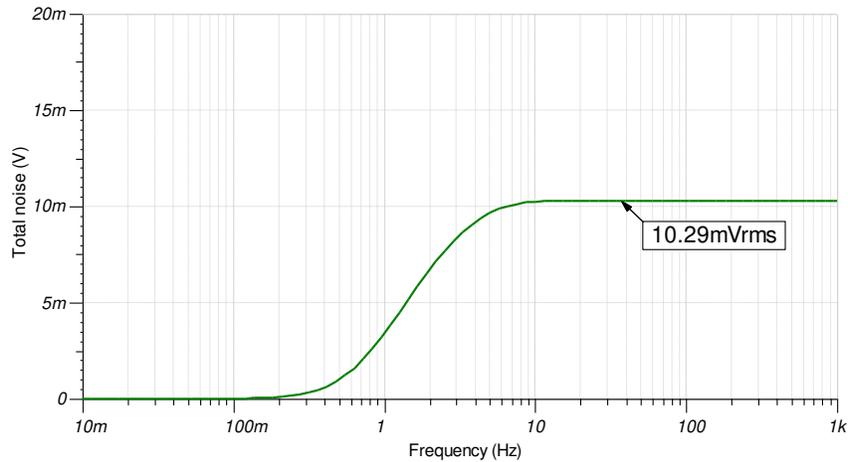
Choose  $R_{11} = 1.5\text{k}\Omega$

## Design Simulations

### AC Simulation Results



### Noise Simulation Results



**References:**

1. [Analog Engineer's Circuit Cookbooks](#)
2. SPICE Simulation File [SBOC524](#)
3. [TI Precision Labs](#)

**Design Featured Op Amp**

TLV9062	
$V_{ss}$	1.8 V to 5.5 V
$V_{inCM}$	Rail-to-rail
$V_{out}$	Rail-to-rail
$V_{os}$	0.3 mV
$I_q$	538 $\mu$ A
$I_b$	0.5 pA
UGBW	10 MHz
SR	6.5 V/ $\mu$ s
#Channels	1, 2, and 4
<a href="http://www.ti.com/product/tlv9062">www.ti.com/product/tlv9062</a>	

**Design Alternate Op Amp**

OPA376	
$V_{ss}$	2.2 V to 5.5 V
$V_{inCM}$	$V_{ee}$ to $V_{cc}-1.3$ V
$V_{out}$	Rail-to-rail
$V_{os}$	5 $\mu$ V
$I_q$	760 $\mu$ A/Ch
$I_b$	0.2 pA
UGBW	5.5 MHz
SR	2 V/ $\mu$ s
#Channels	1, 2, and 4
<a href="http://www.ti.com/product/opa376">http://www.ti.com/product/opa376</a>	

**Revision History**

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

**Changes from December 30, 2018 to February 29, 2020****Page**

- Changed the equations in the following steps of the *Design Steps* section: [2](#), [4](#), [8](#), [9](#), and [10](#) ..... [1](#)

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