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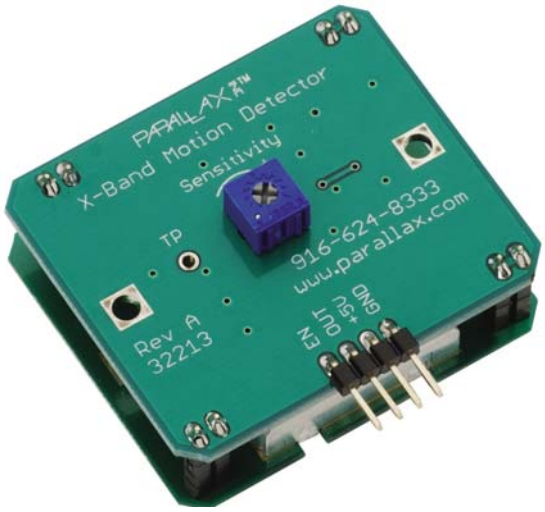
X-Band Motion Detector (#32213)

The X-Band Motion Detector is a common ingredient in security systems and automatic door openers, and can detect movements in a room, yard, or even on the other side of a wall. It's a Doppler radar sensor that operates in the X-band frequency at 10.525 GHz, and indicates movements with oscillations in its high/low output. Sensitivity is manually adjustable with a potentiometer on the back of the device, offering direct line of sight detection from roughly 8 to slightly over 30 ft (~2.4 to 9+ m).

Features



- Operation frequency of 10.525 GHz
- Able to detect motion through walls and windows
- More immune to false triggers than passive infrared motion sensors
- Active-high enable pin with internal pull-up resistor
- Trim potentiometer on the back for manually adjustable sensitivity
- 4-Pin SIP header for breadboard or through-hole prototyping
- Built-in series resistor for compatibility with the Propeller microcontroller and other 3.3 V devices
- Plated test point hole for monitoring pre-comparator signal

Key Specifications

- Power supply requirements: regulated 5 VDC, 8 mA
- Communication: High (3.9 V) / low (0 V) signal oscillates with motion
- Dimensions: 1.83 x 1.87 x 0.69 in (46.5 x 47.5 x 17.6 mm)
- Operating temp range: 32 to 131 °F (0 to 55 °C)

Application Ideas

- Security systems
- Automatic door openers
- Automatic lighting
- Nuisance animal deterrence

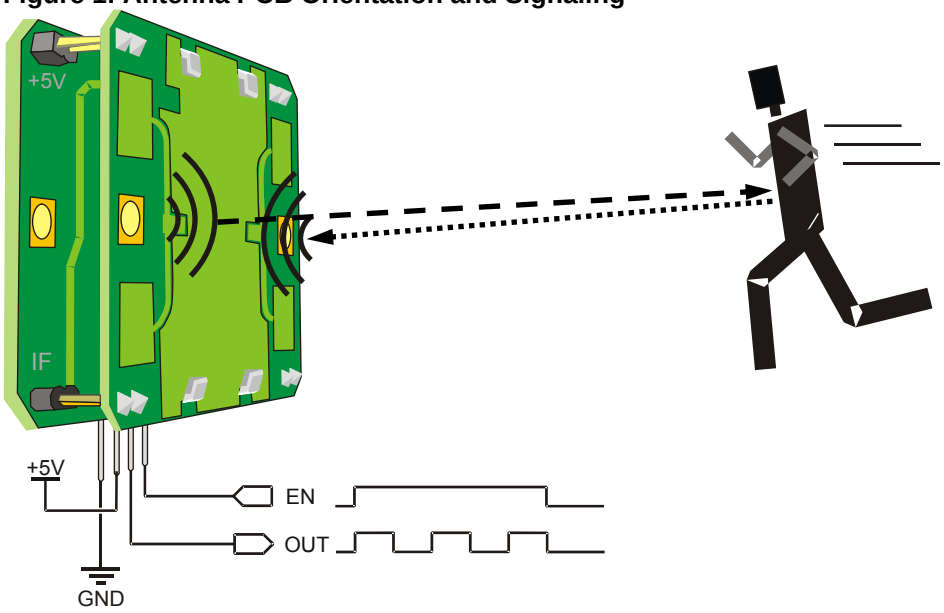
Front
(Antenna side)

Back
(Potentiometer side)

Quick Start

Motion in the detection area causes oscillations at the module's OUT pin, which can be detected by a microcontroller. The front of the device is the antenna PCB, a printed circuit board surface with the module's transmit and receive antennas, as shown in Figure 1. The device should be oriented so that this surface faces the detection area. When the enable (EN) pin is held high or left floating, the device takes brief, periodic, low power Doppler radar measurements. The frequency of the high/low signals the output (OUT) pin transmits corresponds to the speed of the motion.

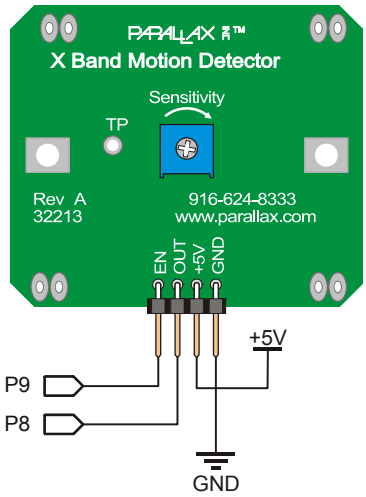
Figure 1: Antenna PCB Orientation and Signaling



Test Circuit

Figure 2 shows a test circuit for either the BASIC Stamp 2 or Propeller microcontrollers. The optional enable (EN) pin is connected to I/O pin P9, and the module's output signal (OUT) pin is connected to P8. The EN pin can be held low to disable the device. When the EN pin is pulled high it enables the device. Likewise, if the EN pin is left floating, an internal pull-up resistor keeps the device enabled whenever it has power. The OUT pin oscillates whenever motion is detected, and in general, the more motion, the faster the oscillations.

Figure 2: Test circuit schematic



NOTES:

For most Parallax BASIC Stamp carrier boards, the +5V connection is labeled Vdd, and the ground (GND) connection is labeled Vss.

For most Parallax Propeller carrier boards, the +5V connection is labeled 5V, and the ground connection is either labeled GND or Vss.

Test Procedure

This test procedure provides a quick-start for the BASIC Stamp 2 or Propeller microcontroller.

Hardware:

- ✓ Build the circuit shown in Figure 2.
- ✓ For close range motion measurements while connected to a computer, turn the potentiometer adjustment all the way counterclockwise.
- ✓ Connect power and programming cable to your microcontroller board.

BASIC Stamp 2 microcontroller:

- ✓ Test X Band Motion Detector.bs2 is featured in this document's Test Code section and is also available for download from the X-Band Motion Detector product page at www.parallax.com.
- ✓ Download and open Test X Band Motion Detector.bs2.
- ✓ Use the BASIC Stamp Editor and load it into the BASIC Stamp microcontroller.

Propeller Microcontroller:

- ✓ Test X Band Motion Detector.spin is featured in this document's Test Code section and is also available for download from the X-Band Motion Detector product page at www.parallax.com.
- ✓ Open the Parallax Serial Terminal and make sure it is set to the Propeller Chip's programming port at a baud rate of 115200 bps.
- ✓ Use the Propeller Tool software to load the application into the Propeller chip.
- ✓ As soon as the Propeller Communication window reports "Loading…" click the Parallax Serial Terminal's Enable button.

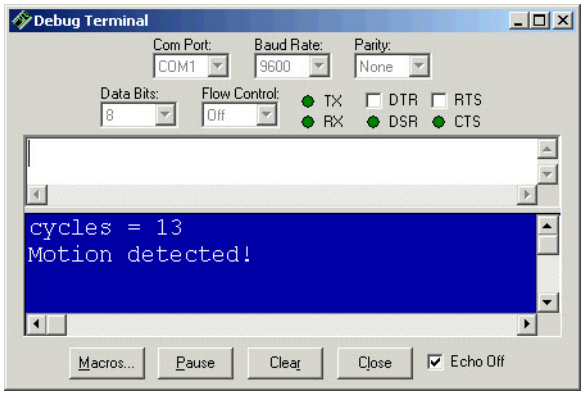
Monitoring the Sensor Output:

Figure 3 shows terminal messages from the BASIC Stamp and Propeller microcontrollers as each one monitors an X-Band Motion Detector.

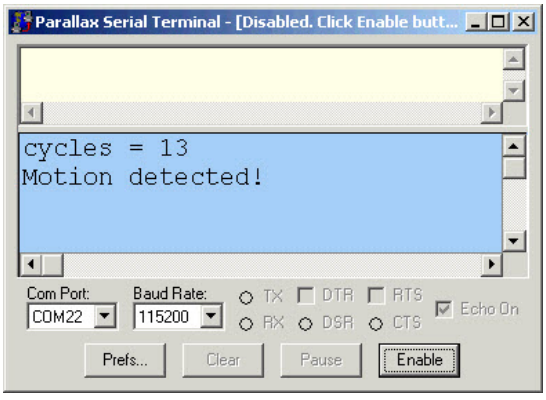
- ✓ Make sure nothing within a 10 ft (3 m approx) radius is moving as you monitor the Debug Terminal. The Debug Terminal should display values of zero or close to zero along with a "Motion not detected." message.
- ✓ Move your hand toward or away from the face of the antenna PCB, and verify that the Debug Terminal displays larger numbers along with the "Motion detected!" message.

Figure 3: Terminal displays

BASIC Stamp Editor Debug Terminal



Parallax Serial Terminal



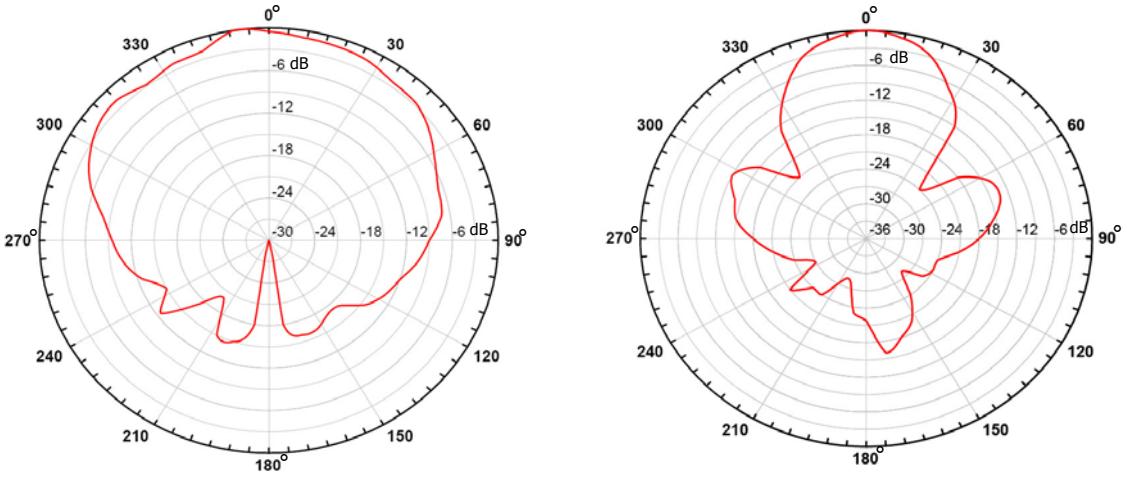
Calibration and Sensitivity

The X-Band Motion Detector's detection range can be adjusted by turning the Sensitivity potentiometer on the back of the device. The "motion/no motion" threshold constant 'MoveThreshld' in each example program can also be adjusted, which allows it to ignore small or brief, quick motions. Larger MoveThreshld values require more motion (larger values in the 'cycles' variable) to trigger a detection; smaller values require less motion to trigger a detection. The device's sensitivity may vary with different kinds of walls and window blinds. For example, direct line-of-sight detection can be adjusted from approximately 8 to slightly over 30 ft (~2.4 to 9+ m). The sensor will still be effective through walls and windows, but not through conductive metals, and testing for the conditions under which it will be used is recommended.

The device's sensitivity also varies with the object's angle, which in turn varies with the antenna radiation plots in Figure 4. It is most sensitive to objects directly in front of the antenna PCB (Figure 1) which corresponds to an angle of 0° in Figure 4. Sensitivity is maximized in the areas where the plot is between the two outermost circles. This is the region between 0 dB (full power signal) and -3 dB (half power signal).

For example, on the horizontal plane, the antenna's radiation pattern stays above half power from approximately 300 degrees to just over 45 degrees. In the vertical plane, the half-power beam width ranges from about 340 to 20 degrees. Keep in mind that angles corresponding to larger –dB values (closer to the center of a graph) indicate that the object will have to be closer to the device for it to detect motion. So, the sensor will still detect motion at angles outside these half-power beam widths, just at a closer range.

Figure 4: Sensitivity vs. angle on the horizontal and vertical planes†



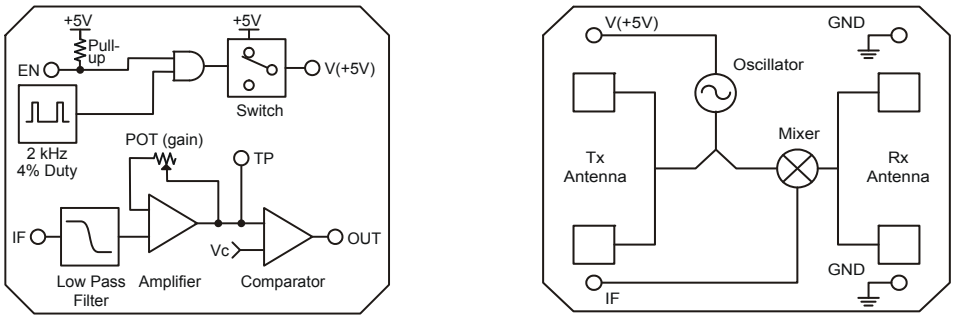
† Source: manufacturer datasheet

Device Information

Theory of Operation

The X-Band Motion Sensor is constructed of two boards connected by posts: a control board, and the antenna PCB with the Doppler sensor. Block diagrams of these boards are shown in Figure 5. When the enable pin is either held high or left floating, the control board cycles the Doppler sensor's power at 2 kHz, 4% duty cycle. The Doppler sensor's 10.525 GHz oscillator signal is routed to the Tx antenna, and also to a mixer diode. The mixer diode's IF output contains signals with the sum and difference of the transmitted and received frequencies along with components of the original signal and some harmonics. The difference signal's frequency that results from mixing the outgoing and returning signal frequencies is the important component. It oscillates at a frequency corresponding to how much the returning signal has been either compressed or stretched as a result of the Doppler Effect that an object has on the signal as the object moves toward or away from the sensor.

Figure 5: Block diagrams



Control Board Antenna PCB

The Doppler sensor's IF terminal passes the signal to the control board, where a low pass filter removes all the higher frequency signals and leaves behind the difference signal. This signal passes through an amplifier whose gain can be adjusted by the control board's potentiometer, and can be monitored by probing the test point, which is a plated hole labeled TP. The TP signal passes though a comparator, which transforms the signal with the difference frequency to a high/low digital output. The difference signal's frequency is related to the component of the object's speed toward or away from the sensor by this equation:

$$F_d = 2V\left(\frac{F_t}{c}\right)\cos\theta$$

Where:

- F_d = Difference frequency (sometimes referred to as Doppler frequency)
- V = Velocity of the target
- F_t = Transmit frequency
- c = Speed of light at 3×10^8 m/s
- θ = Motion direction angle deviation from perpendicular to the antenna PCB (Figure 1).

In contrast to speed guns, which use a wave guide to direct the antenna radiation pattern, the X-Band Motion Detector's antenna has a wide radiation pattern to convert velocities from multiple points to oscillations that notify the microcontroller that movement was detected. This device is designed to detect motion, not to determine speed of a moving object. However, an application *may* still use a rearranged version of the F_d equation to determine speed *provided everything else in the detection area stays still*.

Specifications†

Symbol	Quantity	Minimum	Typical	Maximum	Units
f	Operating frequency[1]	10.520	10.525	10.530	GHz
EIRP	Radiation power[1, 2]	10	13	14	dBm
	Clutter suppression			-30	dBm
	Spurious emissions at 3 m		3	6	µV/m
RSS	Receiver Signal strength		140		µVpp
	Noise			3	uVrms
$HPBW_H$	Half power beam width (horizontal)		80		°
$HPBW_V$	Half power beam width (vertical)		40		°
V_S	Supply voltage	4.75	5.00	5.25	VDC
I_S	Supply current, EN high (enabled)		10		mA
I_D	Supply current, EN low (disabled)		7		mA
f_P	Pulse frequency		2		kHz
t_P	Pulse duration	10			µs
T	Operating temperature	32		131	°F
W	Weight		15.1		g

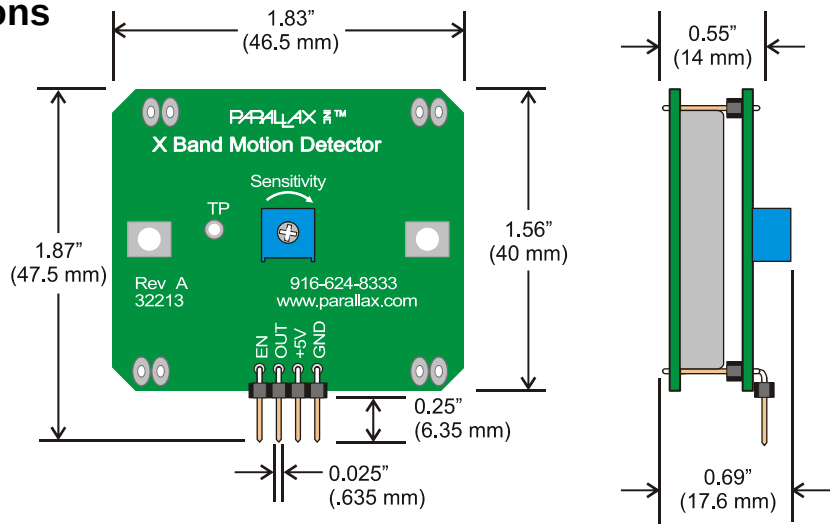
† Source: Manufacturer datasheet, except I_S, I_D, T, and W

1. The X-Band Motion Detector is designed to meet FCC rules Part 15, section 15.245 for use within a building or to open a building door. See the FCC and Liability Disclaimer section at the end of this document for more information.
2. The motion detector's microwave emissions are well below established safety standards for general public environments. See ANSI C95.1-1991 for more information.

Pin Definitions and Ratings

Pin	Name	Function
1	EN	High to enable the Doppler sensor, low to disable. Accepts 3.3 V or 5 V high signals.
2	OUT	Output signal that oscillates high/low = 3.9 V/0 V to indicate detected motion. This output pin has a 1 kΩ series resistor to keep it compatible for direct connection with the Propeller microcontroller's 3.3 V I/O pins.
3	+5V	+5 V power supply
4	GND	0 V = ground

Module Dimensions



Test Code

BASIC Stamp® 2 Program

```
' Test X Band Motion Detector.bs2
' Test to see the number of cycles the X Band Motion Detector
' sends in response to motion.

' {$STAMP BS2}                                ' Module = BASIC Stamp 2
' {$PBASIC 2.5}                               ' Language = PBASIC 2.5

XbandEnPin     PIN     9                      ' Enable pin
XbandOutPin    PIN     8                      ' Output pin

HalfSecond     CON     500                    ' ms in 1/2 s delay
MoveThreshld   CON     2                      ' Motion threshold

cycles         VAR     Word                   ' Cycle counter
reps           VAR     Word                   ' Test repetitions

HIGH XbandEnPin                               ' Enable motion detector

FOR reps = 1 TO 360                           ' Check for 3 minutes

  COUNT XbandOutPin, HalfSecond, cycles       ' Count OUT pin transitions

  DEBUG HOME, "cycles = ",                    ' Display cycle count
        DEC cycles, CLREOL

  IF cycles > MoveThreshld THEN               ' Display motion/no motion
    DEBUG CR, "Motion detected!"
  else
    DEBUG CR, "No motion", clreol
  endif

NEXT                                          ' Repeat detection loop

LOW XbandEnPin                                ' Disable motion detector

DEBUG CR, "Test done, motion detector disabled."  ' Display all done.

STOP                                          ' Stop the program holding EN
                                              ' low
```

Propeller Application

```
' Test X Band Motion Detector.bs2
' Test to see the number of cycles the X Band Motion Detector
' sends in response to motion.

CON

  _clkmode = xtal1 + pll16x                 ' Crystal and PLL settings.
  _xinfreq = 5_000_000                      ' 5 MHz crystal x 16 = 80 MHz.

Baud115k       =     115200                 ' Baud rate
XbandEnPin     =     9                      ' Enable pin
XbandOutPin    =     8                      ' Output pin
HalfSecond     =     500                    ' ms in 1/2 s delay
MoveThreshld   =     2                      ' Motion threshold
```

```
OBJ

  pst   : "Parallax Serial Terminal"         ' Serial communication object
  xband : "X Band Motion Detector"           ' X Band Motion Detector object

PUB go | cycles

  pst.Start(Baud115k)                        ' Parallax Serial Terminal → cog
  xband.Enable(XbandEnPin)                   ' Set optional enable pin
  xband.Out(XbandOutPin)                     ' Initialize

  repeat 360                                 ' Main loop

    cycles := xband.GetCycles(HalfSecond)    ' Check X Band Motion Detector

      pst.Str(String(pst#HM, "cycles = "))   ' Display cycles
      pst.Dec(cycles)
      pst.Str(String(pst#CE, pst#NL))

    if xband.GetCycles(500) > MoveThreshld   ' Decide if motion & display
      pst.Str(String("Motion detected!"))
    else
      pst.Str(String("Not detected.", pst#CE))
```

FCC Notice and Liability Disclaimer

These modules (boards) are not FCC approved. They are designed to comply with FCC Part 15 Rules and Regulations. They are not in a finished product form. They are strictly intended for experimental purposes only. If you wish to use these modules in an actual product (a non-experimental capacity), the module must first be designed into the product then the whole product must be approved by the FCC. Parallax, Inc. is not responsible for special, incidental, or consequential damages resulting from any breach of warranty, or under any legal theory, including lost profits, downtime, goodwill, damage to or replacement of equipment or property, and any costs of recovering, reprogramming, or reproducing any data stored in or used with Parallax products.

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