Web Site: www.parallax.com
Forums: forums.parallax.com
Sales: sales@parallax.com
Technical: support@parallax.com

Office: (916) 624-8333
Fax: (916) 624-8003
Sales: (888) 512-1024
Tech Support: (888) 997-8267

Hitachi® H48C 3-Axis Accelerometer Module (#28026)

General Description

The Hitachi H48C 3-Axis Accelerometer is an integrated module that can sense gravitational (g) force of ±3g on three axes (X, Y, and Z). The module contains an onboard regulator to provide 3.3-volt power to the H48C, analog signal conditioning, and an MCP3204 (four channel, 12-bit) analog-to-digital converter to read the H48C voltage outputs. All components are mounted on a breadboard-friendly, 0.7 by 0.8 inch module. Acquiring measurements from the module is simplified through a synchronous serial interface. With the BASIC Stamp® 2 series, for example, this is easily handled with the SHIFTOUT and SHIFTIN commands.

Features

- Measure ±3 g on any axis
- Uses MEMS (Micro Electro-Mechanical System) technology, with compensation for calibration-free operation
- Onboard regulator and high-resolution ADC for simple connection to microcontroller host
  - compatible with BASIC Stamp 2 series SHIFTOUT and SHIFTIN commands
- Free-fall output indicates simultaneous 0g an all axes
- Small, breadboard-friendly package: 0.7" x 0.8" (17.8 mm x 20.3 mm)
- Wide operational range: -25° to 75° C

Application Ideas

- Tilt measurement in robotics applications
- Multi-axis vibration measurement in transit and shipping systems
- Multi-axis movement/lack-of-movement for alarm systems

Packing List

Verify that your H48C Accelerometer kit is complete in accordance with the list below:

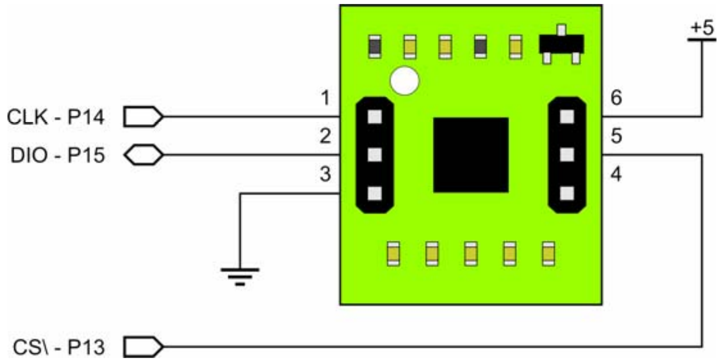
- Hitachi H48C 3-Axis Accelerometer module
- Documentation

Note: Demonstration software files may be downloaded from www.parallax.com.
(*See http://www.parallax.com/detail.asp?product_id=28026*)

Essential Connections

Connecting the H48C module to the BASIC Stamp 2 controller is a straightforward operation, requiring just three I/O pins (the CLK and DIO pins may be shared in systems requiring the use of more than one H48C module). See Figure 1 for connection details.

Figure 1. H48C Connections



How It Works

Through MEMS (Micro Electro-Mechanical System) technology and built-in compensation, the H48C accelerometer provides simultaneous outputs through analog conditioning circuitry to an MCP3204 ADC. To "read" g-force of a given axis we actually read the voltage output from that axis and calculate g-force using this formula:

$$G = ((axis - vRef) / 4095) \times (3.3 / 0.3663)$$

In the formula, *axis* and *vRef* are expressed in counts from the ADC, 4095 is the maximum output count from a 12-bit ADC channel, 3.3 is the H48C supply voltage, and 0.3663 is the H48C output voltage for 1g (when operating at 3.3v). In practice this can be simplified to:

$$G = (axis - vRef) \times 0.0022$$

Using the BASIC Stamp 2 module as a host controller, we should multiply the 0.0022 by 100 (to 0.22) to express the result in units of 0.01g. Using the ** operator, we are able to multiply by 0.22 and convert the raw readings to g-force with this bit of code:

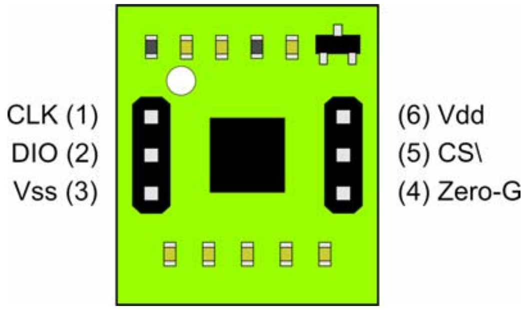
```
IF (axCount >= rvCount) THEN
  gForce = (axCount - rvCount) ** GfCnv      ' positive g-force
ELSE
  gForce = -((rvCount - axCount) ** GfCnv)   ' negative g-force
ENDIF
```

Note the **IF-THEN** structure which prevents a negative number from being divided – this is illegal in PBASIC 2.x and will not return the correct result. By restructuring the conversion equation for negative g-forces we can indeed arrive at the correct value. The output value, *gForce*, is a signed integer.

In application the analog signal conditioning circuitry affects the rate at which readings can be taken H48C module. The filter/buffer circuit is designed to minimize noise while maintaining the highest possible signal resolution into the ADC. By design, the filter circuit limits MC48C axis output rail-to-rail rise/fall time to about five milliseconds. Since MCP3204 has a significantly higher sample rate, the sampling rate of the module is dictated by the filter circuitry and works out to about 200 samples per second.

Pin Definitions and Ratings

(1) CLK Synchronous clock input
(2) DIO Bi-directional data to/from host
(3) Vss Power supply ground (0v)
(4) Zero-G "Free-fall" output; active-high
(5) CS\ Chip select input; active-low
(6) Vdd +5vdc

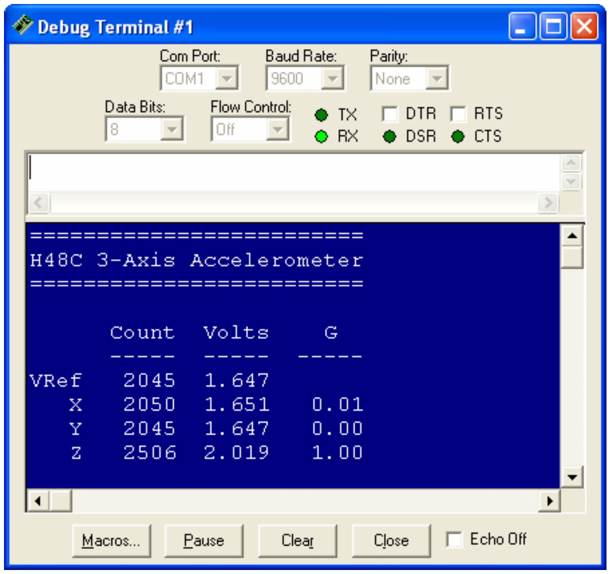


Symbol	Quantity	Minimum	Typical	Maximum	Units
V_{DD}	Operating voltage	4.5	5.0	5.5	V
V_{SS}	Ground reference connection		0		V
I_{DD}	Supply current		7	10	mA
V_{IH}	High Level Voltage Input †	0.7 V_{DD}			V
V_{IL}	Low Level Voltage Input †			0.3 V_{DD}	V
V_{OH}	High Level Voltage Output †	4.1			V
V_{OL}	Low Level Voltage Output †			0.4	V
	Sample Rate			200	sps
	ADC (MCP3204) Resolution †		12		bits
	Measurement Range §	-3		3	g
	Sensitivity §		366.3		mV/g
	Accuracy §	10			%
	Non-linearity §	-2		2	%
	Operating Temperature Range §	-25		75	°C
	High Level Zero-G Voltage Output §	3.2	3.3		V
	Zero-G Output Delay §			1	ms

† From Microchip MCP3204 Datasheet
§ From Hitachi H48C Datasheet

Demonstration Program

This demonstration uses the BASIC Stamp 2 series microcontroller to read the reference voltage and output channels from the H48C using the onboard MCP3204 analog-to-digital converter. For each channel the raw count, channel voltage, and g-force for the X, Y, and Z axes are displayed as shown below:



BASIC Stamp 2 Source Code

```
' =========================================================================
'
'   File....... H48C_3-Axis.BS2
'   Purpose.... Hitachi H48C 3-Axis Accelerometer Demonstration
'   Author..... Copyright (c) 2005-2006 Parallax, Inc.
'   E-mail..... support@parallax.com
'   Started....
'   Updated.... 02 FEB 2006
'
'   {$STAMP BS2}
'   {$PBASIC 2.5}
'
' =========================================================================


' -----[ I/O Definitions ]-------------------------------------------------

Dio             PIN     15                      ' data to/from module
Clk             PIN     14                      ' clock output
CS              PIN     13                      ' active-low chip select


' -----[ Constants ]-------------------------------------------------------

XAxis           CON     0                       ' adc channels
YAxis           CON     1
ZAxis           CON     2
```

```
VRef            CON     3

Cnt2Mv          CON     $CE4C                   ' counts to millivolts
                                                '   0.80586 with **
GfCnv           CON     $3852                   ' g-force conversion
                                                '   0.22 with **

' -----[ Variables ]----------------------------------------------------

axis            VAR     Nib                     ' axis selection
rvCount         VAR     Word                    ' ref voltage adc counts
axCount         VAR     Word                    ' axis voltage adc counts
mVolts          VAR     Word                    ' millivolts
gForce          VAR     Word                    ' axis g-force

dValue          VAR     Word                    ' display value
dPad            VAR     Nib                     ' display pad


' -----[ Initialization ]-----------------------------------------------

Reset:
  HIGH CS                                       ' deselect module
  DEBUG CLS,                                    ' paint display
        "=========================", CR,
        "H48C 3-Axis Accelerometer", CR,
        "=========================", CR,
        CR,
        "      Count  Volts    G  ", CR,
        "      -----  -----  -----", CR,
        "VRef                     ", CR,
        "   X                     ", CR,
        "   Y                     ", CR,
        "   Z                     "


' -----[ Program Code ]-------------------------------------------------

Main:
  FOR axis = XAxis TO ZAxis                     ' loop through each axis
    GOSUB Get_H48C                              ' read vRef & axis counts

    dValue = rvCount                            ' display vRef count
    DEBUG CRSRXY, 6, 6
    GOSUB RJ_Print

    dValue = axCount                            ' display axis count
    DEBUG CRSRXY, 6, (7 + axis)
    GOSUB RJ_Print

    mVolts = rvCount ** Cnt2Mv                  ' convert vref to mv
    DEBUG CRSRXY, 13, 6,                        ' display
          DEC (mVolts / 1000), ".",
          DEC3 mVolts

    mVolts = axCount ** Cnt2Mv                  ' convert axis to mv
    DEBUG CRSRXY, 13, (7 + axis),
```

```
          DEC (mVolts / 1000), ".",
          DEC3 mVolts

    ' calculate g-force
    ' -- "gForce" is signed word

    IF (axCount >= rvCount) THEN
      gForce = (axCount - rvCount) ** GfCnv     ' positive g-force
    ELSE
      gForce = -((rvCount - axCount) ** GfCnv)  ' negative g-force
    ENDIF
    DEBUG CRSRXY, 20, (7 + axis),               ' display g-force
          " " + (gForce.BIT15 * 13),
          DEC1 (ABS(gForce) / 100), ".",
          DEC2 ABS(gForce)
  NEXT
  PAUSE 200
  GOTO Main


' -----[ Subroutines ]-----------------------------------------------------

' Reads VRef and selected H48C axis through an MCP3204 ADC
' -- pass axis (0 - 2) in "axis"
' -- returns reference voltage counts in "rvCount"
' -- returns axis voltage counts in "axCounts"

Get_H48C:
  LOW CS
  SHIFTOUT Dio, Clk, MSBFIRST, [%11\2, VRef\3]  ' select vref register
  SHIFTIN  Dio, Clk, MSBPOST, [rvCount\13]      ' read ref voltage counts
  HIGH CS
  PAUSE 1
  LOW CS
  SHIFTOUT Dio, Clk, MSBFIRST, [%11\2, axis\3]  ' select axis
  SHIFTIN  Dio, Clk, MSBPOST, [axCount\13]      ' read axis voltage counts
  HIGH CS
  RETURN

' -------------------------------------------------------------------------

' Right-justify value in 5-digit field
' -- move cursor first, then call with value in "dValue"

RJ_Print:
  LOOKDOWN dValue, >=[10000, 1000, 100, 10, 0], dPad
  DEBUG REP " "\dPad, DEC dValue
  RETURN
```

Principle of free-fall detection by a 3-axis accelerometer

An accelerometer is an inertial sensor to measure the acceleration, which is obtained by deducting the gravitational acceleration (g) from the movement acceleration (a) along the direction of the input axis (sensing axis).

In short, the measured acceleration (A) is expressed by the following formula.

$$A = a - g$$

Here, g is +1g when for the gravitational acceleration, the downward direction perpendicular to the earth surface is defined as positive. And when the sensing axis leans by the angle of θ from the perpendicular direction to the earth surface, the gravitational acceleration is obtained by multiplying +1g by -cos θ.

Therefore, an accelerometer (a= 0), fixed on the earth, indicates +1g when the positive direction of the sensing axis is upward and perpendicular to the earth-surface, and when the sensing axis inclines from an upward plumb line by angle θ, it indicates the value which multiplies +1g by cos θ. On the other hand, since a equals g under free-fall condition, an accelerometer indicates zero whatever the tilt angle of an sensing axis is. Therefore, a 3-axis accelerometer indicates zero about all of the sensing axes simultaneously during free-fall, and never zero except during free-fall. (Note 1)

From this theoretic characteristic, when the indicated values (output value) of three axes show zero simultaneously, it can be judged that this accelerometer is in the condition of free-fall. Here, the free-fall means the state where there is no external force to be added to the accelerometer except for the gravity. On the occasion that the object is thrown upward, the object will be in the condition of free-fall from the moment of leaving a hand. When air resistance is large, it acts as external force. And, when an accelerometer is equipped in the point except for the rotation center of the object (for example, sphere), is rotating and falling, the centrifugal force acts by its rotation. Then, none of these above cases can be strictly called free-fall.

(Note 1) In the specific phase of vertical vibration, it may sometimes be in the state equivalent to free-fall.

Zero-Gravity detection system built in H48C

The Zero-Gravity (ZeroG) detection system is constituted as shown in **Fig. 1**. The ZeroG detector compares the absolute value of the acceleration outputted from the 3-axis accelerometer with threshold Gt for every axis. When the absolute value is smaller than threshold about all axes, the detector judges the state is Zero-Gravity and a ZeroG flag is outputted. The comparison is performed repeatedly every about 0.4ms, and if it stops satisfying the judgment conditions, the flag will disappear. The standard specification of Gt is 0.4g. Although Gt accuracy is ±0.05g, the effective accuracy will become ±0.1g if the offset voltage error (±0.05g) of the

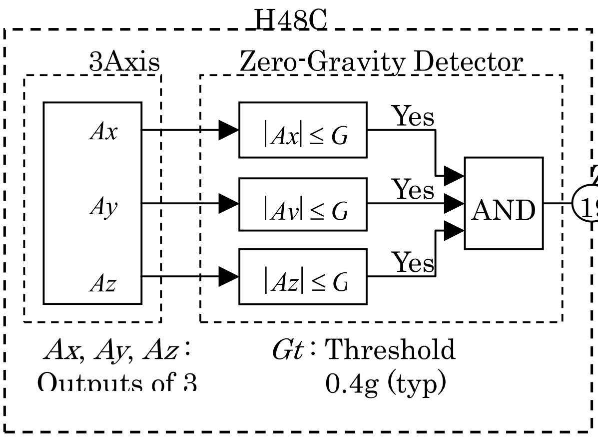


Fig.1 Blockdiagram of the ZeroG detector

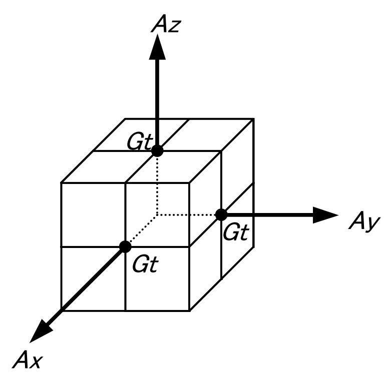


Fig.2 ZeroG detection range

acceleration detection voltage *Ax*, *Ay*, and *Az* is taken into account. In addition, the ZeroG detection range can be expressed as shown in **Fig. 2**, and a cubical inner side is the detection range.

Example of ZeroG flag waveforms

Fig. 3 shows the sensor block used for the fall experiment. H48C is mounted in a sensor block and three wires, a power supply, a ground, and a ZeroG flag, are pulled out from the block.

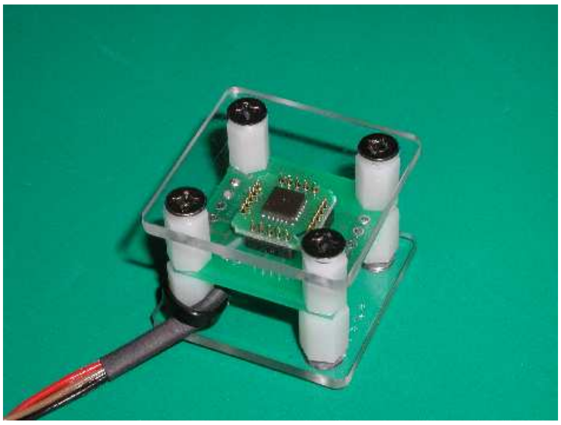


Fig.3 Photo of the sensor block

The example of the ZeroG flag is shown in **Fig. 4** when the sensor block was dropped from a height of 60cm. Once ZeroG is detected, a flag, which is equal to Vcc, is outputted. In the figure, the duration time of zero to about 350ms corresponds to free-falling, and the next duration corresponds to the period of a collision and a rebound. The graph on the upper side shows the waveform of the ZeroG flag observed directly, and the graph on the lower side shows the waveform observed through CR low pass filter (time constant is 10ms).

Next, the flag waveforms are simulated when the walking is done, holding a mobile apparatus with the sensor H48C. In the experiment, the vertical vibration was applied to the sensor block by hand with the magnitude of about 3 cmp-p. The result is shown in **Fig. 5**. The flag waveforms of the width for several 10ms occurred according to the cycle of the vibration. Moreover, chattering was also generated.

Thus, there is a case that ZeroG flags are also generated under the conditions other than free fall. However, when the above-mentioned two cases are compared about waveform width, it is clear that the waveform width is wide in the case of free fall and narrow in the case of the vibration. Therefore, it is considered to be possible to discriminate the free-fall from other cases with high accuracy by using the difference in these characteristics between the above-mentioned two cases, free-fall and vibration.

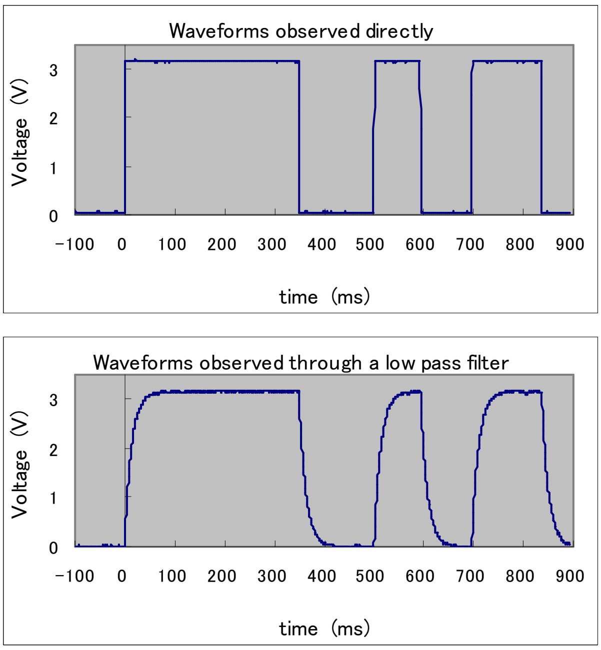


Fig.4 ZeroG Flag waveform in free-fall

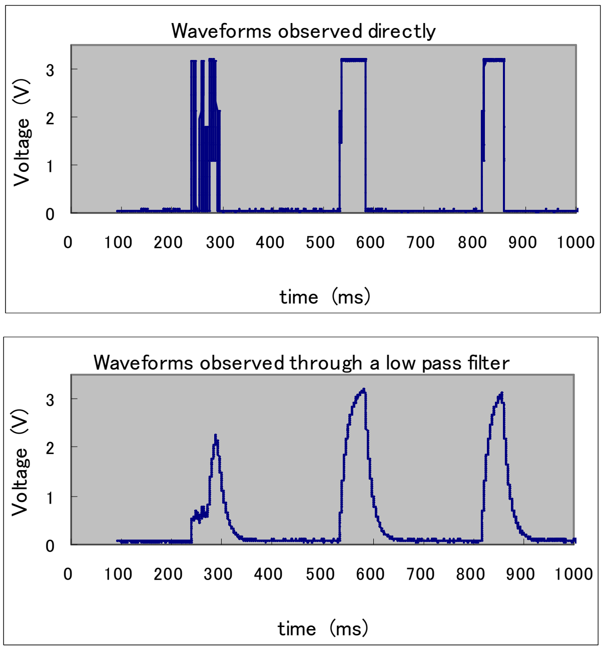


Fig.5 ZeroG Flag waveform in vibration

The method of free-fall judgment

Fig. 6 shows the block diagram of the free-fall judging based on the above-mentioned idea.

Below, a series of operation for a free-fall judgment is explained briefly.

The width T_{ZG} of the pulse of a ZeroG flag is equivalent to the continuation time of the Zero-Gravity condition. T_{ZG} is compared with the continuation judging time (*Tjud*), set in the resister in advance, by using the timer-counter function of a microcomputer, and when T_{ZG} becomes equal with *Tjud*, the alarm of free-fall is generated. And the CPU, interrupted by the alarm, starts the protective action to minimize the damage by the collision to the floor as a task of the 1st priority.

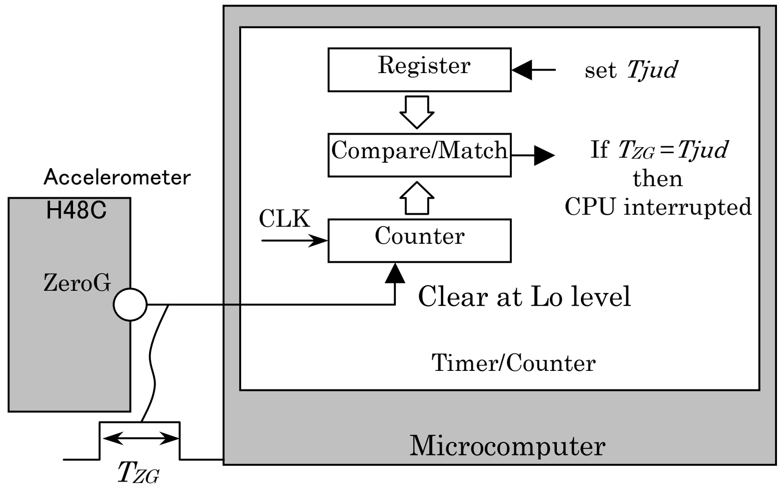


Fig. 6 Block diagram of the free-fall judging

Supplementary explanation is given below. The counter is controlled by the T_{ZG} pulse in the operation, only Hi-level period of a T_{ZG} pulse counts up CLK, and the period of Lo level continues clearing a count value. Therefore, when a T_{ZG} pulse rises to Hi from Lo level, a count value is surely started from zero. The compare-match part is continuously watching the count value and the register value. And when a count value reaches the register value corresponding to *Tjud*, an output is generated, and high priority interruption is passed to the CPU.

In addition, since the timer-counter operates independently of the CPU, the operation of the above-mentioned free-fall detection does not become load excessive for the CPU during free-fall monitoring.

Among the number (*B*) of bits of a counter, the clock frequency (*fclk*), and the continuation judging time (*Tjud*), the restrictions conditions exist, expressed with the following formula.

$$fclk < 2\ B/Tjud$$

For example, since it is required in the case of *B*= 16 and *Tjud*=100ms that a clock frequency should be 650kHz or less, the count down ratio from a main clock must be set up along with these values.

For the lower probability to misjudge the vibration as free-fall, the longer continuation judging time *Tjud* is desirable. However, attention must be paid to that the time for the protection processing, performed after free-fall judgment, decreases if *Tjud* is too long. There is some reports referred to *Tjud* for which around 100ms was suitable.

A logic circuit can also be substituted for a microcomputer. **Fig. 7** shows the example of a logic circuit for free-fall judging. When free-fall is judged, an LED drawn on the upper right part lights up. This circuit is convenient, when examining the optimal value of *Tjud*, since a setup of *Tjud* can be performed in the combination of the 8-bit DIP switch drawn on the right end of a figure. In addition, in this example of a circuit, the low pass filtering and the pulse reforming circuits with a comparator are used for avoiding the influence of chattering. However, these are not necessarily required.

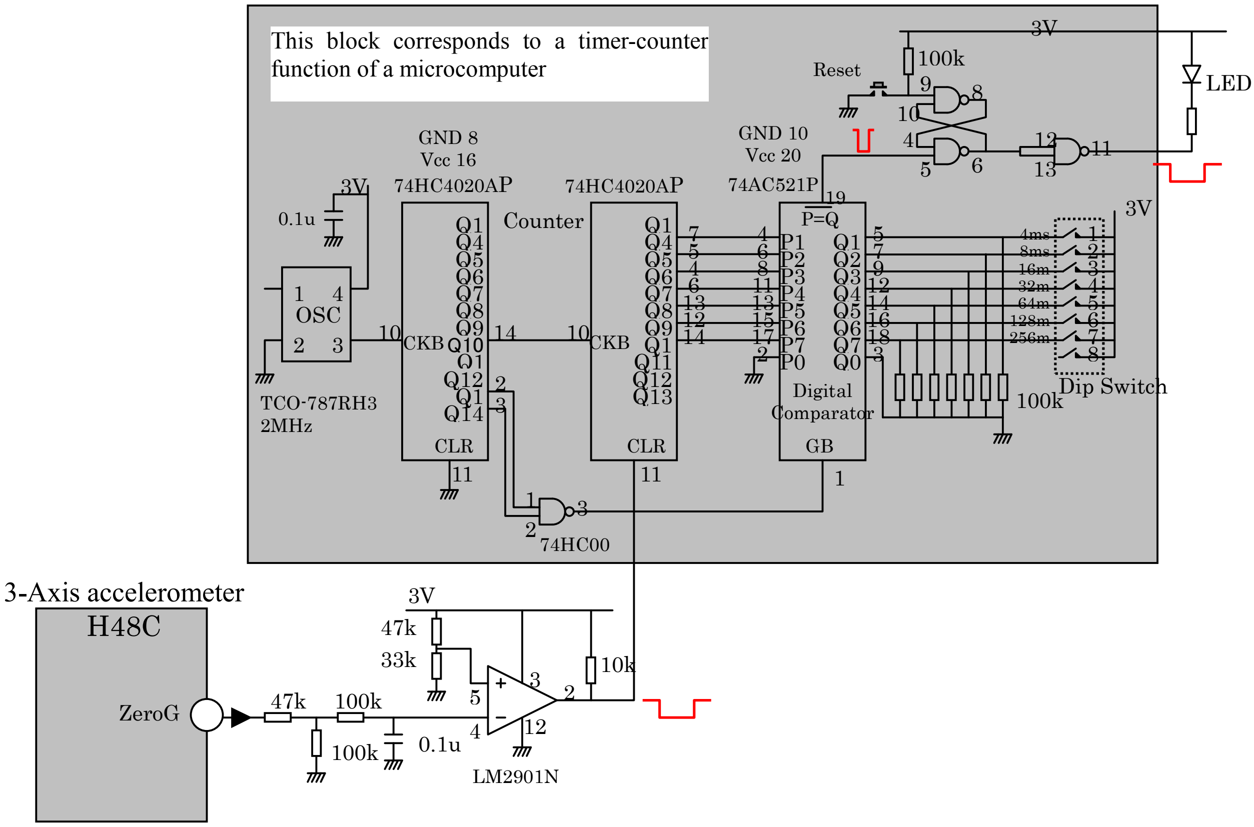


Fig.7 Example of a logic circuit for free-fall judgment

±3g 3−Axis Accelerometer with IC

H48C

The model H48C is a 3-axis accelerometer module, which is composed of a precise sensor's chip, produced by MEMS (Micro Electro Mechanical System) technology, and CMOS-IC chip with the op-amplifiers and the several new functions written below. For each products, the performance variations among products, and moreover those drifts over temperature are compensated before shipment, whose novel function is first realized in the small and thin package size. So H48C could be used without calibration for most applications. And also H48C has the high reliability due to the ceramic package and the air-tight seal.

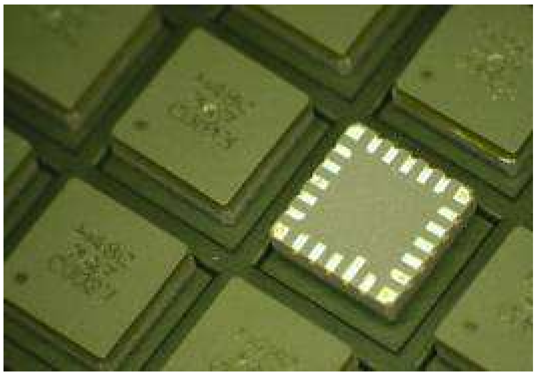
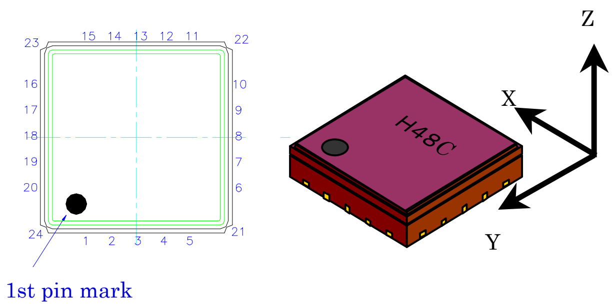


Fig. 1 H48C appearance



Features

■Detect three(X,Y,Z) axes simultaneously

■High total-accuracy of 10% by "compensation IC" so as not need the calibration.

■Single supply voltage of +2.2 to +3.6V

■Very low power consumption and further, STBY mode equipped.

Operation current 0.58mA at 3V

Stand by current 1μA max.

■Capable to detect "Static(Tilt) and "Dynamic" acceleration

■High shock durability (>5000g)

■With a new function of "Free Fall Detection"

Send the pulse during almost zero G for all of three axes at the same time.

■With an output of temperature sensor

■Very small and thin package(QFN type)

Package dimensions ; 4.8×4.8×1.5mm

■Leadless solder is available.

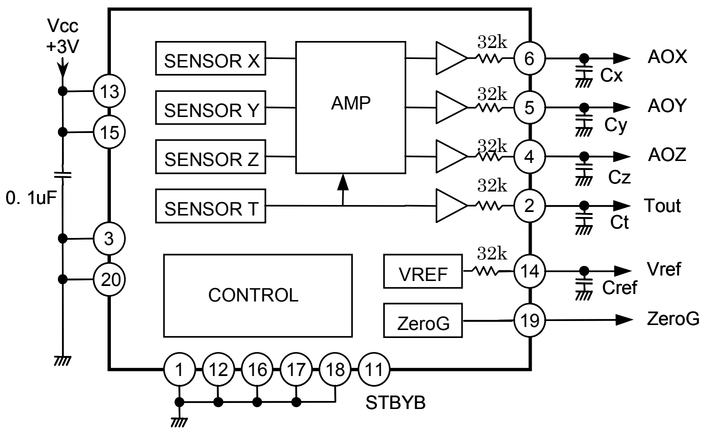


Fig. 2 Functional block diagram

Table 1 Pin description

Pin No.	Name	Description
1	Reserved	To Ground
2	Tout	Output voltage on temperature sensor
3	AGND	Ground for analog circuit block
4	AOZ	Analog output voltage of Z axis
5	AOY	Analog output voltage of Y axis
6	AOX	Analog output voltage of X axis
7	NC	No connection
8	NC	No connection
9	NC	No connection
10	NC	No connection
11	STBYB	Control of standby mode (Low(0V):Standby, High(Vcc±0.3):Operating)
12	Reserved	To Ground
13	AVCC	Operating voltage for analog circuit block
14	Vref	Reference voltage (1/2VCC)
15	DVCC	Operating voltage for digital circuit block
16	Reserved	To Ground
17	Reserved	To Ground
18	Reserved	To Ground
19	ZeroG	Flag output on zero g detection (Free fall detection)
20	DGND	Ground for digital circuit block

Note : Pin numbers of 21, 22, 23 and 24 are the lands to enhance the soldering strength.

Note 1) Output voltages are designed to be ratiomeric to Vcc. The power supply for A/D converter is recommended to use the same power supply as H48C.

2)The magnitudes of 3 axes acceleration and temperature are calculated by the below equations.

g x=(AOX-Vref)/333mV [g] T=(Tout-Vref)/10mV+25 [℃]

g y=(AOY-Vref)/333mV [g]

g z=(AOZ-Vref)/333mV [g]

3) The recommended values of Cx, Cy, Cz, Ct and Cref are 0.01 to 0.1μF. In detail, the technical note No.2 shall be referred.

4) When Zero G detection not necessary, Pin No.19 must not be connected.

Table 2 General specifications

	Parameters	Conditions	Specifications			Units
			Min.	Typ.	Max.	
1	Operating Voltage Vcc	Temperature range −25℃ to +75℃	2.2	3	3.6	V
2	Current	Vcc=3.0V		0.58	0.85	mA
3	Stand by current	Vcc=3.0V、Temp.≦65℃			1	uA
4	Turn on time	Output level of 99% after standby changed to be high.	150×Cx, Cy, Cz(μF)			ms
5	Storage temp. range		−40		85	℃
6	Operating temp. range		−25		75	℃
7	Measurement range		−3		+3	g
8	Sensitivity	Operating voltage 3V and 25 ℃	318	333	348	mV/g
		Operating voltage 3V and 65 ℃	315	333	351	mV/g
		Operating voltage 3V and within operating temp. range	306		360	mV/g
9	Zero g voltage	Operating voltage 3V and 25 ℃	−15	0	15	mV
		Operating voltage 3V and 65 ℃	−18	0	18	mV
		Operating voltage 3V and within operating temp. range	−23		23	mV
10	Cross−axis sensitivity			2	6	%
11	Non−linearity		−2		+2	%
12	Frequency response	Cx,Cy,Cz=0.01uF ,−3dB	DC	500		Hz
13	Noise performance	BW =0.1 to 100Hz		0.6 1.8		mVrms mgrms
14	Shock durability	Pendulum type tester	5000			g
15	Accuracy of temp. sensor	within 0 to 75℃	−3		3	℃
16	Zero g threshold for free fall detection			0.4		g

Note 1) Above sensitivity and zero g voltage specifications are the initial data when those devices will be shipped out, and all specifications shall be changed without any notifications.
2) 1g=9.81m/s^2
3) Sensitivity and zero g voltage are defined as the difference between output voltage of each axis(AOX, AOY, AOZ) and reference voltage(Vref). Those voltages are proportional to Vcc because they are designed to be retiometric to Vcc.

Table 3 Absolute maximum ratings

Parameter	Rating	Unit
Operating voltage Vcc	-0.3 to +4.5	V
Each external terminal voltage	-0.3 to Vcc+0.3	V
Operating temp. range	-25 to +75	℃
Storage temp. range	-40 to +85	℃

Note: Stresses above those listed under Table 3 may cause permanent damage to the device.

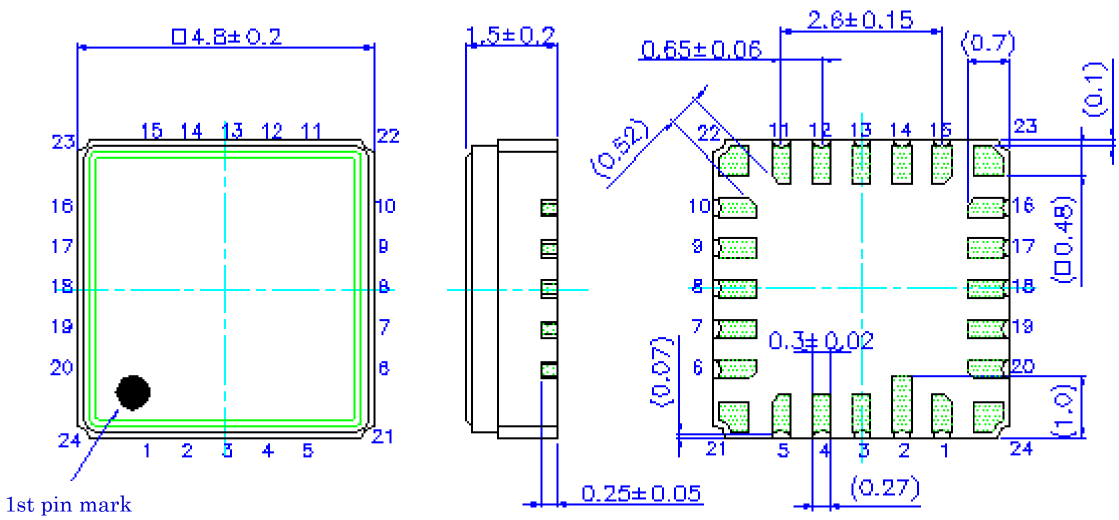


Fig. 3 Package dimensions

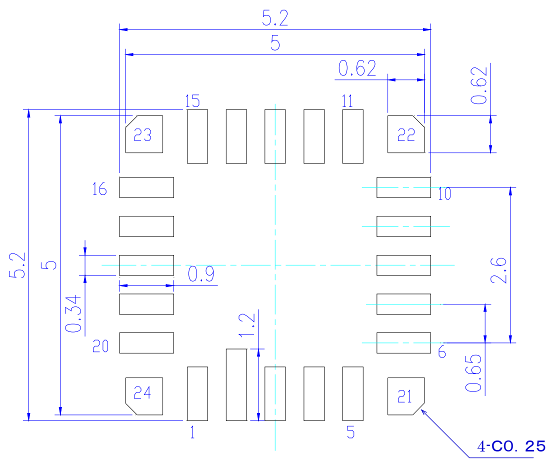


Fig. 4 Reference pattern of footprint for circuit board