

**Gambar A.1 Board Arduino**

The Arduino Uno is a microcontroller board based on the ATmega328 . It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.

The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converter.

"Uno" means one in Italian and is named to mark the upcoming release of Arduino 1.0. The Uno and version 1.0 will be the reference versions of Arduino, moving forward. The Uno is the latest in a series of USB Arduino boards, and the reference model for the Arduino platform; for a comparison with previous versions, see the [index of Arduino boards](#).

### Summary

|                             |  |
|-----------------------------|--|
| Microcontroller             | ATmega328  |
| Operating Voltage           | 5V   |
| Input Voltage (recommended) | 7-12V  |
| Input Voltage (limits)      | 6-20V  |
| Digital I/O Pins            | 14 (of which 6 provide PWM output)                   |
| Analog Input Pins           | 6  |
| DC Current per I/O Pin      | 40 mA  |
| DC Current for 3.3V Pin     | 50 mA  |
| Flash Memory                | 32 KB (ATmega328) of which 0.5 KB used by bootloader |
| SRAM                        | 2 KB (ATmega328)                                     |

|             |                  |
|-------------|------------------|
| EEPROM      | 1 KB (ATmega328) |
| Clock Speed | 16 MHz           |

## Schematic & Reference Design

EAGLE files: [arduino-uno-Rev3-reference-design.zip](#) (NOTE: works with Eagle 6.0 and newer)

Schematic: [arduino-uno-Rev3-schematic.pdf](#)

**Note:** The Arduino reference design can use an Atmega8, 168, or 328, Current models use an ATmega328, but an Atmega8 is shown in the schematic for reference. The pin configuration is identical on all three processors.

## Power

The Arduino Uno can be powered via the USB connection or with an external power supply. The power source is selected automatically.

External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the Gnd and Vin pin headers of the POWER connector.

The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts.

The power pins are as follows:

- **VIN.** The input voltage to the Arduino board when it's using an external power source (as opposed to 5 volts from the USB connection or other regulated power source). You can supply voltage through this pin, or, if supplying voltage via the power jack, access it through this pin.
- **5V.** This pin outputs a regulated 5V from the regulator on the board. The board can be supplied with power either from the DC power jack (7 - 12V), the USB connector (5V), or the VIN pin of the board (7-12V). Supplying voltage via the 5V or 3.3V pins bypasses the regulator, and can damage your board. We don't advise it.
- **3V3.** A 3.3 volt supply generated by the on-board regulator. Maximum current draw is 50 mA.
- **GND.** Ground pins.

## Memory

The ATmega328 has 32 KB (with 0.5 KB used for the bootloader). It also has 2 KB of SRAM and 1 KB of EEPROM (which can be read and written with the [EEPROM library](#)).

## Input and Output

Each of the 14 digital pins on the Uno can be used as an input or output, using `pinMode()`, `digitalWrite()`, and `digitalRead()` functions. They operate at 5 volts. Each pin can provide or receive a maximum of 40 mA and has an internal pull-up resistor (disconnected by default) of 20-50 kOhms. In addition, some pins have specialized functions:

- **Serial: 0 (RX) and 1 (TX).** Used to receive (RX) and transmit (TX) TTL serial data. These pins are connected to the corresponding pins of the ATmega8U2 USB-to-TTL Serial chip.
- **External Interrupts: 2 and 3.** These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value. See the `attachInterrupt()` function for details.
- **PWM: 3, 5, 6, 9, 10, and 11.** Provide 8-bit PWM output with the `analogWrite()` function.
- **SPI: 10 (SS), 11 (MOSI), 12 (MISO), 13 (SCK).** These pins support SPI communication using the `SPI` library.
- **LED: 13.** There is a built-in LED connected to digital pin 13. When the pin is HIGH value, the LED is on, when the pin is LOW, it's off.

The Uno has 6 analog inputs, labeled A0 through A5, each of which provide 10 bits of resolution (i.e. 1024 different values). By default they measure from ground to 5 volts, though is it possible to change the upper end of their range using the AREF pin and the `analogReference()` function. Additionally, some pins have specialized functionality:

- **TWI: A4 or SDA pin and A5 or SCL pin.** Support TWI communication using the `Wire` library.

There are a couple of other pins on the board:

- **AREF.** Reference voltage for the analog inputs. Used with `analogReference()`.
- **Reset.** Bring this line LOW to reset the microcontroller. Typically used to add a reset button to shields which block the one on the board.

See also the [mapping between Arduino pins and ATmega328 ports](#). The mapping for the Atmega8, 168, and 328 is identical.

## Communication

The Arduino Uno has a number of facilities for communicating with a computer, another Arduino, or other microcontrollers. The ATmega328 provides UART TTL (5V) serial communication, which is available on digital pins 0 (RX) and 1 (TX). An ATmega16U2 on the board channels this serial communication over USB and appears as a virtual com port to software on the computer. The '16U2 firmware uses the standard USB COM drivers, and no

external driver is needed. However, on Windows, a .inf file is required. The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the Arduino board. The RX and TX LEDs on the board will flash when data is being transmitted via the USB-to-serial chip and USB connection to the computer (but not for serial communication on pins 0 and 1).

A SoftwareSerial library allows for serial communication on any of the Uno's digital pins.

The ATmega328 also supports I2C (TWI) and SPI communication. The Arduino software includes a Wire library to simplify use of the I2C bus; see the documentation for details. For SPI communication, use the SPI library.

## Programming

The Arduino Uno can be programmed with the Arduino software (download). Select "Arduino Uno" from the **Tools > Board** menu (according to the microcontroller on your board). For details, see the reference and tutorials.

The ATmega328 on the Arduino Uno comes preburned with a bootloader that allows you to upload new code to it without the use of an external hardware programmer. It communicates using the original STK500 protocol (reference, C header files).

You can also bypass the bootloader and program the microcontroller through the ICSP (In-Circuit Serial Programming) header; see these instructions for details.

The ATmega16U2 (or 8U2 in the rev1 and rev2 boards) firmware source code is available. The ATmega16U2/8U2 is loaded with a DFU bootloader, which can be activated by:

- On Rev1 boards: connecting the solder jumper on the back of the board (near the map of Italy) and then resetting the 8U2.
- On Rev2 or later boards: there is a resistor that pulling the 8U2/16U2 HWB line to ground, making it easier to put into DFU mode.

You can then use Atmel's FLIP software (Windows) or the DFU programmer (Mac OS X and Linux) to load a new firmware. Or you can use the ISP header with an external programmer (overwriting the DFU bootloader). See this user-contributed tutorial for more information.

## Automatic (Software) Reset

Rather than requiring a physical press of the reset button before an upload, the Arduino Uno is designed in a way that allows it to be reset by software running on a connected computer. One of the hardware flow control lines (DTR) of the ATmega8U2/16U2 is connected to the reset line of the ATmega328 via a 100 nanofarad capacitor. When this line is asserted (taken low), the reset line drops long enough to reset the chip. The Arduino software uses this capability to allow you to upload code by simply pressing the upload button in the Arduino environment. This means that the bootloader can have a shorter timeout, as the lowering of DTR can be well-coordinated with the start of the upload.

This setup has other implications. When the Uno is connected to either a computer running Mac OS X or Linux, it resets each time a connection is made to it from software (via USB). For the following half-second or so, the bootloader is running on the Uno. While it is programmed to ignore malformed data (i.e. anything besides an upload of new code), it will intercept the first few bytes of data sent to the board after a connection is opened. If a sketch running on the board receives one-time configuration or other data when it first starts, make sure that the software with which it communicates waits a second after opening the connection and before sending this data.

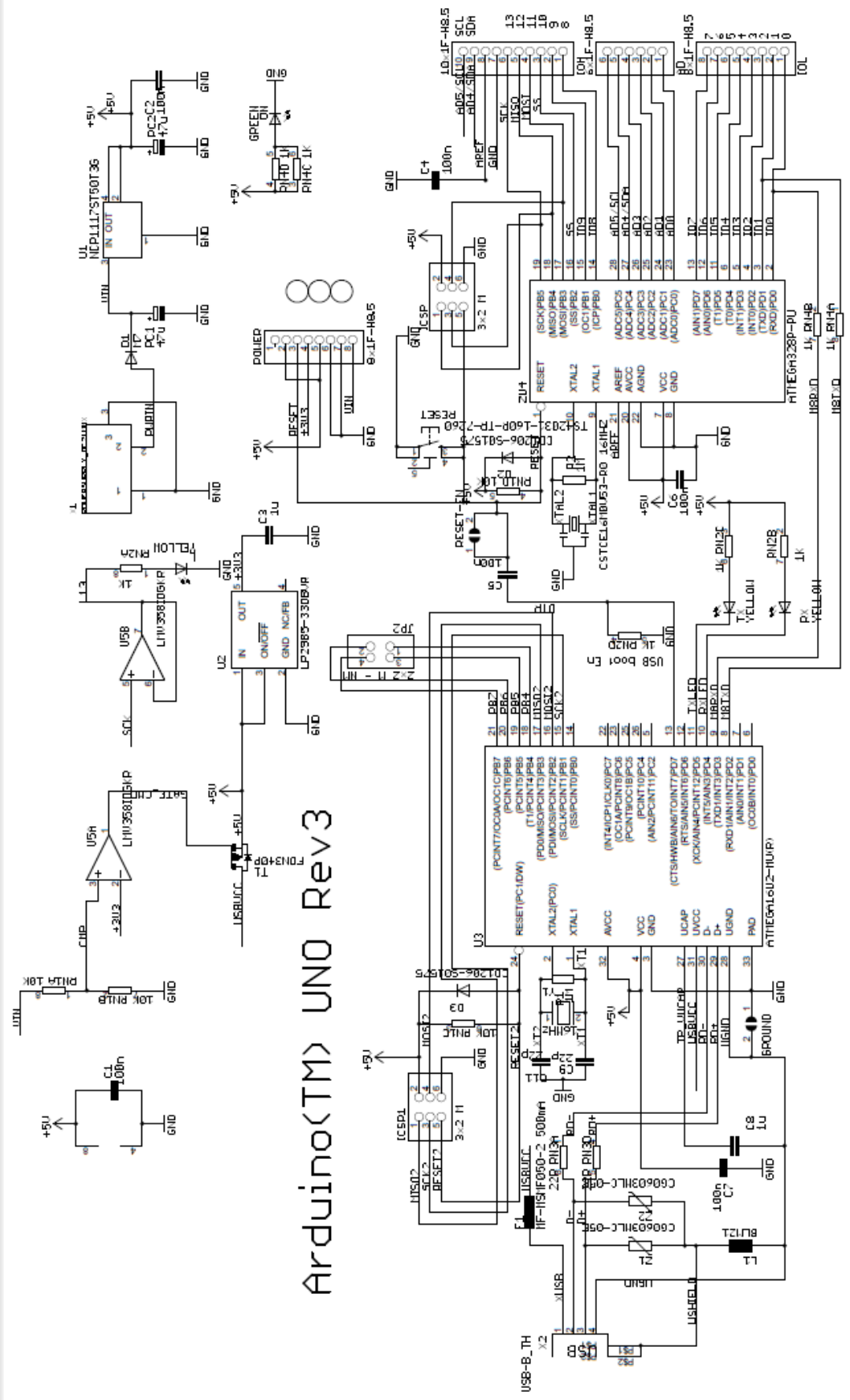
The Uno contains a trace that can be cut to disable the auto-reset. The pads on either side of the trace can be soldered together to re-enable it. It's labeled "RESET-EN". You may also be able to disable the auto-reset by connecting a 110 ohm resistor from 5V to the reset line; see [this forum thread](#) for details.

### **USB Overcurrent Protection**

The Arduino Uno has a resettable polyfuse that protects your computer's USB ports from shorts and overcurrent. Although most computers provide their own internal protection, the fuse provides an extra layer of protection. If more than 500 mA is applied to the USB port, the fuse will automatically break the connection until the short or overload is removed.

### **Physical Characteristics**

The maximum length and width of the Uno PCB are 2.7 and 2.1 inches respectively, with the USB connector and power jack extending beyond the former dimension. Four screw holes allow the board to be attached to a surface or case. Note that the distance between digital pins 7 and 8 is 160 mil (0.16"), not an even multiple of the 100 mil spacing of the other pins.



# Arduino(TM) UNO Rev3

## LAMPIRAN B

## AKSELEROMETER ADXL 345

### FEATURES

Ultralow power: as low as 23  $\mu\text{A}$  in measurement mode and 0.1  $\mu\text{A}$  in standby mode at  $V_S = 2.5$  V (typical) Power consumption scales automatically with bandwidth

User-selectable resolution

Fixed 10-bit resolution

Full resolution, where resolution increases with  $g$  range, up to 13-bit resolution at  $\pm 16 g$  (maintaining 4 mg/LSB scale factor in all  $g$  ranges)

Patent pending, embedded memory management system with FIFO technology minimizes host processor load

Single tap/double tap detection

Activity/inactivity monitoring

Free-fall detection

Supply voltage range: 2.0 V to 3.6 V

I/O voltage range: 1.7 V to  $V_S$  SPI (3- and 4-wire) and I2C digital interfaces

Flexible interrupt modes mappable to either interrupt pin

Measurement ranges selectable via serial command

Bandwidth selectable via serial command

Wide temperature range ( $-40^\circ\text{C}$  to  $+85^\circ\text{C}$ )

10,000  $g$  shock survival

Pb free/RoHS compliant

Small and thin: 3 mm  $\times$  5 mm  $\times$  1 mm LGA package

### APPLICATIONS

Handsets

Medical instrumentation

Gaming and pointing devices

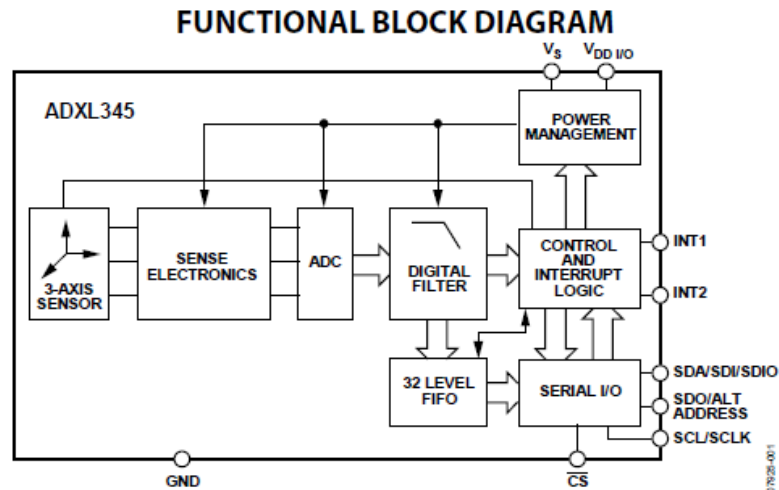
Industrial instrumentation

Personal navigation devices

Hard disk drive (HDD) protection

## GENERAL DESCRIPTION

The ADXL345 is a small, thin, ultralow power, 3-axis accelerometer with high resolution (13-bit) measurement at up to  $\pm 16$  g. Digital output data is formatted as 16-bit two's complement and is accessible through either a SPI (3- or 4-wire) or I<sup>2</sup>C digital interface. The ADXL345 is well suited for mobile device applications. It measures the static acceleration of gravity in tilt-sensing applications, as well as dynamic acceleration resulting from motion or shock. Its high resolution (3.9 mg/LSB) enables measurement of inclination changes less than  $1.0^\circ$ . Several special sensing functions are provided. Activity and inactivity sensing detect the presence or lack of motion by comparing the acceleration on any axis with user-set thresholds. Tap sensing detects single and double taps in any direction. Free-fall sensing detects if the device is falling. These functions can be mapped individually to either of two interrupt output pins. An integrated, patent pending memory management system with a 32-level first in, first out (FIFO) buffer can be used to store data to minimize host processor activity and lower overall system power consumption. Low power modes enable intelligent motion-based power management with threshold sensing and active acceleration measurement at extremely low power dissipation. The ADXL345 is supplied in a small, thin, 3 mm  $\times$  5 mm  $\times$  1 mm, 14-lead, plastic package.



## SPECIFICATIONS

$T_A = 25^\circ\text{C}$ ,  $V_S = 2.5\text{ V}$ ,  $V_{DD\ I/O} = 1.8\text{ V}$ , acceleration = 0 g,  $C_S = 10\text{ }\mu\text{F}$  tantalum,  $C_{I/O} = 0.1\text{ }\mu\text{F}$ , output data rate (ODR) = 800 Hz, unless otherwise noted. All minimum and maximum specifications are guaranteed. Typical specifications are not guaranteed.

| Table 1. Parameter  | Test Conditions   | Min             | Typ <sup>1</sup> | Max  | Unit          |
|---|---|-----------------|------------------|------|---------------|
| SENSOR INPUT  | Each axis   |                 |                  |      |               |
| Measurement Range   | User selectable   | ±2, ±4, ±8, ±16 |                  |      | <i>g</i>      |
| Nonlinearity  | Percentage of full scale  | ±0.5            |                  |      | %             |
| Inter-Axis Alignment Error  |   | ±0.1            |                  |      | Degrees       |
| Cross-Axis Sensitivity <sup>2</sup>   |   | ±1              |                  |      | %             |
| OUTPUT RESOLUTION   | Each axis   |                 |                  |      |               |
| All <i>g</i> Ranges   | 10-bit resolution   | 10              |                  |      | Bits          |
| ±2 <i>g</i> Range   | Full resolution   | 10              |                  |      | Bits          |
| ±4 <i>g</i> Range   | Full resolution   | 11              |                  |      | Bits          |
| ±8 <i>g</i> Range   | Full resolution   | 12              |                  |      | Bits          |
| ±16 <i>g</i> Range  | Full resolution   | 13              |                  |      | Bits          |
| SENSITIVITY   | Each axis   |                 |                  |      |               |
| Sensitivity at X <sub>OUT</sub> , Y <sub>OUT</sub> , Z <sub>OUT</sub>       | All <i>g</i> -ranges, full resolution   | 230             | 256              | 282  | LSB/ <i>g</i> |
|   | ±2 <i>g</i> , 10-bit resolution   | 230             | 256              | 282  | LSB/ <i>g</i> |
|   | ±4 <i>g</i> , 10-bit resolution   | 115             | 128              | 141  | LSB/ <i>g</i> |
|   | ±8 <i>g</i> , 10-bit resolution   | 57              | 64               | 71   | LSB/ <i>g</i> |
|   | ±16 <i>g</i> , 10-bit resolution  | 29              | 32               | 35   | LSB/ <i>g</i> |
| Sensitivity Deviation from Ideal  | All <i>g</i> -ranges  | ±1.0            |                  |      | %             |
| Scale Factor at X <sub>OUT</sub> , Y <sub>OUT</sub> , Z <sub>OUT</sub>      | All <i>g</i> -ranges, full resolution   | 3.5             | 3.9              | 4.3  | mg/LSB        |
|   | ±2 <i>g</i> , 10-bit resolution   | 3.5             | 3.9              | 4.3  | mg/LSB        |
|   | ±4 <i>g</i> , 10-bit resolution   | 7.1             | 7.8              | 8.7  | mg/LSB        |
|   | ±8 <i>g</i> , 10-bit resolution   | 14.1            | 15.6             | 17.5 | mg/LSB        |
|   | ±16 <i>g</i> , 10-bit resolution  | 28.6            | 31.2             | 34.5 | mg/LSB        |
| Sensitivity Change Due to Temperature                                       |   | ±0.01           |                  |      | %/°C          |
| 0 <i>g</i> OFFSET   | Each axis   |                 |                  |      |               |
| 0 <i>g</i> Output for X <sub>OUT</sub> , Y <sub>OUT</sub>                   |   | −150            | 0                | +150 | mg            |
| 0 <i>g</i> Output for Z <sub>OUT</sub>                                      |   | −250            | 0                | +250 | mg            |
| 0 <i>g</i> Output Deviation from Ideal, X <sub>OUT</sub> , Y <sub>OUT</sub> |   | ±35             |                  |      | mg            |
| 0 <i>g</i> Output Deviation from Ideal, Z <sub>OUT</sub>                    |   | ±40             |                  |      | mg            |
| 0 <i>g</i> Offset vs. Temperature for X-, Y-Axes                            |   | ±0.4            |                  |      | mg/°C         |
| 0 <i>g</i> Offset vs. Temperature for Z-Axis                                |   | ±1.2            |                  |      | mg/°C         |
| NOISE   |   |                 |                  |      |               |
| X-, Y-Axes  | ODR = 100 Hz for ±2 <i>g</i> , 10-bit resolution or all <i>g</i> -ranges, full resolution | 0.75            |                  |      | LSB rms       |
| Z-Axis  | ODR = 100 Hz for ±2 <i>g</i> , 10-bit resolution or all <i>g</i> -ranges, full resolution | 1.1             |                  |      | LSB rms       |
| OUTPUT DATA RATE AND BANDWIDTH  | User selectable   |                 |                  |      |               |
| Output Data Rate (ODR) <sup>3, 4, 5</sup>                                   |   | 0.1             |                  | 3200 | Hz            |
| SELF-TEST <sup>6</sup>  |   |                 |                  |      |               |
| Output Change in X-Axis   |   | 0.20            |                  | 2.10 | <i>g</i>      |

|  |               |       |       |                |    |
|--|---------------|-------|-------|----------------|----|
| Output Change in Y-Axis                        |               | −2.10 | −0.20 | <i>g</i>       |    |
| Output Change in Z-Axis                        |               | 0.30  | 3.40  | <i>g</i>       |    |
| POWER SUPPLY                                   |               |       |       |                |    |
| Operating Voltage Range (V <sub>S</sub> )      |               | 2.0   | 2.5   | 3.6            | V  |
| Interface Voltage Range (V <sub>DD I/O</sub> ) |               | 1.7   | 1.8   | V <sub>S</sub> | V  |
| Supply Current                                 | ODR ≥ 100 Hz  | 140   |       |                | μA |
|  | ODR < 10 Hz   | 30    |       |                | μA |
| Standby Mode Leakage Current                   |               | 0.1   |       |                | μA |
| Turn-On and Wake-Up Time <sup>7</sup>          | ODR = 3200 Hz | 1.4   |       |                | ms |
| TEMPERATURE                                    |               |       |       |                |    |
| Operating Temperature Range                    |               | −40   | +85   |                | °C |
| WEIGHT   |               |       |       |                |    |
| Device Weight                                  |               | 30    |       |                | mg |

<sup>1</sup> The typical specifications shown are for at least 68% of the population of parts and are based on the worst case of mean  $\pm 1 \sigma$ , except for 0 *g* output and sensitivity, which represents the target value. For 0 *g* offset and sensitivity, the deviation from the ideal describes the worst case of mean  $\pm 1 \sigma$ .

<sup>2</sup> Cross-axis sensitivity is defined as coupling between any two axes.

<sup>3</sup> Bandwidth is the –3 dB frequency and is half the output data rate, bandwidth = ODR/2.

<sup>4</sup> The output format for the 3200 Hz and 1600 Hz ODRs is different than the output format for the remaining ODRs. This difference is described in the Data Formatting of Upper Data Rates section.

<sup>5</sup> Output data rates below 6.25 Hz exhibit additional offset shift with increased temperature, depending on selected output data rate. Refer to the Offset Performance at Lowest Data Rates section for details.

<sup>6</sup> Self-test change is defined as the output (*g*) when the SELF\_TEST bit = 1 (in the DATA\_FORMAT register, Address 0x31) minus the output (*g*) when the SELF\_TEST bit = 0. Due to device filtering, the output reaches its final value after  $4 \times \tau$  when enabling or disabling self-test, where  $\tau = 1/(\text{data rate})$ . The part must be in normal power operation (LOW\_POWER bit = 0 in the BW\_RATE register, Address 0x2C) for self-test to operate correctly.

<sup>7</sup> Turn-on and wake-up times are determined by the user-defined bandwidth. At a 100 Hz data rate, the turn-on and wake-up times are each approximately 11.1 ms. For other data rates, the turn-on and wake-up times are each approximately  $\tau + 1.1$  in milliseconds, where  $\tau = 1/(\text{data rate})$ .

## ABSOLUTE MAXIMUM RATINGS

| Table 2. Parameter                                | Rating   |
|---|--|
| Acceleration                                      |  |
| Any Axis, Unpowered                               | 10,000 <i>g</i>  |
| Any Axis, Powered                                 | 10,000 <i>g</i>  |
| $V_S$   | –0.3 V to +3.9 V   |
| $V_{DD I/O}$                                      | –0.3 V to +3.9 V   |
| Digital Pins                                      | –0.3 V to $V_{DD I/O} + 0.3$ V or 3.9 V, whichever is less |
| All Other Pins                                    | –0.3 V to +3.9 V   |
| Output Short-Circuit Duration (Any Pin to Ground) | Indefinite   |
| Temperature Range                                 |  |
| Powered   | –40°C to +105°C  |
| Storage   | –40°C to +105°C  |

Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only; functional operation of the device at these or any other conditions above those indicated in the operational section of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

## THERMAL RESISTANCE

| Table 3. Package Characteristics | Package Type | $\theta_{JA}$ | $\theta_{JC}$ | Device Weight |
|----------------------------------|--------------|---------------|---------------|---------------|
|----------------------------------|--------------|---------------|---------------|---------------|

|                 |         |        |       |
|-----------------|---------|--------|-------|
| 14-Terminal LGA | 150°C/W | 85°C/W | 30 mg |
|-----------------|---------|--------|-------|

**PACKAGE INFORMATION**

The information in Figure 2 and Table 4 provide details about the package branding for the ADXL345. For a complete listing of product availability, see the Ordering Guide section.

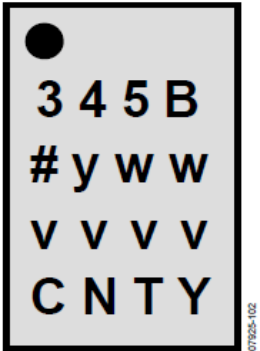


Figure 2. Product Information on Package (Top View)

| Table 4. Package Branding Information Branding Key | Field Description           |
|--|-----------------------------|
| 345B   | Part identifier for ADXL345 |
| #  | RoHS-compliant designation  |
| yww  | Date code                   |
| vvvv   | Factory lot code            |
| CNTY   | Country of origin           |

**ESD CAUTION**

|  |   |
|--|---|
|  | <p><b>ESD (electrostatic discharge) sensitive device.</b> Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.</p> |
|--|---|

## PIN CONFIGURATION AND FUNCTION DESCRIPTIONS

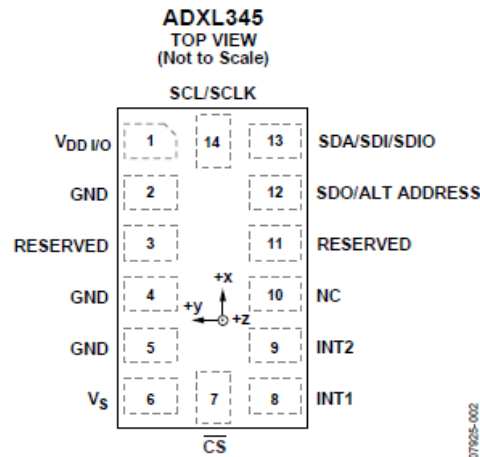


Figure 3. Pin Configuration (Top View)

Table 5. Pin Function Descriptions

| Pin No. | Mnemonic        | Description  |
|---------|-----------------|--|
| 1       | VDD I/O         | Digital Interface Supply Voltage.  |
| 2       | GND             | This pin must be connected to ground.  |
| 3       | RESERVED        | Reserved. This pin must be connected to VS or left open.   |
| 4       | GND             | This pin must be connected to ground.  |
| 5       | GND             | This pin must be connected to ground.  |
| 6       | VS              | Supply Voltage.  |
| 7       | CS              | Chip Select.   |
| 8       | INT1            | Interrupt 1 Output.  |
| 9       | INT2            | Interrupt 2 Output.  |
| 10      | NC              | Not Internally Connected.  |
| 11      | RESERVED        | Reserved. This pin must be connected to ground or left open.   |
| 12      | SDO/ALT ADDRESS | Serial Data Output (SPI 4-Wire)/Alternate I <sup>2</sup> C Address Select (I <sup>2</sup> C).            |
| 13      | SDA/SDI/SDIO    | Serial Data (I <sup>2</sup> C)/Serial Data Input (SPI 4-Wire)/Serial Data Input and Output (SPI 3-Wire). |
| 14      | SCL/SCLK        | Serial Communications Clock. SCL is the clock for I <sup>2</sup> C, and SCLK is the clock for SPI.       |

## THEORY OF OPERATION

The ADXL345 is a complete 3-axis acceleration measurement system with a selectable measurement range of  $\pm 2g$ ,  $\pm 4g$ ,  $\pm 8g$ , or  $\pm 16g$ . It measures both dynamic acceleration resulting from motion or shock and static acceleration, such as gravity, that allows the device to be used as a tilt sensor.

The sensor is a polysilicon surface-micromachined structure built on top of a silicon wafer. Polysilicon springs suspend the structure over the surface of the wafer and provide a resistance against forces due to applied acceleration.

Deflection of the structure is measured using differential capacitors that consist of independent fixed plates and plates attached to the moving mass. Acceleration deflects the proof mass and unbalances the differential capacitor, resulting in a sensor output whose amplitude is proportional to acceleration. Phase-sensitive demodulation is used to determine the magnitude and polarity of the acceleration.

## POWER SEQUENCING

Power can be applied to  $V_S$  or  $V_{DD\ I/O}$  in any sequence without damaging the ADXL345. All possible power-on modes are summarized in Table 6. The interface voltage level is set with the interface supply voltage,  $V_{DD\ I/O}$ , which must be present to ensure that the ADXL345 does not create a conflict on the communication bus. For single-supply operation,  $V_{DD\ I/O}$  can be the same as the main supply,  $V_S$ . In a dual-supply application, however,  $V_{DD\ I/O}$  can differ from  $V_S$  to accommodate the desired interface voltage, as long as  $V_S$  is greater than or equal to  $V_{DD\ I/O}$ .

After  $V_S$  is applied, the device enters standby mode, where power consumption is minimized and the device waits for  $V_{DD\ I/O}$  to be applied and for the command to enter measurement mode to be received. (This command can be initiated by setting the measure bit (Bit D3) in the POWER\_CTL register (Address 0x2D).) In addition, while the device is in standby mode, any register can be written to or read from to configure the part. It is recommended to configure the device in standby mode and then to enable measurement mode. Clearing the measure bit returns the device to the standby mode.

Table 6. Power Sequencing

| Condition              | $V_S$ | $V_{DD\ I/O}$ | Description   |
|------------------------|-------|---------------|---|
| Power Off              | Off   | Off           | The device is completely off, but there is a potential for a communication bus conflict.  |
| Bus Disabled           | On    | Off           | The device is on in standby mode, but communication is unavailable and creates a conflict on the communication bus. The duration of this state should be minimized during power-up to prevent a conflict.                 |
| Bus Enabled            | Off   | On            | No functions are available, but the device does not create a conflict on the communication bus.   |
| Standby or Measurement | On    | On            | At power-up, the device is in standby mode, awaiting a command to enter measurement mode, and all sensor functions are off. After the device is instructed to enter measurement mode, all sensor functions are available. |

## POWER SAVINGS

### Power Modes

The ADXL345 automatically modulates its power consumption in proportion to its output data rate, as outlined in Table 7. If additional power savings is desired, a lower power mode is available. In this mode, the internal sampling rate is reduced, allowing for power savings in the 12.5 Hz to 400 Hz data rate range at the expense of slightly greater noise. To enter low power mode, set the LOW\_POWER bit (Bit 4) in the BW\_RATE register (Address 0x2C). The current consumption in low power mode is shown in Table 8 for cases where there is an advantage to using low power mode. Use of low power mode for a data rate not shown in Table 8 does not provide any advantage over the same data rate in normal power mode. Therefore, it is recommended that only data rates shown in Table 8 are used in low power mode. The current consumption values shown in Table 7 and Table 8 are for a  $V_S$  of 2.5 V.

Table 7. Typical Current Consumption vs. Data Rate  
( $T_A = 25^\circ\text{C}$ ,  $V_S = 2.5\text{ V}$ ,  $V_{DD\ I/O} = 1.8\text{ V}$ )

| Output Data Rate (Hz) | Bandwidth (Hz) | Rate Code | $I_{DD}$ ( $\mu\text{A}$ ) |
|-----------------------|----------------|-----------|----------------------------|
| 3200                  | 1600           | 1111      | 140                        |
| 1600                  | 800            | 1110      | 90                         |
| 800                   | 400            | 1101      | 140                        |
| 400                   | 200            | 1100      | 140                        |
| 200                   | 100            | 1011      | 140                        |
| 100                   | 50             | 1010      | 140                        |
| 50                    | 25             | 1001      | 90                         |
| 25                    | 12.5           | 1000      | 60                         |
| 12.5                  | 6.25           | 0111      | 50                         |
| 6.25                  | 3.13           | 0110      | 45                         |
| 3.13                  | 1.56           | 0101      | 40                         |
| 1.56                  | 0.78           | 0100      | 34                         |
| 0.78                  | 0.39           | 0011      | 23                         |
| 0.39                  | 0.20           | 0010      | 23                         |
| 0.20                  | 0.10           | 0001      | 23                         |
| 0.10                  | 0.05           | 0000      | 23                         |

Table 8. Typical Current Consumption vs. Data Rate,  
Low Power Mode ( $T_A = 25^\circ\text{C}$ ,  $V_S = 2.5\text{ V}$ ,  $V_{DD\ I/O} = 1.8\text{ V}$ )

| Output Data Rate (Hz) | Bandwidth (Hz) | Rate Code | $I_{DD}$ ( $\mu\text{A}$ ) |
|-----------------------|----------------|-----------|----------------------------|
| 400                   | 200            | 1100      | 90                         |
| 200                   | 100            | 1011      | 60                         |
| 100                   | 50             | 1010      | 50                         |
| 50                    | 25             | 1001      | 45                         |
| 25                    | 12.5           | 1000      | 40                         |
| 12.5                  | 6.25           | 0111      | 34                         |

### Auto Sleep Mode

Additional power can be saved if the ADXL345 automatically switches to sleep mode during periods of inactivity. To enable this feature, set the THRESH\_INACT register (Address 0x25) and the TIME\_INACT register (Address 0x26) each to a value that signifies inactivity (the appropriate value depends on the application), and then set the AUTO\_SLEEP bit (Bit D4) and the link bit (Bit D5) in the POWER\_CTL register (Address 0x2D). Current consumption at the sub-12.5 Hz data rates that are used in this mode is typically 23  $\mu$ A for a  $V_S$  of 2.5 V.

### Standby Mode

For even lower power operation, standby mode can be used. In standby mode, current consumption is reduced to 0.1  $\mu$ A (typical). In this mode, no measurements are made. Standby mode is entered by clearing the measure bit (Bit D3) in the POWER\_CTL register (Address 0x2D). Placing the device into standby mode preserves the contents of FIFO.

## SERIAL COMMUNICATIONS

I<sup>2</sup>C and SPI digital communications are available. In both cases, the ADXL345 operates as a slave. I<sup>2</sup>C mode is enabled if the pin is tied high to  $V_{DD\ I/O}$ . The CS pin is left unconnected. Therefore, not taking these precautions may result in an inability to communicate with the part. In SPI mode, the pin should always be tied high to  $V_{DD\ I/O}$  or be driven by an external controller because there is no default mode if the CS pin is controlled by the bus master. In both SPI and I<sup>2</sup>C modes of operation, data transmitted from the ADXL345 to the master device should be ignored during writes to the ADXL345.

### I<sup>2</sup>C

With tied high to  $V_{DD\ I/O}$ , the ADXL345 is in I<sup>2</sup>C mode, requiring a simple 2-wire connection, as shown in . The ADXL345 conforms to the *UM10204 I<sup>2</sup>C-Bus Specification and User Manual*, Rev. 03—19 June 2007, available from NXP Semiconductor. It supports standard (100 kHz) and fast (400 kHz) data transfer modes if the bus parameters given in and are met. Single- or multiple-byte reads/writes are supported, as shown in . With the ALT ADDRESS pin high, the 7-bit I<sup>2</sup>C address for the device is 0x1D, followed by the R/ (Figure 40 Table 11 Table 12 Figure 41 CS W W bit) can be chosen by grounding the ALT ADDRESS pin (Pin 12). This translates to 0xA6 for a write and 0xA7 for a read. bit. This translates to 0x3A for a write and 0x3B for a read. An alternate I<sup>2</sup>C address of 0x53 (followed by the R/ There are no internal pull-up or pull-down resistors for any unused pins; therefore, there is no known state or default state for the or ALT ADDRESS pin if left floating or unconnected. It is required that the CS pin be connected to  $V_{DD\ I/O}$  and that the ALT ADDRESS pin be connected to either  $V_{DD\ I/O}$  or GND when using I<sup>2</sup>C.

Due to communication speed limitations, the maximum output data rate when using 400 kHz I<sup>2</sup>C is 800 Hz and scales linearly with a change in the I<sup>2</sup>C communication speed. For example, using I<sup>2</sup>C at 100 kHz would limit the maximum ODR to 200 Hz. Operation at an output data rate above the recommended maximum may result in undesirable effect on the acceleration data, including missing samples or additional noise.

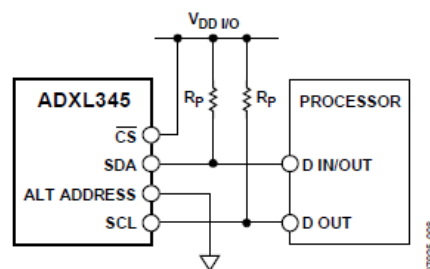


Figure 40. I<sup>2</sup>C Connection Diagram (Address 0x53)

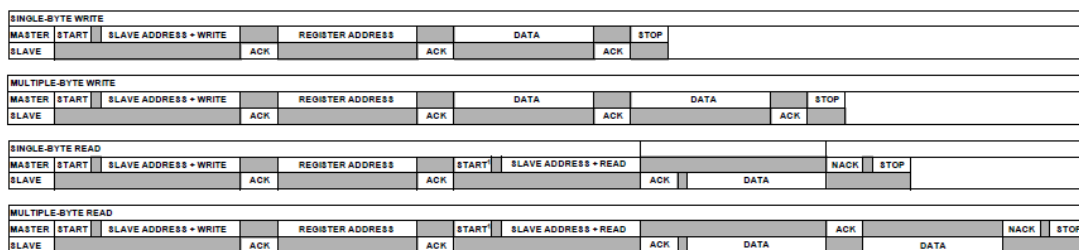
If other devices are connected to the same I<sup>2</sup>C bus, the nominal operating voltage level of these other devices cannot exceed  $V_{DD\ I/O}$  by more than 0.3 V. External pull-up resistors,  $R_P$ , are necessary for

proper I<sup>2</sup>C operation. Refer to the *UM10204 I<sup>2</sup>C-Bus Specification and User Manual*, Rev. 03—19 June 2007, when selecting pull-up resistor values to ensure proper operation.

Table 11. I<sup>2</sup>C Digital Input/Output

| Parameter                                   | Test Conditions                                   | Limit <sup>1</sup>       |                          | Unit |
|---|---|--------------------------|--------------------------|------|
|   |   | Min                      | Max                      |      |
| Digital Input                               |   |                          |                          |      |
| Low Level Input Voltage (V <sub>IL</sub> )  |   |                          | $0.3 \times V_{DD\ I/O}$ | V    |
| High Level Input Voltage (V <sub>IH</sub> ) |   | $0.7 \times V_{DD\ I/O}$ |                          | V    |
| Low Level Input Current (I <sub>IL</sub> )  | V <sub>IN</sub> = V <sub>DD I/O</sub>             |                          | 0.1                      | μA   |
| High Level Input Current (I <sub>IH</sub> ) | V <sub>IN</sub> = 0 V                             | −0.1                     |                          | μA   |
| Digital Output                              |   |                          |                          |      |
| Low Level Output Voltage (V <sub>OL</sub> ) | V <sub>DD I/O</sub> < 2 V, I <sub>OL</sub> = 3 mA |                          | $0.2 \times V_{DD\ I/O}$ | V    |
|   | V <sub>DD I/O</sub> ≥ 2 V, I <sub>OL</sub> = 3 mA |                          | 400                      | mV   |
| Low Level Output Current (I <sub>OL</sub> ) | V <sub>OL</sub> = V <sub>OL, max</sub>            | 3                        |                          | mA   |
| Pin Capacitance                             | f <sub>IN</sub> = 1 MHz, V <sub>IN</sub> = 2.5 V  |                          | 8                        | pF   |

<sup>1</sup> Limits based on characterization results; not production tested.



NOTES

1. THIS START IS EITHER A RESTART OR A STOP FOLLOWED BY A START.
2. THE SHADED AREAS REPRESENT WHEN THE DEVICE IS LISTENING.

Figure 41. I<sup>2</sup>C Device Addressing

07925-003

Table 12. I<sup>2</sup>C Timing ( $T_A = 25^\circ\text{C}$ ,  $V_S = 2.5\text{ V}$ ,  $V_{DDIO} = 1.8\text{ V}$ )

| Parameter          | Limit <sup>1, 2</sup> |     | Unit          | Description   |
|--------------------|-----------------------|-----|---------------|---|
|                    | Min                   | Max |               |   |
| $f_{\text{SCL}}$   |                       | 400 | kHz           | SCL clock frequency   |
| $t_1$              | 2.5                   |     | $\mu\text{s}$ | SCL cycle time  |
| $t_2$              | 0.6                   |     | $\mu\text{s}$ | $t_{\text{HIGH}}$ , SCL high time   |
| $t_3$              | 1.3                   |     | $\mu\text{s}$ | $t_{\text{LOW}}$ , SCL low time   |
| $t_4$              | 0.6                   |     | $\mu\text{s}$ | $t_{\text{HD, STA}}$ , start/repeated start condition hold time                 |
| $t_5$              | 100                   |     | ns            | $t_{\text{SU, DAT}}$ , data setup time  |
| $t_6^{3, 4, 5, 6}$ | 0                     | 0.9 | $\mu\text{s}$ | $t_{\text{HD, DAT}}$ , data hold time   |
| $t_7$              | 0.6                   |     | $\mu\text{s}$ | $t_{\text{SU, STA}}$ , setup time for repeated start                            |
| $t_8$              | 0.6                   |     | $\mu\text{s}$ | $t_{\text{SU, STO}}$ , stop condition setup time                                |
| $t_9$              | 1.3                   |     | $\mu\text{s}$ | $t_{\text{BUF}}$ , bus-free time between a stop condition and a start condition |
| $t_{10}$           |                       | 300 | ns            | $t_R$ , rise time of both SCL and SDA when receiving                            |
|                    | 0                     |     | ns            | $t_R$ , rise time of both SCL and SDA when receiving or transmitting            |
| $t_{11}$           |                       | 300 | ns            | $t_F$ , fall time of SDA when receiving   |
|                    |                       | 250 | ns            | $t_F$ , fall time of both SCL and SDA when transmitting                         |
| $C_b$              |                       | 400 | pF            | Capacitive load for each bus line   |

<sup>1</sup> Limits based on characterization results, with  $f_{\text{SCL}} = 400\text{ kHz}$  and a 3 mA sink current; not production tested.

<sup>2</sup> All values referred to the  $V_{\text{IH}}$  and the  $V_{\text{IL}}$  levels given in Table 11.

<sup>3</sup>  $t_6$  is the data hold time that is measured from the falling edge of SCL. It applies to data in transmission and acknowledge.

<sup>4</sup> A transmitting device must internally provide an output hold time of at least 300 ns for the SDA signal (with respect to  $V_{\text{IL(min)}}$  of the SCL signal) to bridge the undefined region of the falling edge of SCL.

<sup>5</sup> The maximum  $t_6$  value must be met only if the device does not stretch the low period ( $t_3$ ) of the SCL signal.

<sup>6</sup> The maximum value for  $t_6$  is a function of the clock low time ( $t_3$ ), the clock rise time ( $t_{10}$ ), and the minimum data setup time ( $t_{5(\text{min})}$ ). This value is calculated as  $t_{6(\text{max})} = t_3 - t_{10} - t_{5(\text{min})}$ .

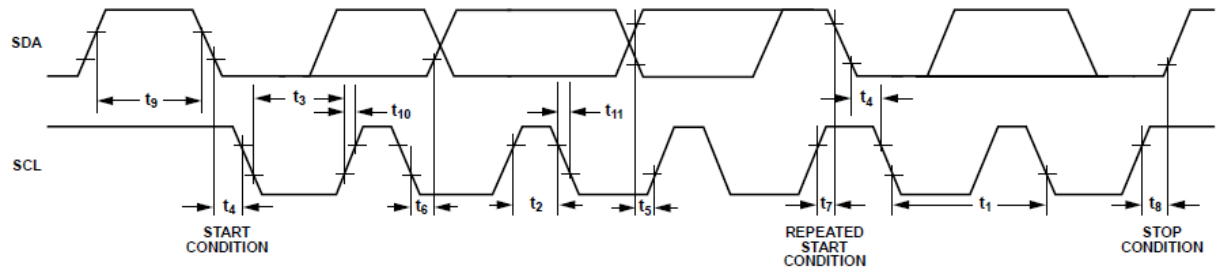


Figure 42. I<sup>2</sup>C Timing Diagram

## MECHANICAL CONSIDERATIONS FOR MOUNTING

The ADXL345 should be mounted on the PCB in a location close to a hard mounting point of the PCB to the case. Mounting the ADXL345 at an unsupported PCB location, as shown in Figure 45, may result in large, apparent measurement errors due to undamped PCB vibration. Locating the accelerometer near a hard mounting point ensures that any PCB vibration at the accelerometer is above the accelerometer's mechanical sensor resonant frequency and, therefore, effectively invisible to the accelerometer. Multiple mounting points, close to the sensor, and/or a thicker PCB also help to reduce the effect of system resonance on the performance of the sensor.

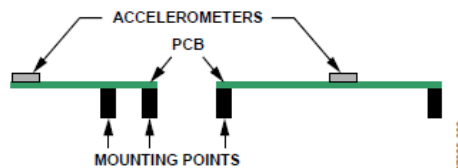


Figure 45. Incorrectly Placed Accelerometers

## AXES OF ACCELERATION SENSITIVITY

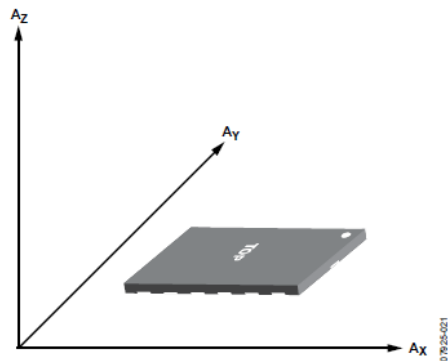


Figure 57. Axes of Acceleration Sensitivity (Corresponding Output Voltage Increases When Accelerated Along the Sensitive Axis)

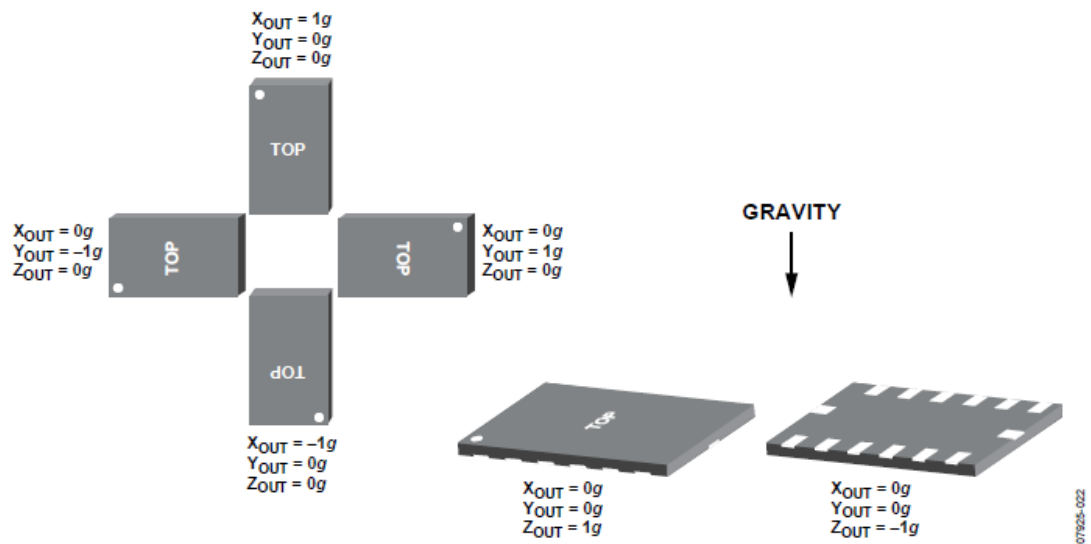


Figure 58. Output Response vs. Orientation to Gravity

## LAMPIRAN C

## MAGNETOMETER - HMC5883L

The Honeywell HMC5883L is a surface-mount, multi-chip module designed for low-field magnetic sensing with a digital interface for applications such as low-cost compassing and magnetometry. The HMC5883L includes our state-of-the-art, high-resolution HMC118X series magneto-resistive sensors plus an ASIC containing amplification, automatic degaussing strap drivers, offset cancellation, and a 12-bit ADC that enables 1° to 2° compass heading accuracy. The I2C serial bus allows for easy interface. The HMC5883L is a 3.0x3.0x0.9mm surface mount 16-pin leadless chip carrier (LCC). Applications for the HMC5883L include Mobile Phones, Netbooks, Consumer Electronics, Auto Navigation Systems, and Personal Navigation Devices.

The HMC5883L utilizes Honeywell's Anisotropic Magnetoresistive (AMR) technology that provides advantages over other magnetic sensor technologies. These anisotropic, directional sensors feature precision in-axis sensitivity and linearity. These sensors' solid-state construction with very low cross-axis sensitivity is designed to measure both the direction and the magnitude of Earth's magnetic fields, from milli-gauss to 8 gauss. Honeywell's Magnetic Sensors are among the most sensitive and reliable low-field sensors in the industry.

| FEATURES   | BENEFITS   |
|--|--|
| ▶ Three-Axis Magnetoresistive Sensors and ASIC in a 3.0x3.0x0.9mm LCC Surface Mount Package          | ▶ Small Size for Highly Integrated Products. Just Add a Micro-Controller Interface, Plus Two External SMT Capacitors Designed for High Volume, Cost Sensitive OEM Designs Easy to Assemble & Compatible with High Speed SMT Assembly |
| ▶ 12-Bit ADC Coupled with Low Noise AMR Sensors Achieves 5 milli-gauss Resolution in ±8 Gauss Fields | ▶ Enables 1° to 2° Degree Compass Heading Accuracy   |
| ▶ Built-In Self Test   | ▶ Enables Low-Cost Functionality Test after Assembly in Production   |
| ▶ Low Voltage Operations (2.16 to 3.6V) and Low Power Consumption (100 µA)                           | ▶ Compatible for Battery Powered Applications  |
| ▶ Built-In Strap Drive Circuits  | ▶ Set/Reset and Offset Strap Drivers for Degaussing, Self Test, and Offset Compensation  |
| ▶ I <sup>2</sup> C Digital Interface   | ▶ Popular Two-Wire Serial Data Interface for Consumer Electronics  |
| ▶ Lead Free Package Construction   | ▶ RoHS Compliance  |
| ▶ Wide Magnetic Field Range (+/-8 Oe)  | ▶ Sensors Can Be Used in Strong Magnetic Field Environments with a 1° to 2° Degree Compass Heading Accuracy  |
| ▶ Software and Algorithm Support Available   | ▶ Compassing Heading, Hard Iron, Soft Iron, and Auto Calibration Libraries Available   |
| ▶ Fast 160 Hz Maximum Output Rate  | ▶ Enables Pedestrian Navigation and LBS Applications   |

**SPECIFICATIONS** (\* Tested and specified at 25°C except stated otherwise.)

| Characteristics             | Conditions*  | Min  | Typ            | Max     | Units       |
|-----------------------------|--|------|----------------|---------|-------------|
| <b>Power Supply</b>         |  |      |                |         |             |
| Supply Voltage              | VDD Referenced to AGND   | 2.16 |                | 3.6     | Volts       |
|                             | VDDIO Referenced to DGND   | 1.71 | 1.8            | VDD+0.1 | Volts       |
| Average Current Draw        | Idle Mode  | -    | 2              | 6       | µA          |
|                             | Measurement Mode (7.5 Hz ODR;<br>No measurement average, MA1:MA0 = 00)<br>Specified at: VDD = 2.5V, VDDIO = 1.8V | -    | 100            | -       | µA          |
| <b>Performance</b>          |  |      |                |         |             |
| Field Range                 | Full scale (FS) – total applied field (Typical)  | -8   |                | +8      | gauss       |
| Mag Dynamic Range           | 3-bit gain control   | ±1   |                | ±8      | gauss       |
| Resolution                  | VDD=3.0V, GN=2   |      | 5              |         | milli-gauss |
| Linearity                   | ±2.0 gauss input range   |      |                | 0.1     | ±% FS       |
| Hysteresis                  | ±2.0 gauss input range   |      | ±25            |         | ppm         |
| Cross-Axis Sensitivity      | Test Conditions: Cross field = 0.5 gauss,<br>Happlied = ±3 gauss   |      | ±0.2%          |         | %FS/gauss   |
| Output Rate (ODR)           | Continuous Measurement Mode  | 0.75 |                | 75      | Hz          |
|                             | Single Measurement Mode  |      |                | 160     | Hz          |
| Measurement Period          | From receiving command to data ready   |      | 6              |         | msec        |
| Turn-on Time                | Ready for I2C commands   |      | 200            |         | µs          |
| Gain Tolerance              | All gain/dynamic range settings  |      | ±5             |         | %           |
| I <sup>2</sup> C Address    | 7-bit address  |      | 0x1E           |         | hex         |
|                             | 8-bit read address   |      | 0x3D           |         | hex         |
|                             | 8-bit write address  |      | 0x3C           |         | hex         |
| I <sup>2</sup> C Rate       | Controlled by I <sup>2</sup> C Master  |      |                | 400     | kHz         |
| I <sup>2</sup> C Hysteresis | Hysteresis of Schmitt trigger inputs on SCL<br>and SDA - Fall (VDDIO=1.8V)<br>Rise (VDDIO=1.8V)                  |      | 0.2*VDDIO      |         | Volts       |
|                             |  |      | 0.8*VDDIO      |         | Volts       |
| Self Test                   | X & Y Axes<br>Z Axis   |      | ±1.16<br>±1.08 |         | gauss       |
|                             | X & Y Axes (GN=100)<br>Z Axis (GN=100)   |      | 440            |         | LSb         |
| <b>General</b>              |  |      |                |         |             |
| ESD Voltage                 | Human Body Model (all pins)  |      |                | 2000    | Volts       |
|                             | CDM  |      |                | 750     | Volts       |
| Operating Temperature       | Ambient  | -30  |                | 85      | °C          |
| Storage Temperature         | Ambient, unbiased  | -40  |                | 125     | °C          |
| Reflow Classification       | MSL 3, 260 °C Peak Temperature   |      |                |         |             |
| Package Size                | Length and Width   | 2.85 | 3.00           | 3.15    | mm          |
| Package Height              |  | 0.8  | 0.9            | 1.0     | mm          |
| Package Weight              |  |      | 18             |         | mg          |

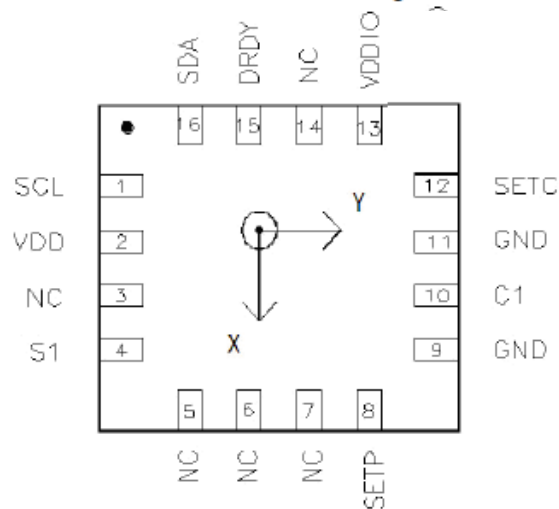
**Absolute Maximum Ratings** (\* Tested at 25°C except stated otherwise.)

| Characteristics      | Min  | Max | Units |
|----------------------|------|-----|-------|
| Supply Voltage VDD   | -0.3 | 4.8 | Volts |
| Supply Voltage VDDIO | -0.3 | 4.8 | Volts |

**PIN CONFIGURATIONS**

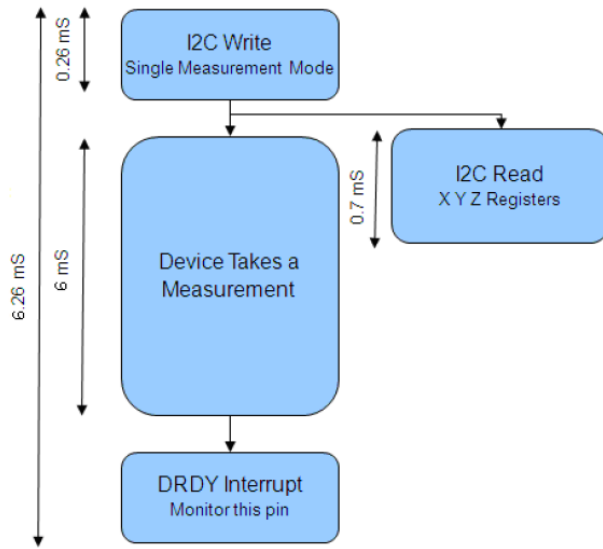
| Pin | Name  | Description   |
|-----|-------|---|
| 1   | SCL   | Serial Clock – I <sup>2</sup> C Master/Slave Clock  |
| 2   | VDD   | Power Supply (2.16V to 3.6V)  |
| 3   | NC    | Not to be Connected   |
| 4   | S1    | Tie to VDDIO  |
| 5   | NC    | Not to be Connected   |
| 6   | NC    | Not to be Connected   |
| 7   | NC    | Not to be Connected   |
| 8   | SETP  | Set/Reset Strap Positive – S/R Capacitor (C2) Connection  |
| 9   | GND   | Supply Ground   |
| 10  | C1    | Reservoir Capacitor (C1) Connection   |
| 11  | GND   | Supply Ground   |
| 12  | SETC  | S/R Capacitor (C2) Connection – Driver Side   |
| 13  | VDDIO | IO Power Supply (1.71V to VDD)  |
| 14  | NC    | Not to be Connected   |
| 15  | DRDY  | Data Ready, Interrupt Pin. Internally pulled high. Optional connection. Low for 250 $\mu$ sec when data is placed in the data output registers. |
| 16  | SDA   | Serial Data – I <sup>2</sup> C Master/Slave Data  |

Table 1: Pin Configurations



TOP VIEW (looking through)

### Typical Measurement Period in Single-Measurement Mode



\* Monitoring of the DRDY Interrupt pin is only required if maximum output rate is desired.

## MODES OF OPERATION

This device has several operating modes whose primary purpose is power management and is controlled by the Mode Register. This section describes these modes.

### Continuous-Measurement Mode

During continuous-measurement mode, the device continuously makes measurements, at user selectable rate, and places measured data in data output registers. Data can be re-read from the data output registers if necessary; however, if the master does not ensure that the data register is accessed before the completion of the next measurement, the data output registers are updated with the new measurement. To conserve current between measurements, the device is placed in a state similar to idle mode, but the Mode Register is not changed to Idle Mode. That is, MD[n] bits are unchanged. Settings in the Configuration Register A affect the data output rate (bits DO[n]), the measurement configuration (bits MS[n]), when in continuous-measurement mode. All registers maintain values while in continuous-measurement mode. The I<sup>2</sup>C bus is enabled for use by other devices on the network in while continuous-measurement mode.

### Single-Measurement Mode

This is the default power-up mode. During single-measurement mode, the device makes a single measurement and places the measured data in data output registers. After the measurement is complete and output data registers are updated, the device is placed in idle mode, and the Mode Register is changed to idle mode by setting MD[n] bits. Settings in the configuration register affect the measurement configuration (bits MS[n]) when in single-measurement mode. All registers maintain values while in single-measurement mode. The I<sup>2</sup>C bus is enabled for use by other devices on the network while in single-measurement mode.

### Idle Mode

During this mode the device is accessible through the I<sup>2</sup>C bus, but major sources of power consumption are disabled, such as, but not limited to, the ADC, the amplifier, and the sensor bias current. All registers maintain values while in idle mode. The I<sup>2</sup>C bus is enabled for use by other devices on the network while in idle mode.

## I<sup>2</sup>C COMMUNICATION PROTOCOL

The HMC5883L communicates via a two-wire I<sup>2</sup>C bus system as a slave device. The HMC5883L uses a simple protocol with the interface protocol defined by the I<sup>2</sup>C bus specification, and by this document. The data rate is at the standard-mode 100kbps or 400kbps rates as defined in the I<sup>2</sup>C Bus Specifications. The bus bit format is an 8-bit Data/Address send and a 1-bit acknowledge bit. The format of the data bytes (payload) shall be case sensitive ASCII characters or binary data to the HMC5883L slave, and binary data returned. Negative binary values will be in two's complement form. The default (factory) HMC5883L 8-bit slave address is 0x3C for write operations, or 0x3D for read operations.

The HMC5883L Serial Clock (SCL) and Serial Data (SDA) lines require resistive pull-ups (Rp) between the master device (usually a host microprocessor) and the HMC5883L. Pull-up resistance values of about 2.2K to 10K ohms are recommended with a nominal VDDIO voltage. Other resistor values may be used as defined in the I<sup>2</sup>C Bus Specifications that can be tied to VDDIO.

The SCL and SDA lines in this bus specification may be connected to multiple devices. The bus can be a single master to multiple slaves, or it can be a multiple master configuration. All data transfers are initiated by the master device, which is responsible for generating the clock signal, and the data transfers are 8 bit long. All devices are addressed by I<sup>2</sup>C's unique 7-bit address. After each 8-bit transfer, the master device generates a 9<sup>th</sup> clock pulse, and releases the SDA line. The receiving device (addressed slave) will pull the SDA line low to acknowledge (ACK) the successful transfer or leave the SDA high to negative acknowledge (NACK).

Per the I<sup>2</sup>C spec, all transitions in the SDA line must occur when SCL is low. This requirement leads to two unique conditions on the bus associated with the SDA transitions when SCL is high. Master device pulling the SDA line low while the SCL line is high indicates the Start (S) condition, and the Stop (P) condition is when the SDA line is pulled high while the SCL line is high. The I<sup>2</sup>C protocol also allows for the Restart condition in which the master device issues a second start condition without issuing a stop.

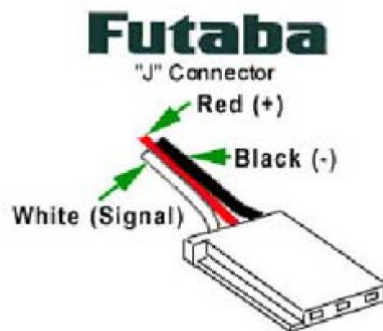
All bus transactions begin with the master device issuing the start sequence followed by the slave address byte. The address byte contains the slave address; the upper 7 bits (bits 7-1), and the Least Significant bit (LSb). The LSb of the address byte designates if the operation is a read (LSb=1) or a write (LSb=0). At the 9<sup>th</sup> clock pulse, the receiving slave device will issue the ACK (or NACK). Following these bus events, the master will send data bytes for a write operation, or the slave will clock out data with a read operation. All bus transactions are terminated with the master issuing a stop sequence.

I<sup>2</sup>C bus control can be implemented with either hardware logic or in software. Typical hardware designs will release the SDA and SCL lines as appropriate to allow the slave device to manipulate these lines. In a software implementation, care must be taken to perform these tasks in code.

## LAMPIRAN D

## MOTOR SERVO

### S3003 FUTABA SERVO



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##### Detailed Specifications

|                                 |   |                           |   |
|---------------------------------|---|---------------------------|---|
| Control System:                 | +Pulse Width Control 1520usec<br>Neutral    | Current Drain (4.8V):     | 7.2mA/idle  |
| Required Pulse:                 | 3-5 Volt Peak to Peak Square<br>Wave        | Current Drain (6.0V):     | 8mA/idle  |
| Operating Voltage:              | 4.8-6.0 Volts                               | Direction:                | Counter Clockwise/Pulse Traveling 1520-<br>1900usec |
| Operating Temperature<br>Range: | -20 to +60 Degree C                         | Motor Type:               | 3 Pole Ferrite                                      |
| Operating Speed (4.8V):         | 0.23sec/60 degrees at no load               | Potentiometer Drive:      | Indirect Drive                                      |
| Operating Speed (6.0V):         | 0.19sec/60 degrees at no load               | Bearing Type:             | Plastic Bearing                                     |
| Stall Torque (4.8V):            | 44 oz/in. (3.2kg.cm)                        | Gear Type:                | All Nylon Gears                                     |
| Stall Torque (6.0V):            | 56.8 oz/in. (4.1kg.cm)                      | Connector Wire<br>Length: | 12"   |
| Operating Angle:                | 45 Deg. one side pulse traveling<br>400usec | Dimensions:               | 1.6" x 0.8"x 1.4" (41 x 20 x 36mm)                  |
| 360 Modifiable:                 | Yes   | Weight:                   | 1.3oz. (37.2g)                                      |



MG995 Servo Digital de Alta Velocidad y Torque  
Voltage recomendable: 3.5 - 8.4 Volts , nominal 5 volts.

Dimension:

Velocidad de Operación (4.8V sin carga):

Velocidad de Operación (6V sin carga):

Torque de parada (4.8V):

Torque de Parada (6.0V):

Mass: 55.2g

Range Temperature:

1.57" x 0.79" x 1.44" (40 x 20 x 36.5mm)

1.78oz (48g)

0.17seg / 60 s

0.13seg / 60 s

(13kg/cm)

(15kg/cm)

-30 to +60 C

