
# Smartphone Hardware Sensors

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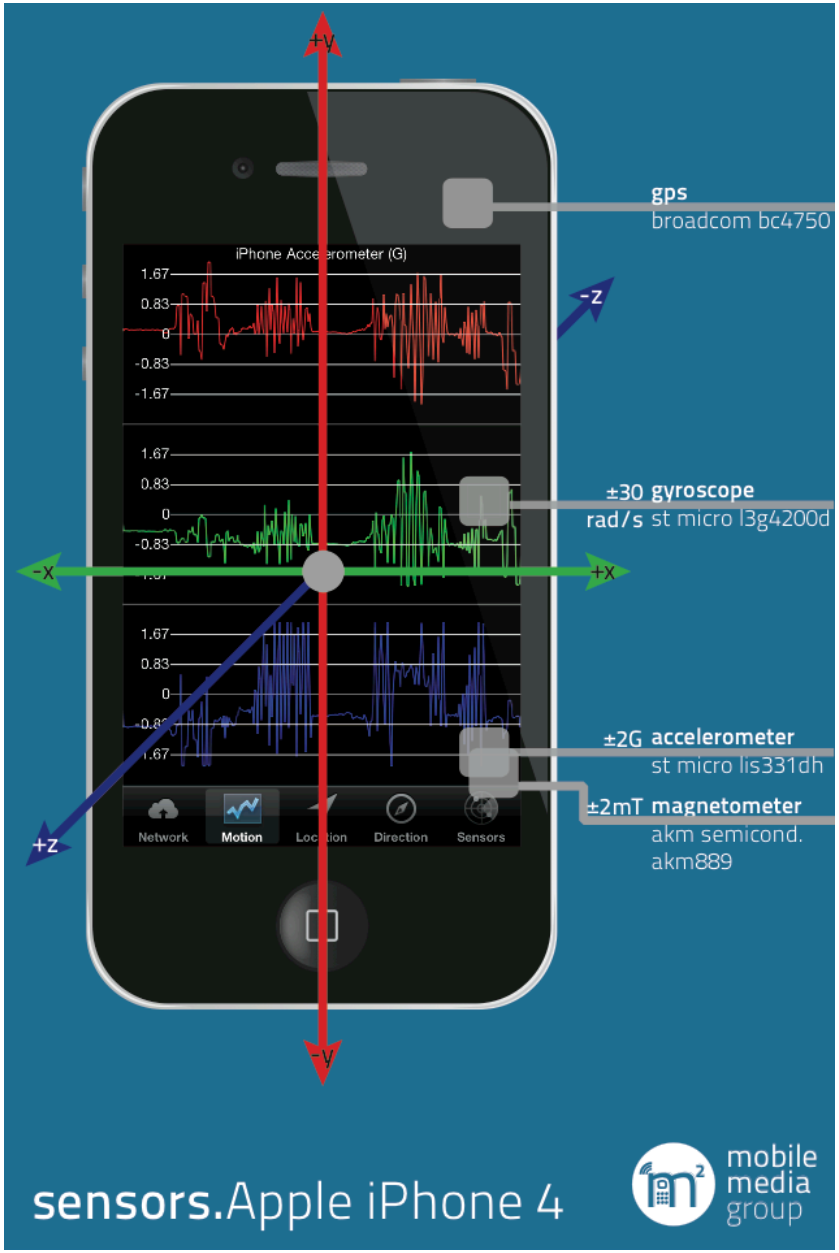
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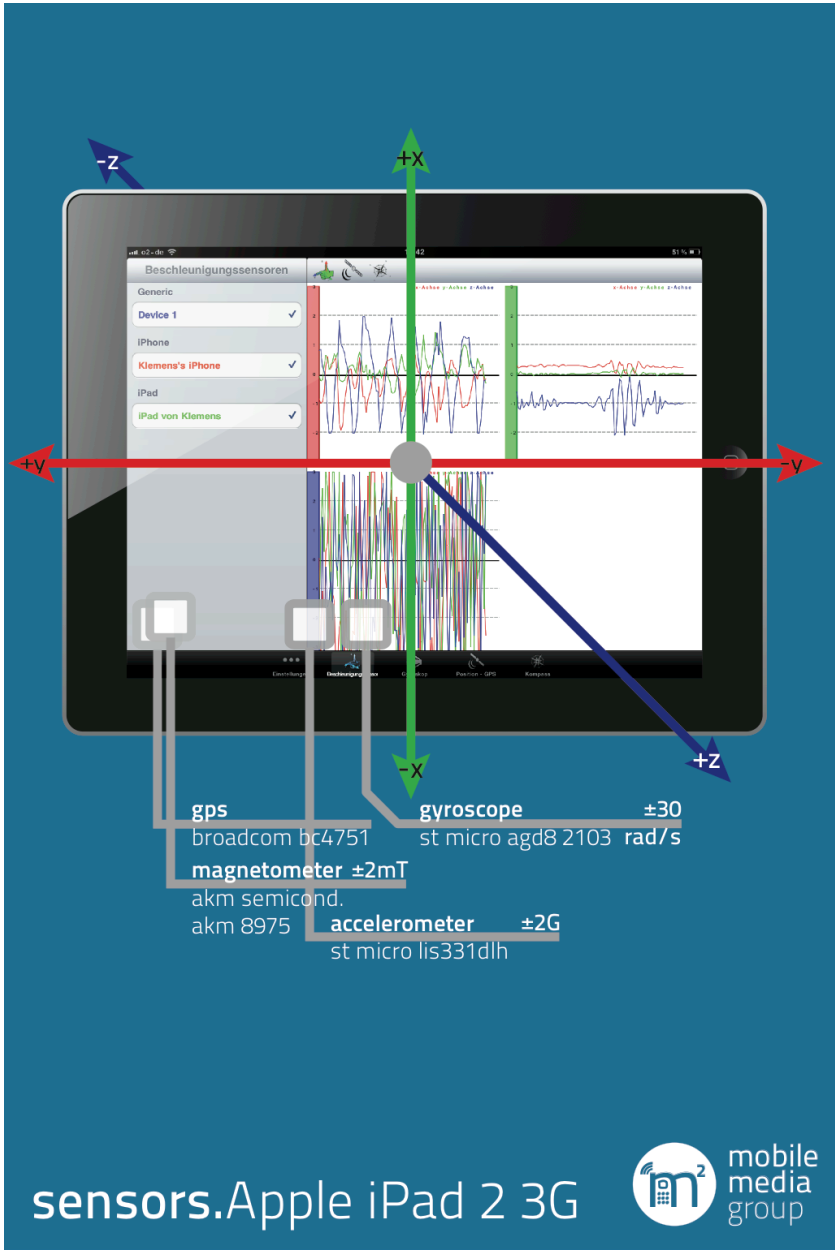
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# Overview

- Accelerometer
- GPS
- Gyroscope
- Magnetometer
- Luxmeter
- Microphone
- Proximity Sensor

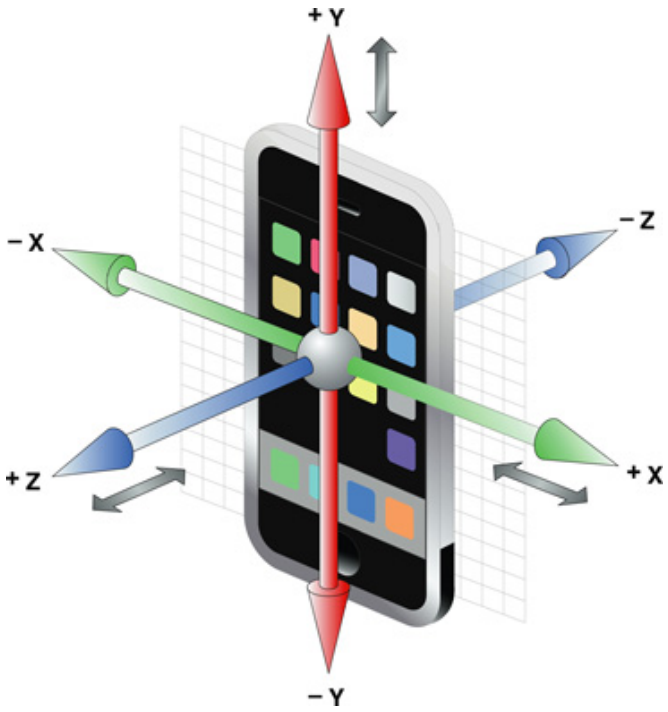
# Accelerometer

- Measures **proper acceleration** (acceleration it experiences relative to **freefall**), felt by people or objects
- **Units**: $m/s^2$ or g
- Most **smartphone** accelerometers trade large value range for **high precision**, iPhone 4 range: ±2g, precision 0.018g

| Example | G Force |
|---|---|
| Standing on earth at sea level | 1g |
| Bugatti Veyron from 0 to 100 km/h (2.4s) | 1.55g |
| Space Shuttle, maximum during launch and reentry | 3g |
| Formula 1 car, peak lateral in turns | 5-6g |
| Death or serious injury | 50g |
| Shock capability of mechanical Omega watches | 5000g |

# Accelerometer

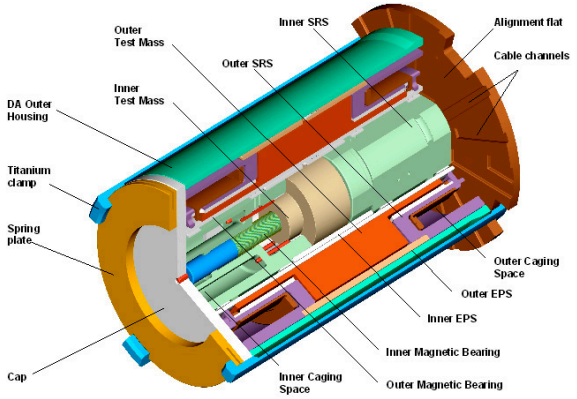
- Acceleration is measured on 3 axes



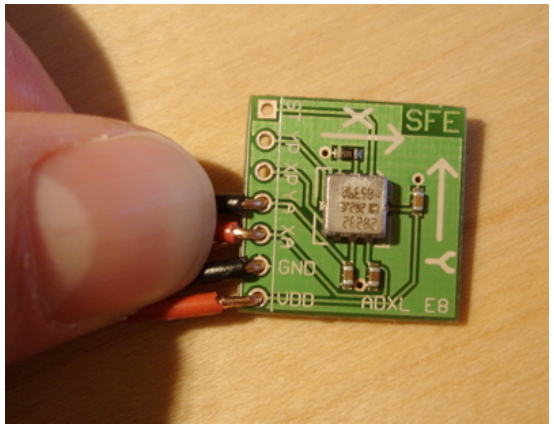

- Orientation of sensor (and coordinate system) varies among different devices

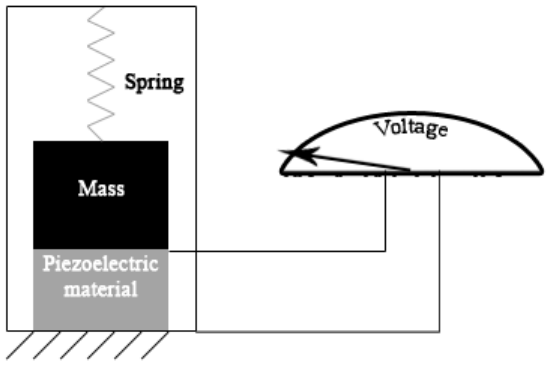
# Accelerometer

- Space flight accelerometer:



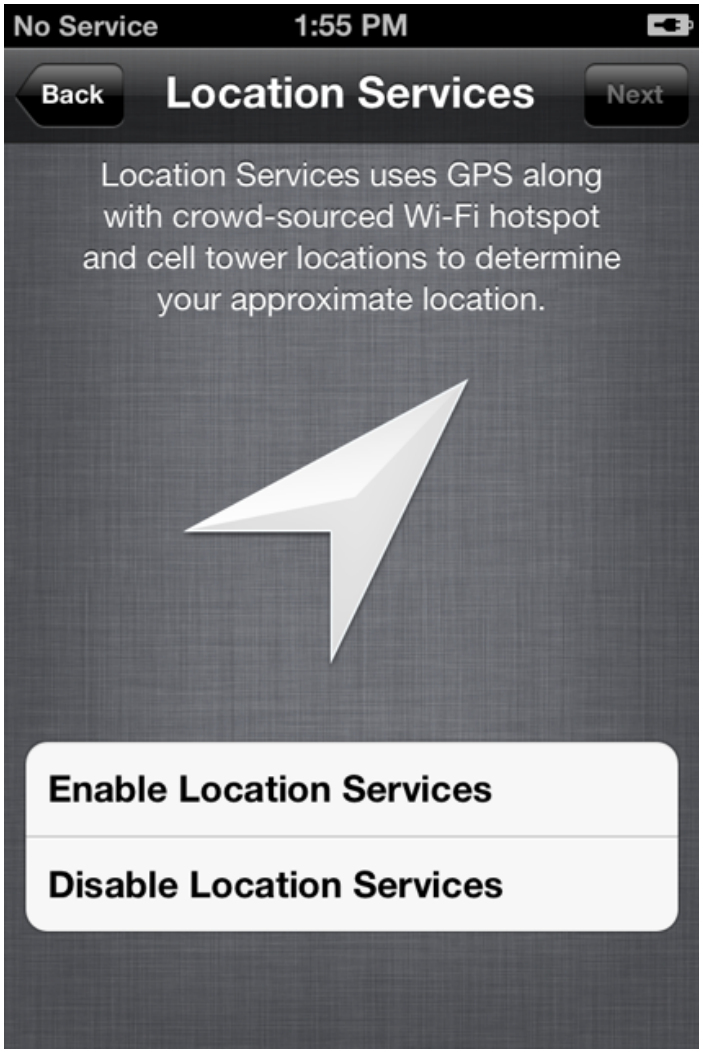

- Smartphone accelerometer (piezoelectric):



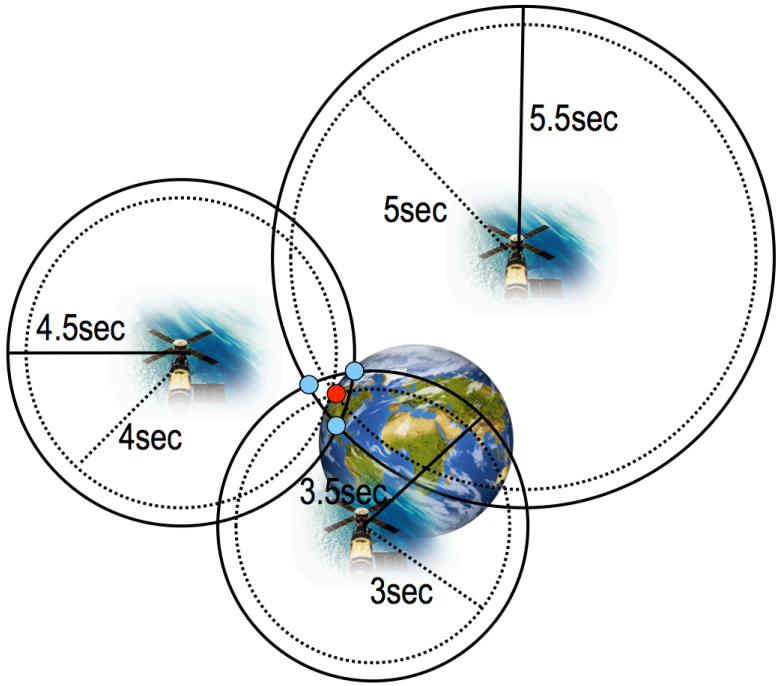
# GPS

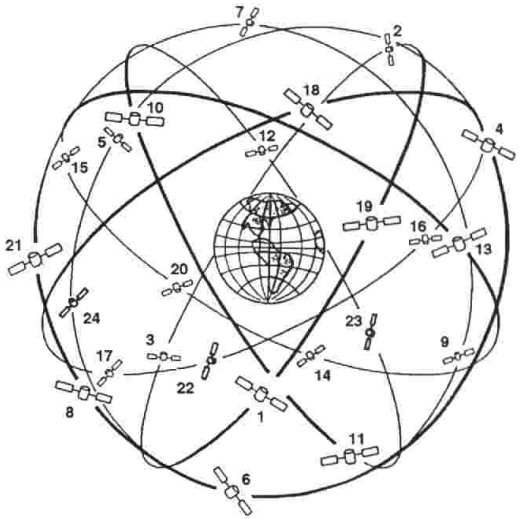
- **Location** sensors detect the location of the smartphone using either
  - **GPS**
  - Lateration/Triangulation of **cell towers** or **wifi networks** (with **database** of known locations for towers and networks)
  - Location of **associated** cell tower or wifi network



# GPS

- Connection to **3** satellites is required for **2D** fix (latitude/ longitude), **4** satellites for **3D** fix (altitude)
- **More** visible satellites increase **precision** of positioning
- **Typical** precision: 20-50m, **maximum** precision: 10m



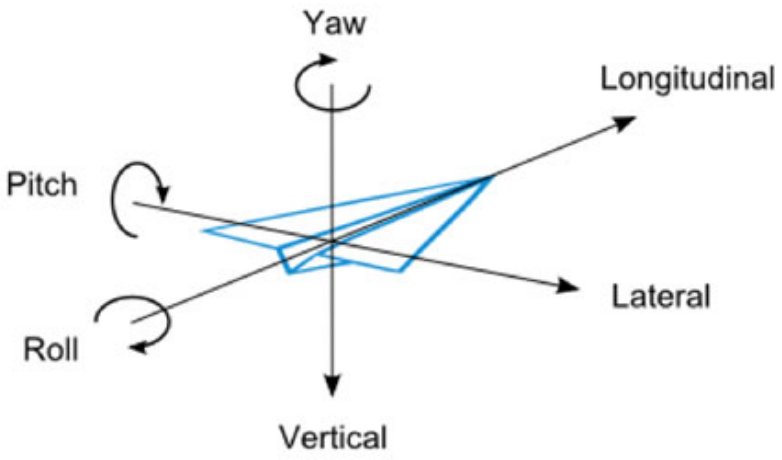
# GPS

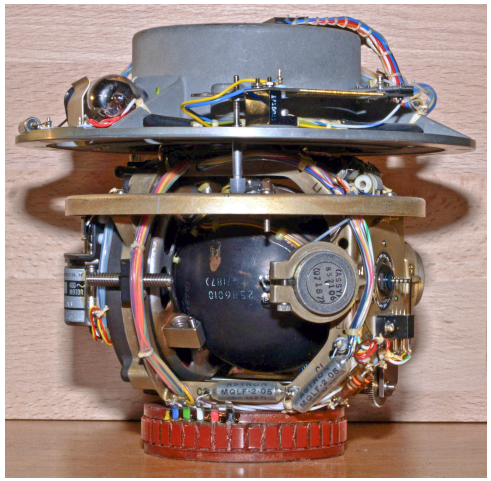
- **Caveats**
  - GPS will not work **indoors**
  - GPS quickly **kills** your **battery**
  - A location **fix** takes a **long period** of **time** (30s…12m), **A-GPS** helps
  - **Buildings reflect** and **occlude** satellite **signals** – thereby **reducing precision** of positioning in **urban environments**

- Smartphones can try to automatically select the best-suited **alternative** location provider (gps, cell towers, wifi), mostly based on **desired precision**

# Gyroscope

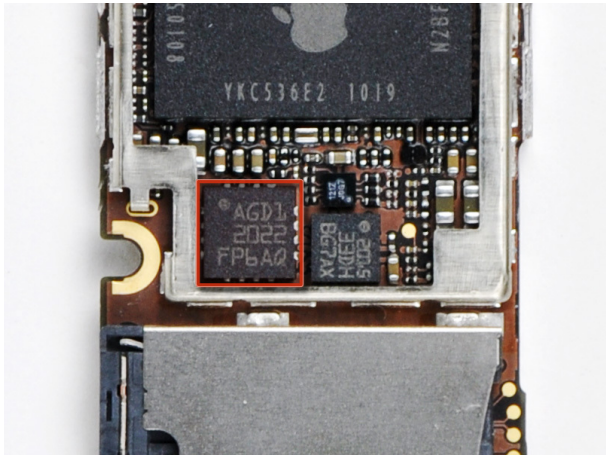
- Detects the **current orientation** of the device, or **changes** in the **orientation**
- **Precisely**: orientation can be **computed** from the **angular rate** that is detected by the gyroscope, expressed in rad/s on 3 axis:

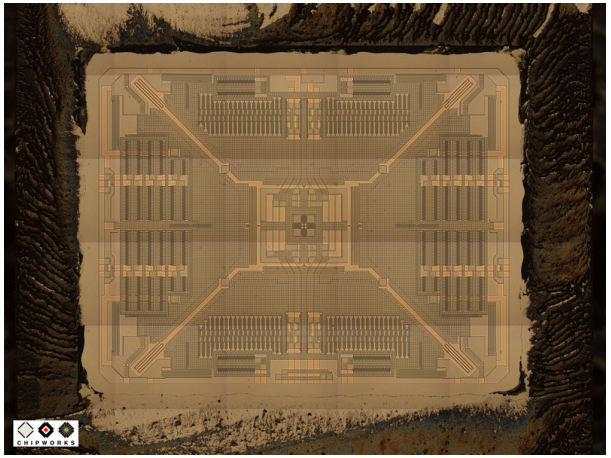


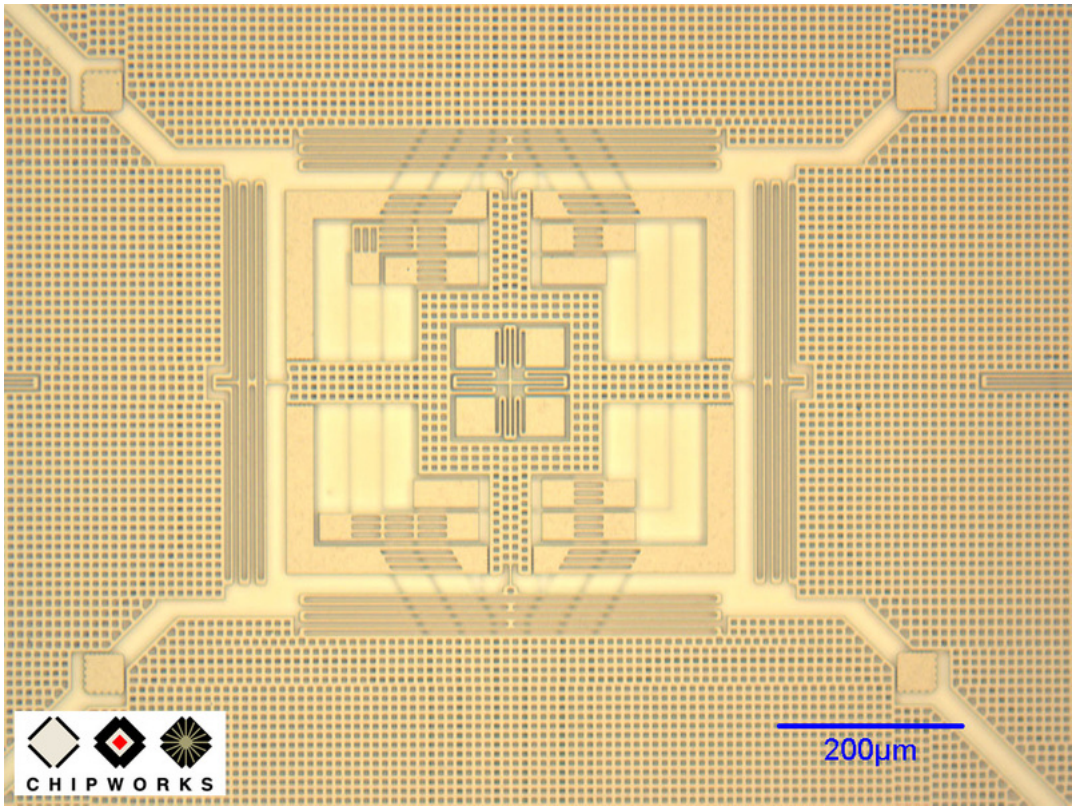



# Gyroscope

- **iPhone 4:** MEMS (microelectromechanical system) gyro: displacement of vibrating proof mass






Source: http://www.ifixit.com/Teardown/iPhone-4-Gyroscope-Teardown/3156/1

# Magnetometer

- Measures the **strength** of **earth's magnetic field**
- **Strength** is expressed in **tesla** [T]
- iPhone 4 magnetometer range: ±2mT

| Example | Field strength |
|---|---|
| Earth's magnetic field on the equator (0° latitude) | 31µT (0.00031T) |
| Typical fridge magnet | 5mT (0.005T) |
| Strong neodymium magnet | 1.25T |
| MRI system | 1.5T – 3T |

- **Pro tip**: prolonged exposure to a fridge magnet decalibrates your iPhone 4's magnetometer for at least a week ;-)

# Magnetometer

- Smartphones provide raw magnetometer data and a computed compass bearing

- Applications
  - **Compass**, of course – rotate maps/interfaces/graphics according to bearing
  - **Tricorder**, detect magnets, force fields, klingon shield strength ;-)

# Demo