REMOTE ACOUSTIC URBAN SENSING - 03/06/18

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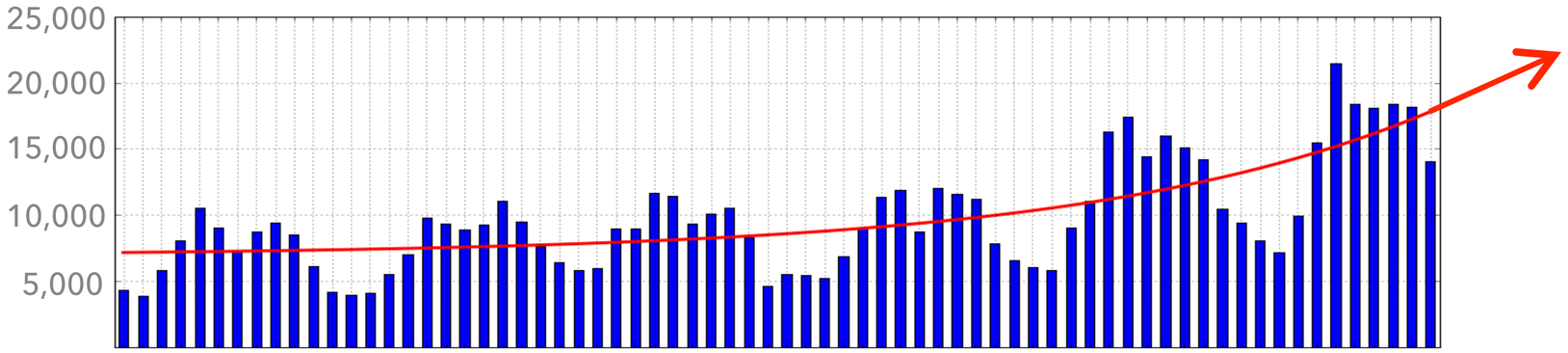
ACOUSTIC REMOTE URBAN SENSING

- **Noise monitoring** - why noise? sounds of new york city
- **Sensing sound** - what can we use? what are we sensing? what are the metrics?
- **Calibration** - how do we collect accurate data? what happens over time?
- **Analysis** - how do we handle sound data?

WHY NOISE?

Estimated 9 of 10 adults in NYC exposed to HARMFUL levels of NOISE

Over 3.4 MILLION complaints since 2003 [based on 311 data]



Complaints per month since 2010

SLEEP LOSS

HEARING LOSS

PRODUCTIVITY

LEARNING IMPAIRMENT

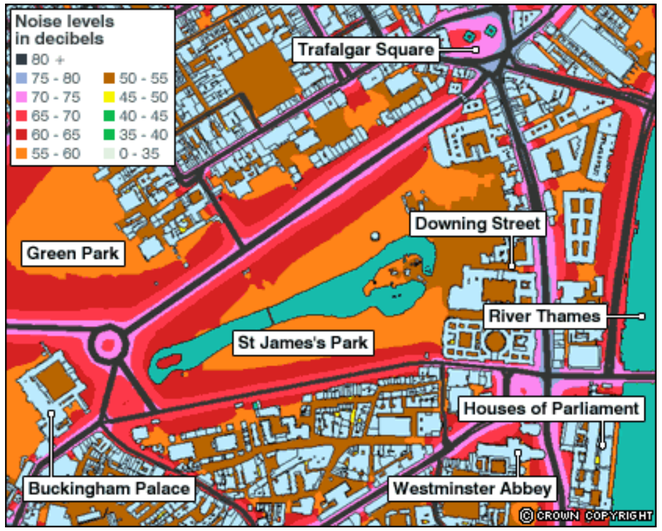
STRESS

NOISE SURVEYING

NOISE SURVEYING

Expensive equipment

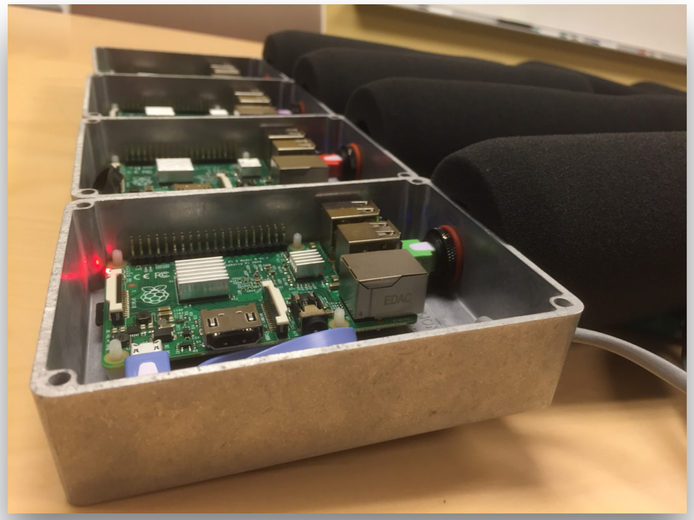
Expensive people



Inadequate data

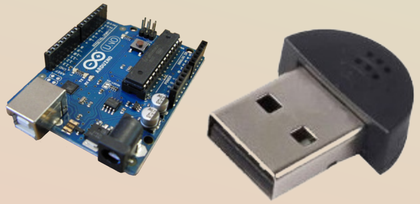
SONYC — ACOUSTIC SENSING DEVICES

- Design focussed on:
  - Accuracy
  - Resilience
  - Scalability

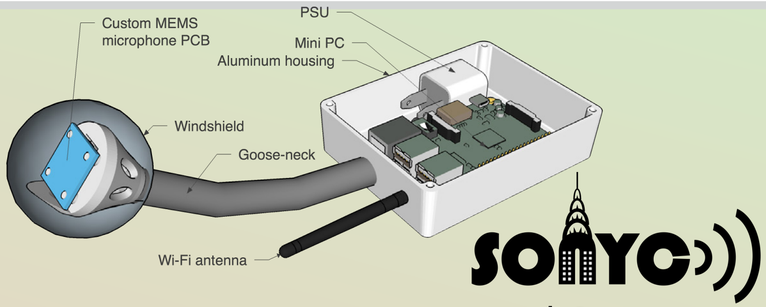


SONYC — ACOUSTIC SENSING DEVICES

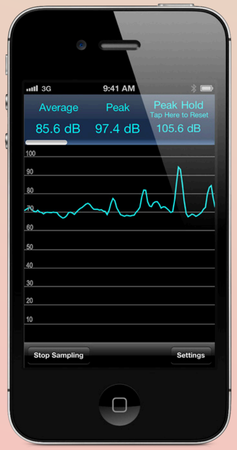
Affordability



generic IoT
$100



SONYC
$85



smart phones
$500

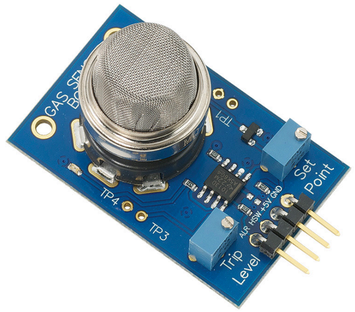
commercial acoustic sensors
$600

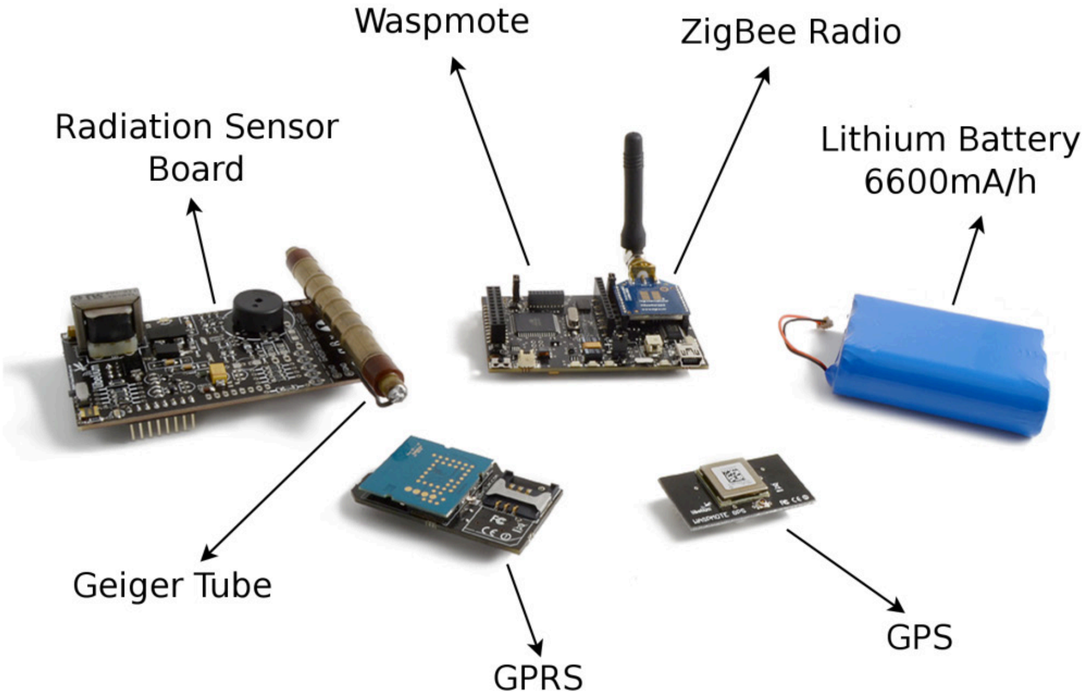
high-end acoustic sensors
$15,000

Accuracy

SENSORS & TRANSDUCERS

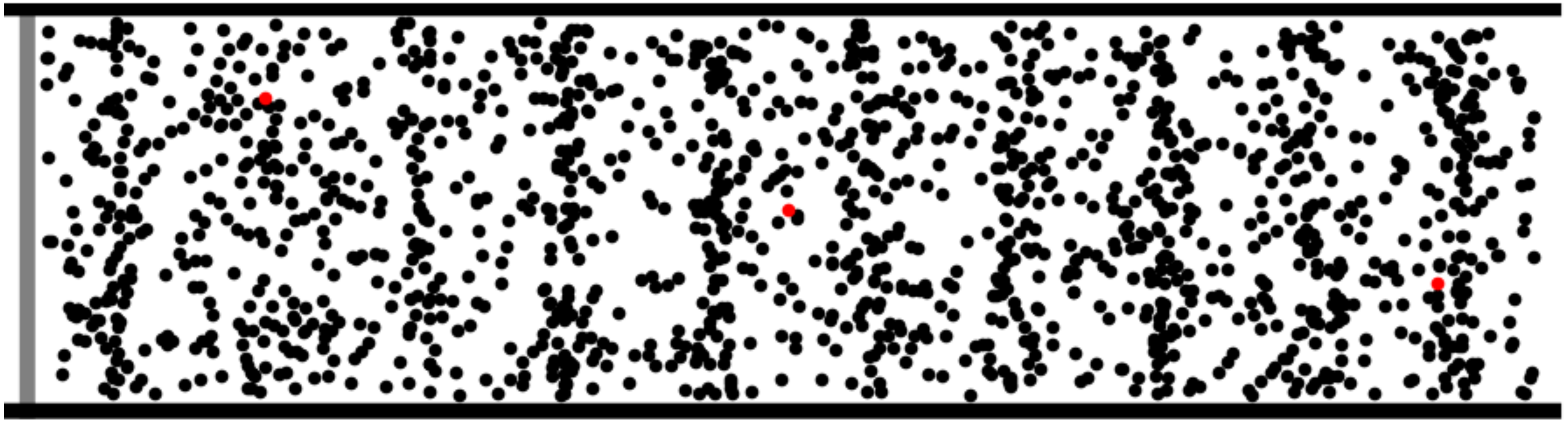
- **Sensor** - a device that converts some physical phenomenon into an electrical signal
- **Transducer** - a component that converts one type of energy into another type of energy





WHAT IS SOUND?

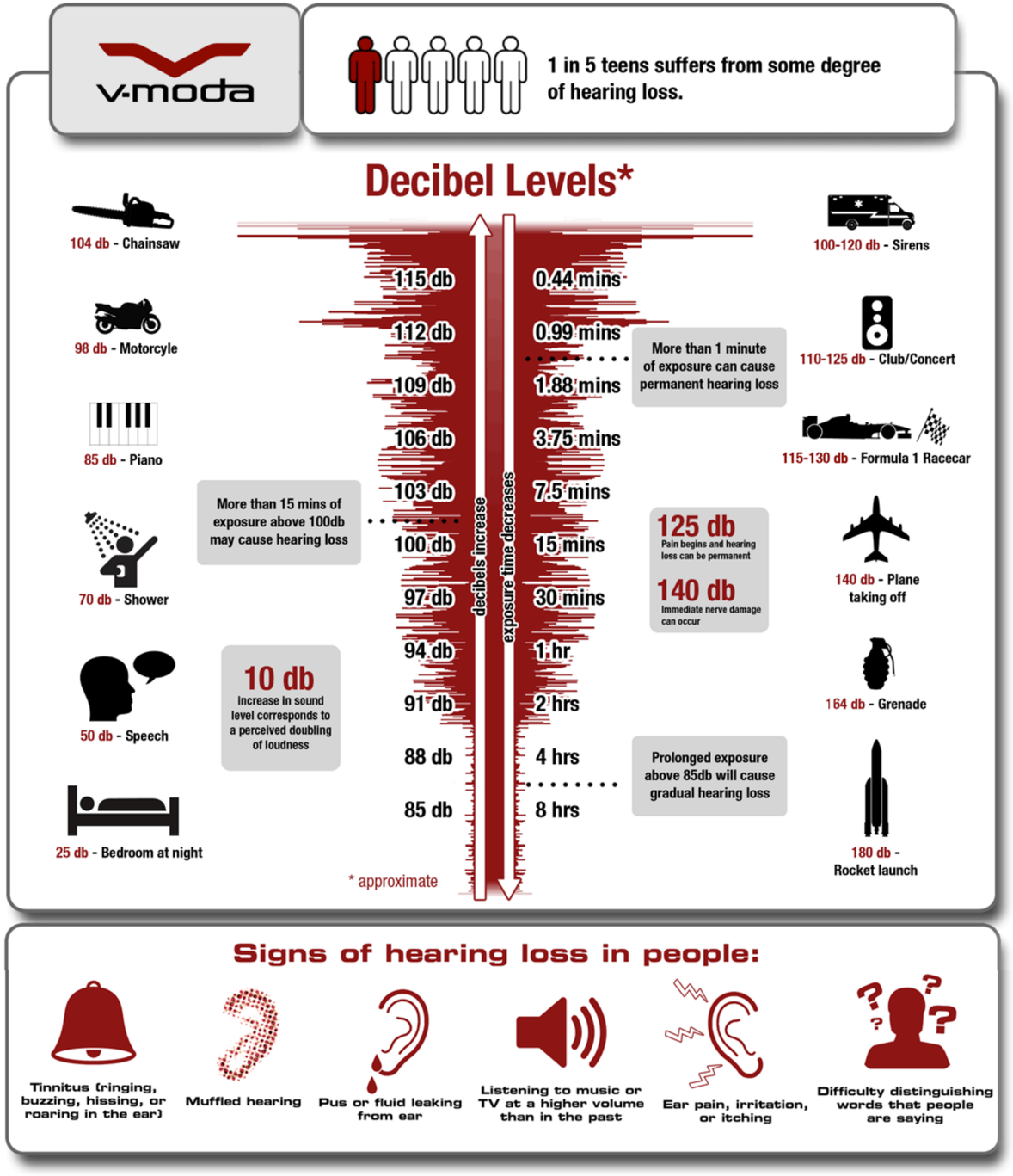
Sound is the energy transferred when something vibrates in a medium



SOUND PRESSURE LEVEL

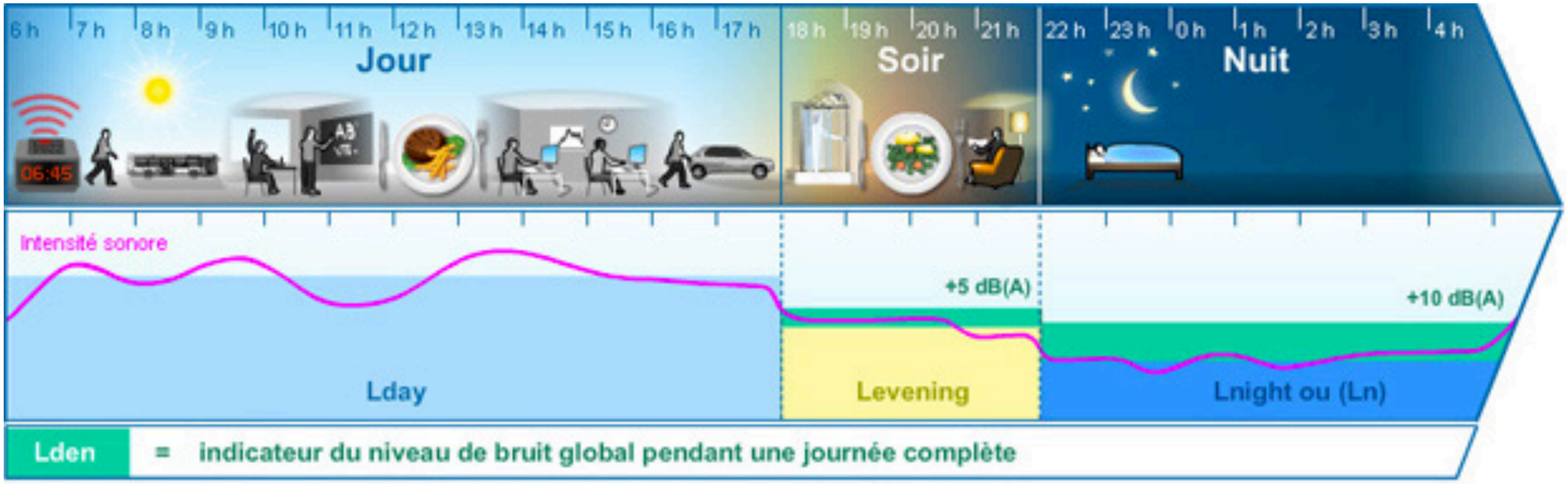
- Our ears response to sound pressure is ~log10
- A 3dB increase doubles sound intensity
- For example:
  - 10dB is x10 more intense than 1dB
  - 20dB is x100 more intense than 1dB
- Sound pressure level in dB is a log10 ratio relative to the threshold of hearing:

$$20 \log_{10}\left(\frac{p}{p_0}\right) \text{ dB}$$



SOUND PRESSURE LEVEL - DAY, EVENING, NIGHT

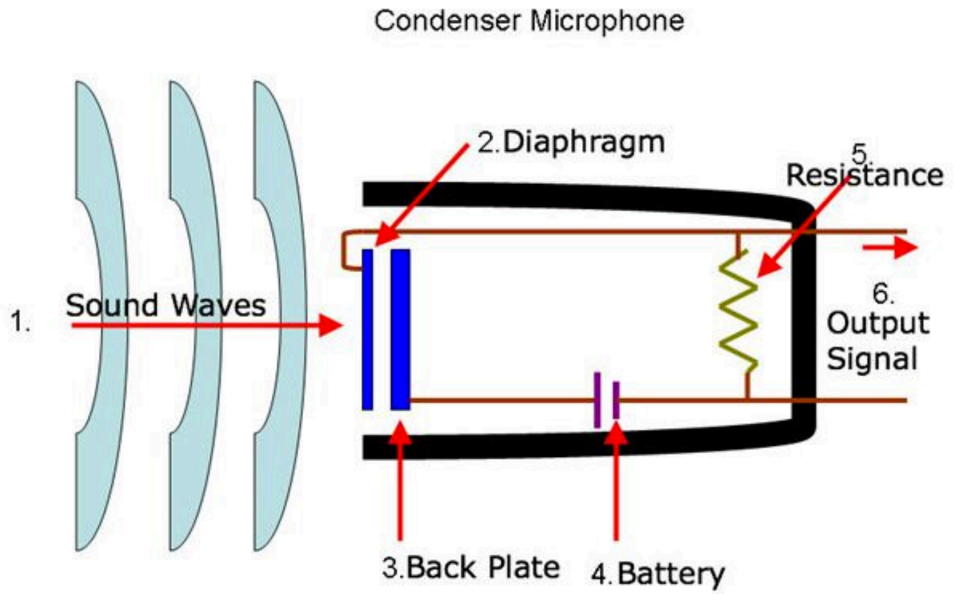
- Average equivalent sound pressure level over a 24 hour period
- Penalty added to reflect the increased impact of noise at different times of the day
- 5dB(A) added during the evening hours of 18:00 – 22:00
- 10dB(A) added during the nighttime hours of 22:00 – 07:00



ACOUSTIC TRANSDUCTION

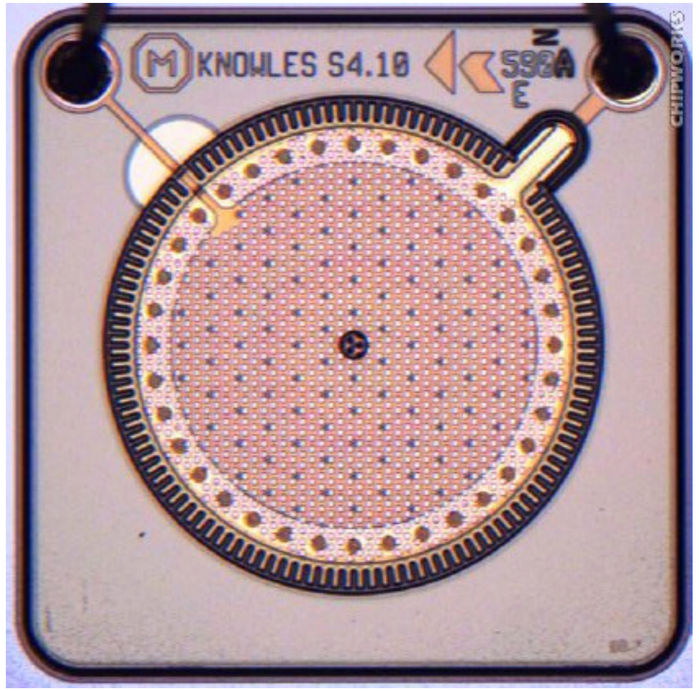
- The microphone diaphragm acts as a capacitor
- As the diaphragm vibrates a varying voltage is generated
- This varying voltage (±1.0) is the audio signal
- Linear relationship between sound pressure and voltage
- You can convert to **uncalibrated** decibels using the formula below, where p = instantaneous voltage and p_0 = the reference voltage of 1.0

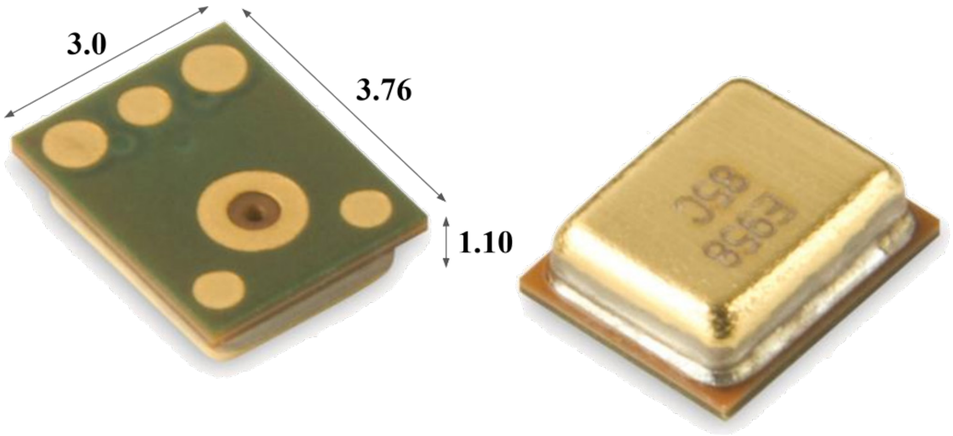
$$20 \log_{10} \left(\frac{p}{p_0} \right) \text{ dB}$$

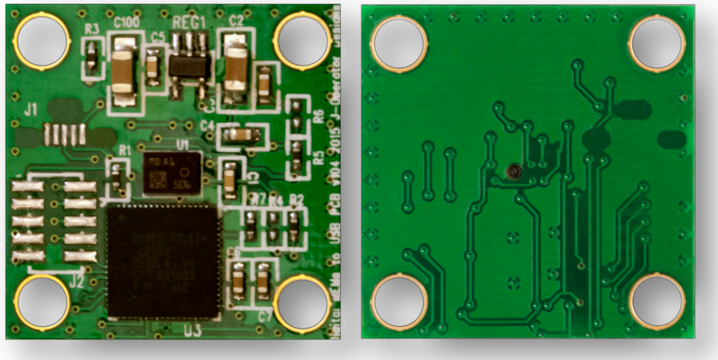


MEMS MICROPHONES

- Diaphragm is etched directly onto a silicon chip using Micro Electro Mechanical System techniques
- Variant of the condenser microphone type
- Extremely small
- Very rugged
- Very high part to part consistency

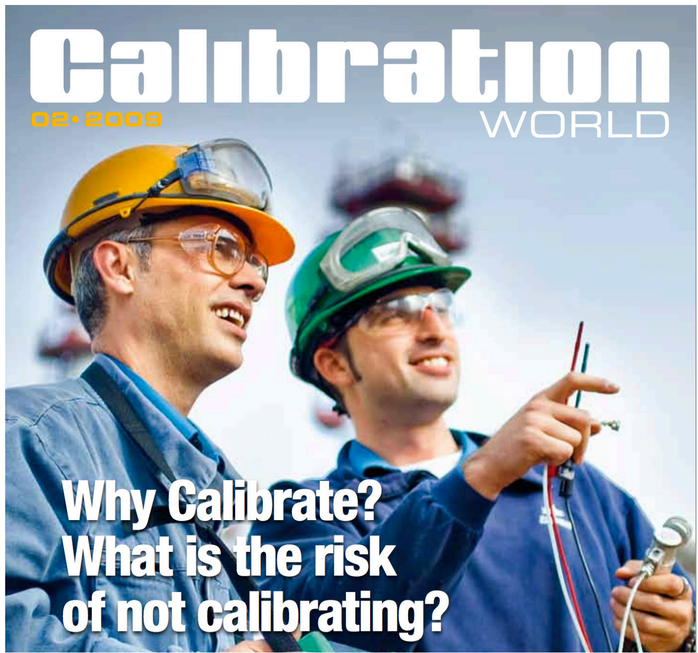




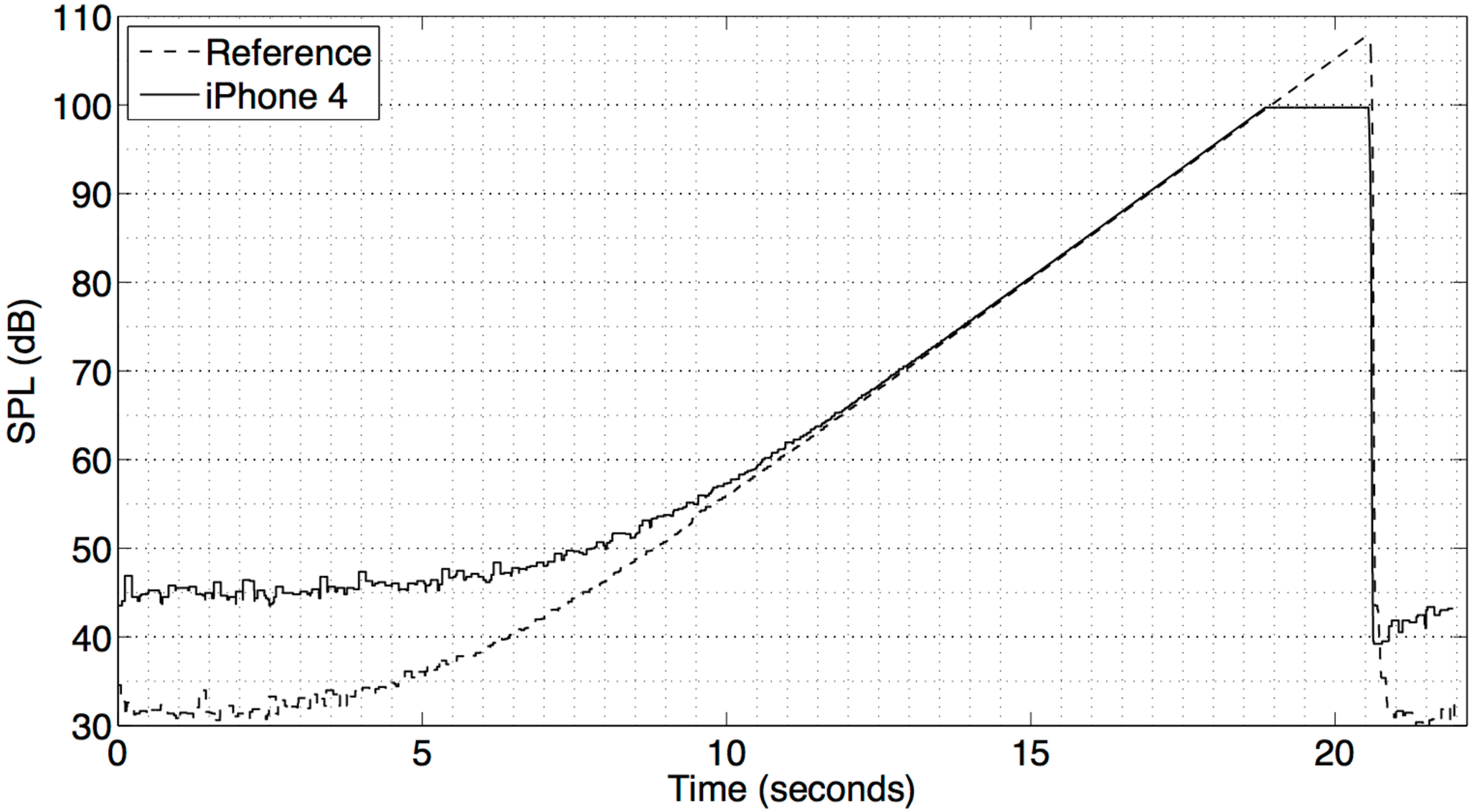


WHY DO WE NEED CALIBRATED SPL DATA?

- Need to be sure of the accuracy of a set of measurements
- American National Standards Institute (ANSI) specify 3 classes for SPL measurements:
  - 0 = laboratory grade (±<1dB)
  - 1 = precision field measurement grade (±1dB)
  - 2 = general purpose measurement grade(±2dB)
- Involves the generation of a known SPL in comparison to a reference device such as a class 1 sound level meter (SLM)

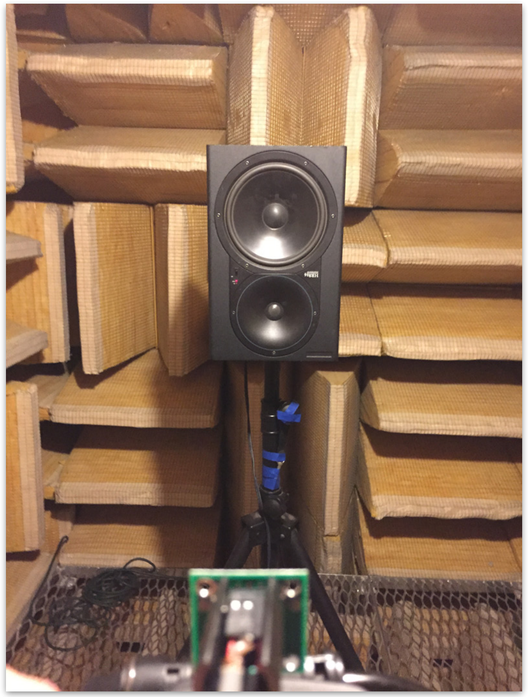


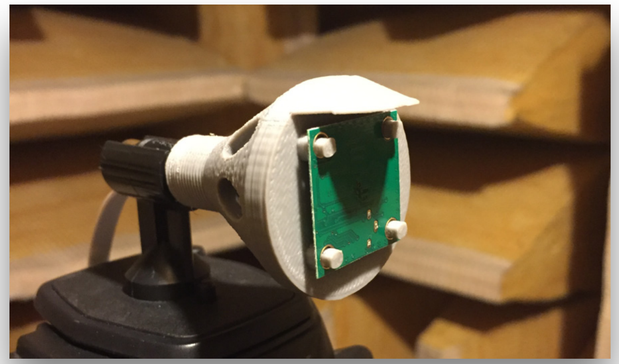
COMPARISON TO A CALIBRATED DEVICE



ACOUSTIC SENSOR CALIBRATION

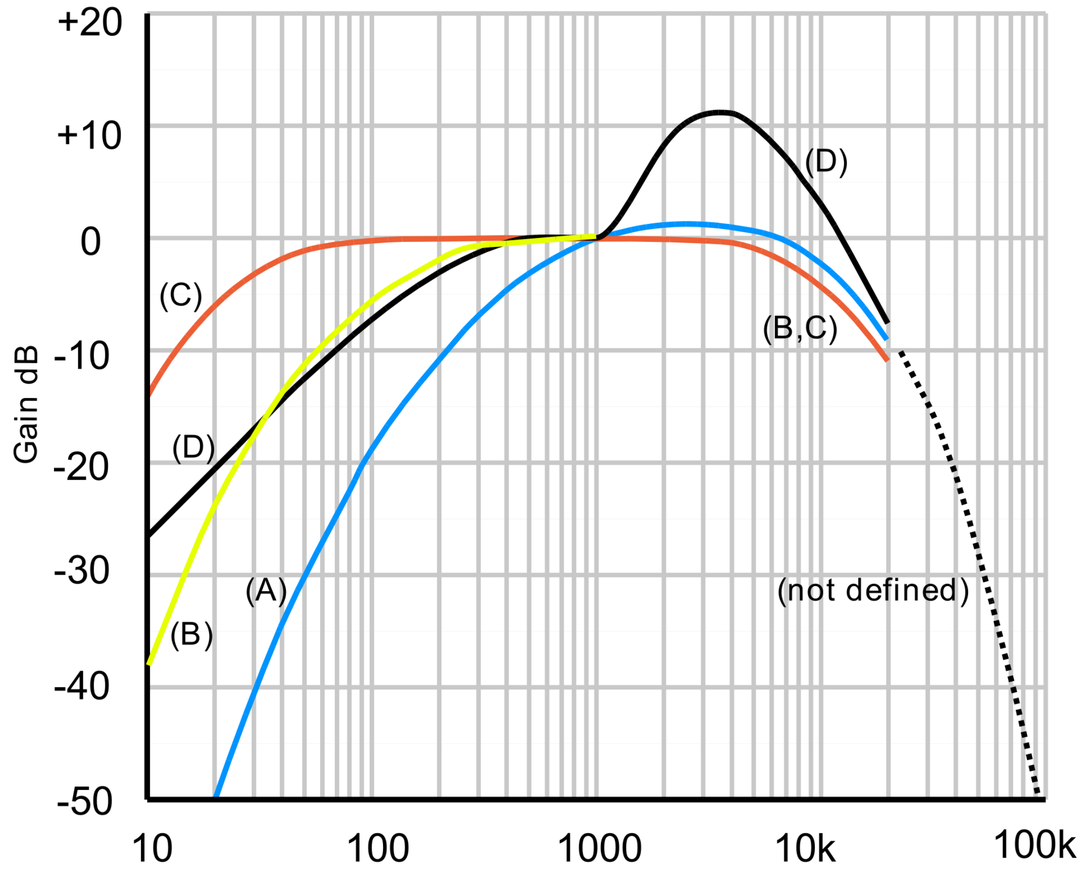
- Repeat measurements using ref. meter & device under test (DUT)
- Determine dB offset
- Use of MEMS microphone simplifies network calibration
- Noise floor of the system
- How does the microphone perform after 6 months in the field?





SOUND PRESSURE LEVEL METRICS

- Human ear more sensitive to frequencies between 500Hz – 8kHz
- Urban noise policies rely on the use of A weighted sound pressure level
- Approximates the response of the human auditory system
- Dated standard
- Low frequency noise annoyance isn't accounted for – wind turbine noise



A-weighting (blue), B (yellow), C (red), and D-weighting (blk)

PRESBYCUSIS - AGE RELATED HEARING LOSS

- The auditory system's sensitivity to high frequency sound degrades over time
- Hearing damage also results in high frequency losses
- The evil mosquito anti loitering device
- How young are your ears...